HUMAN SYSTEMS INTEGRATION AND SITUATION AWARENESS IN MICROWORLDS: AN EXAMINATION OF EMERGENCY RESPONSE WITHIN THE OFFSHORE COMMAND AND CONTROL TRAINING SYSTEM

by

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The undersigned hereby certify that they have read and recommend to the Faculty of Graduate Studies for acceptance a thesis entitled "HUMAN SYSTEMS INTEGRATION AND SITUATION AWARENESS IN MICROWORLDS: AN EXAMINATION OF EMERGENCY RESPONSE WITHIN THE OFFSHORE COMMAND AND CONTROL TRAINING SYSTEM" by Michael John Taber in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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To my loving wife Nancy, for all of her endless support.

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Abstract

In an effort to reduce the number and severity of offshore incidents, the Canadian Association of Petroleum Producers requires all Emergency Response Team members to complete performance based simulation training at a recognized assessment facility. Although existing guidelines outline possible simulations and assessment criteria that should be used to evaluate emergency response team members' performance, minimal research has been conducted to identify validity and reliability of this testing. Therefore, this thesis examines the impact of including an electronic Emergency Response Focus Board (ERFB) during simulation testing. A Human System Integration approach was used to ensure that interactions between users, the environment, and technology could be considered with respect to establishing objective performance measures. Forty-four individuals with varied levels of offshore experience volunteered to participate in this interdisciplinary research.

Archival emergency response performance videos were analyzed and subject matter experts were interviewed to gauge level of agreement in regard to existing assessment procedures. Through an iterative human-centered design process, potential end users were asked to comment on prototype versions of the ERFB to ensure ecological validity. Situation awareness (SA) assessments, accuracy of response, and corresponding reaction times were used to test three different ERFB configurations in a simulated emergency.

Interview results indicate that subject matter experts use different assessment factors to predict future emergency response performance. Although not considered to be significant, these differences are thought to influence the subjective ratings of performance. Results further indicate that the type of ERFB configuration and the level of offshore experience significantly influenced the speed and accuracy of responses. Participants were also significantly more likely to correctly answer SA questions near the end of the simulation when using a dynamic (interactive features) ERFB.

Based on these results, it can be concluded that a dynamic ERFB improves speed and accuracy of responses while aiding in development and maintenance of SA. It can also be concluded that the dynamic ERFB configuration offers a less subjective measure of emergency response performance than the current assessment criteria. As a consequence, it is recommended that a dynamic ERFB configuration be implemented into all future offshore emergency response assessment training.

List of Abbreviations Used

ANOVA	Analysis of variance
BP	British Petroleum
CAPP	Canadian Association of Petroleum Producers
CNSOPB	Canada Nova Scotia Offshore Petroleum Board
CC	Control Condition
CNOPB	Canada Newfoundland and Labrador Petroleum Board
CIT	Critical Incident Technique
CR	Control Room
CSB	U.S. Chemical Safety and Hazards Investigation Board
DDM	Dynamic Decision Making
EC1	Electronic Condition
EEMUA	Engineering Equipment & Materials Users' Association
ERFB	Emergency Response Focus Board
ERT	Emergency Response Team
FPSO	Floating Production and Storage Offloading Vessel
FSO	Floating Storage and Offloading Vessel
HCI	Human/Computer Interface
HEP	Human Error Probability
HSE	Health, Safety, and Environment
HSI	Human Systems Integration
HTA	Hierarchical Task Analysis
HRV	Heart Rate Variability
KSA	Knowledge Skills and Abilities
MEM	Management of Major Emergencies
MODU	Mobil Offshore Drilling Unit
MOPU	Mobil Offshore Production Unit
MOU	Memorandum of Understanding
NDM	Naturalistic Decision Making
O&G	Oil and Gas
OIM	Offshore Installation Manager
OPITO	Offshore Petroleum Industry Training Organization
PICA	Person in Charge Assessment
ROC	Receiver Operating Characteristics
SA	Situation Awareness
SAGAT	Situation Awareness Global Assessment Technique
SARS	Situation Awareness Rating Scale
SART	Situation Awareness Report Technique
SDT	Signal Detection Theory
SME	Subject Matter Expert
SRK	Skills, Rule, Knowledge Based Decision Making
SSTL	Survival Systems Training Limited
TC	Transport Canada
UKOOA	Untied Kingdom Offshore Operators Association

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One ought never to turn one's back on a threatened danger and try to run away from it. If you do that, you will double the danger. But if you meet it promptly and without flinching, you will reduce the danger by half.

Sir Winston Churchill, (1874 - 1965)

CHAPTER ONE

INTRODUCTION

1.1 Background

The offshore oil and gas industry is in a constant state of upgrading and developing new technologies associated with the search for hydrocarbons in extreme environments. As a result of this highly motivated effort to locate and develop further supplies of the planet's natural resources, technological advances often include an element of automation. As the technological complexity of offshore production systems increase, unfortunately so does the potential for error, injury, death, environmental degradation, and asset loss (Tsang & Wilson, 1997, Ruckart & Burgess, 2007). Research evidence has also shown that as complexity and automation of production systems increase, operator understanding of that system's state frequently decreases (Endsley, 2000a; Wickens, 2008). In particular, increasing system complexity in a normal operational situation will undoubtedly increase the demands placed on the individual during an emergency situation.

Creating a team understanding of an emergency situation can aid in reducing the demands placed on a singular individual (Cooke, Kiekel, Helm, 2001; Wiegmann & Shappell, 2001). That is, by distributing the responsibilities among a number of highly trained individuals it is possible to decrease the cognitive demands for each person (Cooke, Salas, Cannon-Bowers, & Stout, 2000; O'Connor, & Flin, 2003). The benefits of commercial aviation emergency management programs utilizing additional human resources in aircraft cockpits has shown that errors can be reduced. Based on this understanding of emergency management, the Oil and Gas (O&G) industry typically establishes an Emergency Response Team (ERT), on every offshore installation, that consists of between five and seven trained individuals. Within these five to seven member teams there is:

- An Offshore Installation Manager (OIM) who is responsible for the overall management of the emergency;

- An individual (i.e. Toolpusher, Drilling Supervisor, Offshore Platform Lead) who is responsible as a second-in-command and for communication with a shore based emergency response team;
- A Fire Team Lead who is responsible for all fire team activities;
- A Radio Operator who is responsible to manage communications from various sources such as ships and aircraft in the area, and;
- A scribe who is responsible for recording (transcribing) all incoming communications onto a central information board.

Although there are several individuals attending to different pieces of information, it is the OIM's responsibility to make sense of the situation and identify what steps should be taken to mitigate risks associated with the particular type of emergency. In some cases; however, a seemingly overwhelming and unmanageable amount of information related to the status of the drilling and/or production processes and the nature of the emergency is presented to the team in a relatively short period of time. In extreme situations the emergency response team members (specifically the OIM) may be placed in situations that exceed their cognitive processing capacity, possibly resulting in a failure to attend to pertinent information.

In order to reduce the amount of information that must considered during emergency management, ERT members use a central focus board to consolidate critical response information. The focus board is often a generic dry-erase whiteboard, however, can be any surface that is used to record incoming information from radio, telephone, and verbal communication. The organization and amount of the incoming information is critical during the emergency management decision making process. If the focus board is poorly organized or if the there is too much information recorded on the display, ERT members may have difficulty identifying which details are most important and decision errors may occur.

Unfortunately, anecdotal examples of inappropriate responses during an emergency are abundant throughout the relatively long history of offshore oil and gas exploration and human/system failures have occurred at nearly every stage of operation. In fact, Funnemark and Young (2003) reported that a total of 5563 accidents, hazardous situations, and near misses occurred between 1980 and 2001 for the United Kingdom Continental Shelf alone. Additionally, data collection from various oil and gas accident reporting sources reveals that more than 1,000 lives have been lost in events from 1970 to 2007.

In order to better understand how errors occur, Reason (1990) proposes that industrial accidents are often the result of complex interactions and the accumulation of several separate events. Vincente (2003) further suggests that these errors occur because individuals often work outside the boundaries of safe practices and because catastrophic consequences rarely occur. Related to this line of thinking, Booher (2003) suggests that without using a Human Systems Integration (HSI) approach that incorporates the effects of variables such as personnel selection, training, and human factors engineering, it is difficult for designers to truly understand how individuals overcome system constraints related to information gathering during emergency events.

At an initial stage of risk mitigation and to ensure future performance of offshore personnel in emergency situations will meet expected levels, mandatory safety training is required by all oil industry organizations in Canada (CAPP, 2004, 2005). This requirement for training is legislated by the Canadian Nova Scotia Offshore Petroleum Board (CNSOPB) and the Newfoundland and Labrador Offshore Petroleum Board (CNLOPB) in conjunction with Transport Canada (TC). Specifically, within the offshore oil and gas (O&G) industry, response team members must successfully complete certified training in emergency management. Training of this sort typically consists of emergency situations simulated through the use of control room mock-ups and tabletop exercises as well as a declarative content component (classroom lectures) related to stress identification and human error mitigation techniques (Basra, & Kirwin, 1998). In addition, there is a requirement to overtly demonstrate explicit knowledge (outlined in safe work procedures and standard emergency response documentation for the particular O&G company) concerning proper emergency management procedures for a given situation. For example, OIMs must clearly demonstrate that they understand the situation by verbalizing details of the simulated emergency to the entire ERT (Survival Systems Training Limited, 2008). This verbalization of the critical aspects of the simulation is used as physical evidence of competency and demonstrates the OIMs' explicit knowledge of how to incorporate incoming emergency management information into a coherent working model of the situation. The declarative (verbal) component of this training tends to use previous accident investigation reports as a Critical Incident Technique (CIT) in order to discuss the requirement for vigilance and mindfulness when monitoring trends in operational performance/output during an emergency.

Although complex interdependent relationships occur among multiple factors associated with emergency management, it is the performance of the individuals assigned to mitigate the operating system upsets that is often the focus of emergency management training and intervention strategies (Cooke, Kiekel, Salas, Stout, Bowers, & Cannon-Bowers, 2003; Patrick, James, Amhed, & Halliday, 2006). CIT report discussions typically attempt to identify root or latent causes in an effort to reduce the likelihood of reoccurrence. Related causes such as human error, system design failures, and human/machine interface difficulties (to name only a few) are also used to explore the main reasons behind incident occurrence. Furthermore, monumental emergency events involving human/systems failures that result in considerable loss of human life and substantial revenue loss appear to have generated the bulk of both public and research interest. Evidence of this fact can be seen in the most recent British Petroleum (BP) O&G system failure in the Gulf of Mexico. Reports of poor safety culture and lack of management support have been brought to the general public's attention only because of such catastrophic events (Thomas, Jones, Clotherty, & Ryan, 2010).

Based on CIT studies of catastrophic failures and error management, it appears to be generally accepted that with greater experience, more user-friendly interfaces, and better training, offshore emergency incidents can minimized (Cannon-Bowers, & Salas, 1998; Ericsson, Krampe, & Tesch-Romer, 1993; Mayhew, 1999). It is also generally accepted that by using risk management techniques such as human error probability assessments (DiMattia, Khan, &

Aymotte, 2005), the severity of incidents could be reduced (Glendon, Clarke, & McKenna, 2006). It could however, be argued that as complexity of systems used in more remote locations becomes the norm, the ability to mitigate risks of incidents may in fact be limited. Given the complexity of current oil and gas production systems, operators of multi-billion dollar oil and gas equipment located in remote environments need to ensure that the training and performance assessment procedures examine the level of the emergency management process. For example, the level of complexity in many of the current operating systems may make it virtually impossible for operators and Installation Managers to understand every aspect of an oil and gas process. Therefore, the reliance on equipment that is designed to control all system functions in normal operations becomes a “black box” for operators if control is suddenly passed back to them as a result of a disturbance in the system (Mas, & Flores, 2008). For example, during an emergency, control room operators may be required to adjust aspects of the oil and gas refinement settings or, as in the case of Three Mile Island, bring a system back to normal operating conditions after internally designed limits have been exceeded ('L Razi Ahmadun, Shaluf, & Aini, 2003). Without a clear understanding of what the system state was prior to the upset or what factors caused the system failure, operators may not be able to identify which course of action might reverse the process. In addition, an Installation Manager must comprehend the meaning behind a system state while considering the effect of a change made to correct the original situation on multiple other systems, as well as always ensure the safety of personnel. Thus, an out-of-the-loop design of complex systems does not allow for practice of the critical skills that may be necessary in an emergency and places an immense burden on the ERT management personnel.

Therefore, in order to develop contingency plans that would mitigate possible system failures; simulated emergencies are often used to assess dynamic decision making and cognitive processes of ERTs (Jones & Endsley, 2004). The benefits of using simulated environments that closely match conditions that could be expected in the real-world (often called microworlds) cannot be overstated, particularly when investigating human responses during emergency situations that would (under real conditions) induce unacceptable risk to personnel and the environment. Therefore, creating a complex environment that closely resembles the physical space in which teams operate has increasingly become the focus of cognitive engineers, psychologists, sociologists, and human factors specialists (Booher, 2003; Gorman, Cooke, & Winner, 2006). However, based on Booher's (2003) framework, it is the lack of acknowledging the interactions among humans, technology, and the organizations in which they are embedded (the three basic components of Human System Interaction - HSI) that constitutes the greatest gap in our understanding of human performance in emergency management. By examining the links between these three basic components of HSI (described in more detail below) I examined specific interactions related to emergency response management of O&G safety training and the extent to which this type of risk mitigation might influence future real-world human performance. Therefore, this thesis explores current ERT training methodology (described by subject matter experts) while in a dynamic environment, and the development and testing of a emergency response focus board that was used to display critical information to team members during training simulations through the multidisciplinary lens of HSI.

In order to examine the influence of interactive visual displays on the performance of emergency management teams, this thesis has been divided into 12 chapters. In chapter 1, I have provided an overview of offshore emergency response training and evaluation of response performance. Chapter 1 also introduces the use of HSI as a holistic approach that is used throughout the thesis.

Chapter 2 and 3 are designed to contextualize the need for detailed investigation of factors that influence human response during emergencies. Chapter 2 presents one emergency event case from each of the aviation, marine, and offshore industries that are used to examine risk management and mitigation techniques. Although each emergency event category is unique in its approach to investigation, there are some basic similarities in how human performance is judged and evaluated. For example, each of the three emergency events place a relatively large portion of the responsibility on the operators, while neglecting to identify the possible links between the individual and other humans, the system constraints and the conditions under which particular decisions were made prior to and during the emergency event. Identification of these invisible links highlights the need to consider whether various individuals would make similar decisions under similar circumstances. If the answer to this question is yes, then it must be assumed that the interaction between the available technology and the human, and/or the environment or a combination of all three aspects are responsible for the outcome and not just the operator's actions that resulted in the final outcome. Furthermore, an HSI approach requires that a greater understanding of factors affecting an emergency response management process (i.e. training, evaluation, systems integration) be given thorough consideration. Chapter 3 identifies the importance of visual display systems and how they are integrated into an understanding of what is occurring within a particular situation. Chapter 3 also highlights the need to incorporate human factors design principles for the development of visual display systems such as the focus board. By considering the impact of how incoming emergency response information is organized and displayed on the board, it may be possible to increase ERT members' collective understanding of a situation.

Chapter 4 provides a detailed literature review of the principles of Human Systems Integration and is divided into seven areas of interest to identify factors associated with the development of situation awareness (SA), information processing, decision making, expertise, accident investigation of human performance, training, enhancing interface design, and performance metrics. Each of the factors on its' own is important to human performance during an emergency; however, it is the combination and overlapping aspects of the factors that draws attention to areas that could be missed if examined in isolation. Chapter 4 also provides background information related to information processing and dynamic decision making by exploring the emergency response assessment practices within the context of a petroleum processing plant located in Texas. This emergency event is used to develop the rationale for supporting the use of HSI as the most appropriate methodology to investigate the various interactions among people, technology and organizations.

Chapter 5 presents the specific research objectives and hypotheses of this thesis and provides a rationale for the specific research questions. Chapters 6 through 12 present an outline of phase specific data collection procedures as well a discussion and recommendations for future research. Chapter 6 describes the methodological overview based on implementing a new interactive emergency focus board and how the subject matter experts and ERT personnel interact with this new presentation format of emergency response information. In order to address the various factors associated with ERT training, I have employed a mixed (quantitative and qualitative) research methods approach. Furthermore, the holistic framework known as Human Systems Integration (HSI) is used to demonstrate that by incorporating all relevant aspects of system functioning, individuals in the most vulnerable or hazardous positions of an operation may be able to fully understand how their actions influence the overall system. Chapter 7 through 11 describe the detailed methods used by subject matter experts to assess the performance of offshore ERT members as well as results and specific discussion points related to the each Phase. Specifically, Chapter 7 details the research methods used to examine emergency response performance through the use of existing technical documents and archival MEM/PICA training videos. Chapter 7 highlights the variability in emergency response performance and it is suggested that these differences stem from the manner in which incoming information is organized and used for decision making. Chapter 8 outlines the methods, results, and discussion related to how subject matter experts evaluate MEM/PICA candidates while using six global assessment factors. Chapter 9 of the thesis presents the research conducted to establish a template for the emergency response focus board. Based on the results detailed in Chapter 7 and 8, I identified the need to develop a standardized emergency response focus board that could be used to reduce the variability in ERT responses during simulated emergencies. By completing a focused discussion with Offshore Installation Managers, I was able to identify which information is most crucial to emergency response performance and where this information should be located on a focus board. Chapter 10 details the testing and evaluation of two emergency response focus board templates under simulated

MEM/PICA testing conditions. This Phase of testing involved novice users of the focus board and represents a baseline of emergency response performance with the newly designed templates. Chapter 11 outlines the testing of the final focus board template with actual offshore emergency response personnel attending an MEM/PICA course at Survival Systems Training Limited. Chapter 12 presents a general discussion that incorporates aspects from each of the research phases as well as specific recommendations for future emergency response performance evaluation while using an electronic emergency focus board system. Chapter 12 indentifies that, although one of the primary outcomes of this thesis is the development and testing of the emergency response focus board, it is the integration of technology, humans, and the environment in which they interact that is critical to understanding offshore emergency response performance.

This thesis addresses what I perceived to be gaps in our understanding of how the various factors associated with offshore oil and gas emergency response affect human performance and the subsequent attempt to reduce similar events occurring in the future. Moreover, I believe that although the oil and gas industry might be considered a mature and highly reliable industry, relatively little research has been carried out on how individuals are trained to handle emergency situations. For example, the Canadian Association of Petroleum Producers clearly stipulate that members of an ERT must successfully complete training from a recognized training provider and that the training must involve tabletop exercises as well as simulations to test the Offshore Installation Manager’s capacity to control the situation. However, at present there are no specific international guidelines concerning what must be accomplished during the management of a simulated emergency in order to achieve qualification. Nor is there information detailing the specific type or quantity of performance evidence that is gathered during an emergency simulation to ensure that a transfer of knowledge has taken place. As a result, training providers and offshore operators use training methodologies believed to be beneficial to emergency response management without a firm empirical basis. This “best practices” approach to ERT training may be thought by many to be the best way to prepare individuals for a real-world event; however, until a systematic investigation of the procedures has been carried out, only unsupported assumptions can be made about their effectiveness. Finally, it could be argued that the amount of emergency response information, associated within training and real-world situations, which must be maintained in working memory, is beyond the capacity of the OIM and the ERT members. Therefore, a new way of integrating and displaying this information is needed to ensure that cognitive loading is reduced and that a cohesive understanding of the situation is shared among the entire group of ERT members and the OIM.

CHAPTER TWO
EMERGENCY EVENTS

In order to contextualize the relevance of this thesis research, this chapter examines real world emergency events from three separate industry-based perspectives (aviation, marine, and offshore oil and gas). Although the circumstances surrounding the events are unintentional and include fatalities (required criteria to be termed an accident in all three industries), I believe that it is important to make the distinction between the term *emergency event* and the conventional taxonomic term *accident*. The rationale for making a distinction between the two terms is based on the fact an accident has been described as: "*a***:** an unforeseen and unplanned event or circumstance and, *b***:** lack of intention or necessity" (Merriam-Webster Unabridged Dictionary, http://www.merriam-webster.com/dictionary/accident). Based on the identification that an event is unforeseen, I believe that the term *accident* should only be used in cases where there is no antecedent (human or technology induced) identified during an investigation. Additionally, the term *accident* should be reserved for events in which no possible intervention could have been implemented prior to the event occurrence.

The specific emergency events detailed in this section are explored in order to justify the use of methodological techniques (outlined in Chapters 6 through 11 below) while establishing real-world applications for future training and assessment requirements. As such, the emergency events are used primarily to focus attention on human performance rather than aspects related to equipment malfunction or meteorological (weather) conditions. However, the final event (offshore oil and gas [O&G]) discussed in this part of the thesis is more detailed in its examination given that the primary application is directed at improving human performance of emergency management in an O&G environment. This part of the thesis further outlines recommendations from each industry to highlight commonalities linked to a Human Systems Integration approach.

2.1 Aviation Industry

In order to demonstrate the link between human performance and training, I have chosen to discuss the MK Airlines' flight 1602 on the morning of October 14th, 2004 (Transportation Safety Board of Canada (TSB), 2004). Although there were 100 emergency events within the aviation industry in 2004 (National Transportation Safety Board, 2008), I believe that the MK flight 1602 illustrates well the influence of multiple factors on decision making just prior to an emergency event. This scheduled cargo flight had arrived at Halifax Stanfield International Airport from Connecticut and on its way to Zaragosa, Spain. During the take-off from Halifax, the aircraft failed to gain altitude (striking a berm with the lower tail section of the aircraft) and crashed a short distance from the end of the runway. One of the primary causal factors cited by investigators was the pilot placing incorrect data into the onboard computer (TSB, 2004). When tallying the overall takeoff weight of the aircraft, the investigation report indicates that the crew inadvertently used the take-off weight of their last flight, which was more than 100,000 kg lighter than that of the crash flight. The investigation also revealed that the overall weight calculations did not consider the additional load of wooden pallets supporting the newly loaded cargo, nor did they account for the weight of the crew, a spare parts kit or catering supplies (TSB, 2004). Although considerably less then the extra 100,000 kg, the additional load of 3,120 kg represented an ongoing error in the way that the flight crew entered weight and balance calculations before take-off.

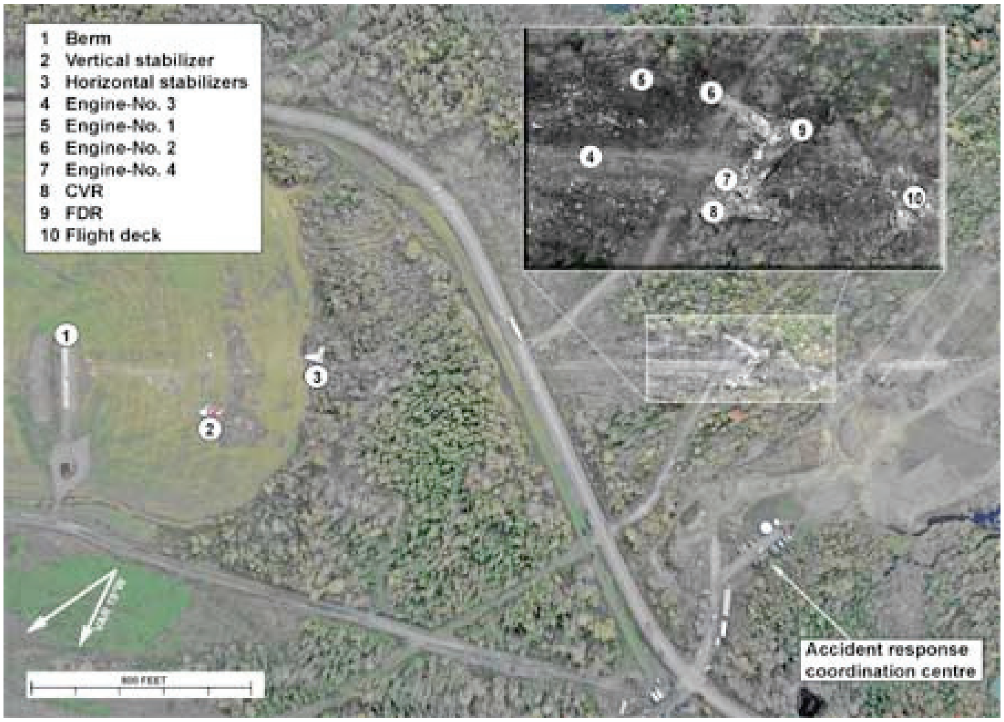

Figure 1. Crash site of MK Airlines flight 1602 (from TSB, 2004).

During its investigation, the TSB (2004) report noted that the captain of flight 1602 was not comfortable using the weight and balance software and identified that during upgrade training, the operating pilot “was not comfortable using personal computers and software, such as the Boeing Laptop Tool (BLT)” (section 1.5.2). It was further noted “most of the MK Airlines Limited flight crew members did not receive any formal training on the BLT, and there was no method to evaluate and identify whether individuals had become competent using the BLT by the end of the self-study training period” (TSB, 2004, section 1.18.1.2).

The findings suggest that had the corrected weights been entered into the BLT (343,120 kg instead of 240,000 kg) the system would have indicated that the “planned weight exceeds max allowable take-off weight” (TSB, 2004, section 1.18.1.5). Based on these findings, it was reported that the only logical explanation of the incident was that the weight data from the previous flight had not been replaced by the new weight in the BLT and when transcribed to an information check card used in the cockpit, the correct weight had been manually entered. Therefore, when the captain checked the pre-flight numbers, there appeared to be nothing wrong with the settings. The TSB (2004) investigators summarize the results of the crew’s performance as “once the take-off had commenced, the crew's situational awareness likely was not sufficient to allow them to detect the inadequate acceleration before it was too late to take off safely” (section 2.8).

This incident highlights the crew’s reliance on the automated weight and balance calculation system (the BLT) and their lack of knowledge regarding the system’s performance requirements. As a consequence, they did not recognize the need to manually remove the old data before a new calculation could be completed. Additionally, the TSB (2004) report indicates that the crew did not fully understand how their error of omission (not completing a final check of the data prior to commencing the takeoff) could affect the performance of the equipment. The crew’s failure to recognize the influence of their actions implies that a number of factors such as confirmation bias (Johnston, 1996), and unintentional actions or slips (Reason, 2002) leading to attentional failure (Delhomme & Meyer, 1998) were taking place at the time that the information was being entered into the flight computer. Confirmation bias is a cognitive strategy that reduces the amount of information that needs to be processed while performing a particular task by only attending to facts that support or confirms one’s original thought or assessment of a situation (Besnard, Greathead, & Baxter, 2004; Lehner, Seyed-Solorforough, O’Connor, Sak, & Mullin, 1997). By selectively attending to data that confirms one’s assessment, particularly while under severe time constraints, disconfirming information that may be relevant could be overlooked and a true understanding of the situation is unlikely to be established. Unintentional acts refer to actions performed by individuals with the belief that they are correctly completing the task (Reason, 1990). For example, the pilot of the MK 1602 flight believed that he was entering the weight and balance information correctly; however, he unintentionally entered the wrong information into his calculations. Unfortunately, it is difficult to identify exactly what factors affected the allocation of attentional resources of the crew as all seven individuals perished in the event. However, as pointed out by the TSB investigators, understanding the crew’s situation awareness (SA) (detailed further below) and fatigue levels prior to the incident could help address factors that were considered most influential during the decision making process.

2.2 Marine Industry

As with the aviation industry, there are several hundred emergency events that have been reported as accidents that could have been selected to examine human decision making behaviour in a dynamic marine environment. However, the Exxon Valdez is one of the most recognized global marine emergency events and clearly demonstrates the link between attention, situation awareness, and human error. During the early morning hours of March 24th, 1989, the Exxon Valdez struck a reef in Prince William Sound, Alaska, causing a rupture in the hull plating of the ship (Alaska Oil Spill Commission, 1990). More than 11 million gallons of crude oil leaked out, creating one of the largest spills in North American history.

Figure 2. Exxon Valdez leaking oil near Prince William Sound, Alaska (Photo courtesy of the *Exxon Valdez* Oil Spill Trustee Council).

Figure 2 shows only a small portion of the spill as it spread out over the Sound. Reports indicate that the main causes of the disaster were related to fatigue and human error as well as procedural violations (Alaska Oil Spill Commission, 1990). Within a traditional maritime organization, the captain is ultimately responsible for all actions that take place onboard a ship. The first, second, and third mate follow the directions of the captain in a hierarchical chain of command. In the case of the Exxon Valdez, it was reported that the third mate had been working for approximately 18 hours prior to the grounding and was the only person on the bridge monitoring the ship's position just prior to the grounding (Alaska Oil Spill Commission, 1990).

The report from the Alaska Oil Spill Commission (1990) identifies that the role of a human within an automated system is less demanding manually, but more mentally challenging when using a traditional manual configuration. This distinction of separate cognitive (mental processing) and physical (performance of manual tasks) requirements is important in that it highlights the notion that once a task becomes automated within a system, it may be both beneficial as well as detrimental to operators. Benefits may include reduced levels of manual labor or decreased demands for constant monitoring. However, under certain circumstances, these benefits may be outweighed by the fact that it is difficult for operators to maintain an understanding of what the system is doing. This "out-of-the-loop" situation (Alfredson, 2007; Endsley, & Kiris, 1995) poses considerable problems when attempting to plan or practice a response skill set that may be needed during an emergency situation. The Exxon Valdez emergency event demonstrates that although plans were made to correct the course of the ship prior to the grounding, there was no look-out person on duty (which violated written company policies) to identify and relay the ship's close proximity to shore. It was also identified that, contrary to required practice, the autopilot system remained on during the close transit to shore (Alaska Oil Spill Commission, 1990).

Vincente (2003) points out that individuals will often work outside safety boundaries set by industry and equipment manufacturers due to a lack of relevant information provided through some form of system feedback (see also Rasmussen, 1997). Specifically, operators are not always informed that deviations from the prescribed safe work practices can eventually lead to complete system failures. The lack of negative feedback provides positive reinforcement to the operator that the system can tolerate slight deviations without severe consequences. That is, when nothing adverse happens the first time someone operates a system outside established safety guidelines, there is an incremental shift in the operator’s understanding of the maximum allowable tolerances that a system can safely be operated. As operators normalize operations that occur outside a suggested safety range, the system is incrementally pushed further from its intended procedures. Turning a huge supertanker in a narrow passage may offer considerably more feedback than it would out at sea; however, the resulting operator input may occur too slowly to alleviate the consequences. It is this insidious incremental shift from established safety boundaries (Vincente, 2000) that reduces an individual’s ability to develop and maintain an appropriate level of situation awareness that will be beneficial during times of emergency operations.

2.3 Offshore Oil and Gas Industry

The final industry-based incident used in this section demonstrates a link between decision making, situation awareness, and expertise. This emergency event occurred 110 miles off the coast of Aberdeen, Scotland onboard the Piper Alpha oil platform on July 6, 1988. The explosion and subsequent fire resulted in the death of 167 individuals as well as causing immeasurable environmental damage. The public inquiry reported that a number of factors led to the incident, including insufficient emergency response training of the crew, non-compliance to operating procedures, and deficiencies in organizational safety policies (Cullen, 1990). Lord Cullen (1990) (the public inquiry commissioner) clearly indicated that a lack of safety training contributed to the loss of life. It was further reported that although the personnel onboard the Piper Alpha had attended a half-day safety training course, it was not considered adequate to prepare the individuals for the events that took place on the day of the explosion (Cullen, 1990). Following the investigation, Lord Cullen (1990) made recommendations indicating that communication of information between onshore and other offshore platforms should be modified to allow for better decision making by installation managers. In addition, the report also indicated that the actions of the installation managers from connected platforms occurred too slowly and most likely contributed to the death toll.

Figure 3. Piper Alpha installation engulfed in flames (from Cullen, 1990).

Reason (1990) argues that although industrial organizations implement safeguards into critical systems, it is often the combination of more than one event that leads to an incident. Reason (1990) further suggests that gaps in the safety systems at each level of an organization leave room for catastrophic events to occur. During the hours leading up to the explosion and fire onboard the Piper Alpha, specific events such as crew changes and loss of crucial documentation set the chain of events in motion (Cullen, 1990). One of the difficulties associated with a complex and dynamic environment is that the combinations of events leading to an emergency are often difficult to identify prior to the event actually occurring. There rarely exists a system in which all interrelated activities are identified in such a way that operators or system users fully understand the contributory nature of the combined effects. As an example, the deluge system (a massive sprinkler system that sucks in water from below the ocean surface and sprays it over the outside of the installation) systems onboard Piper Alpha had been turned to a *manual* instead of an *automatic* setting which significantly contributed to the difficulties experienced by the platform's firefighting capabilities (Cullen, 1990). It was not clear why or who had switched the deluge system to the manual setting (Cullen, 1990), however, the importance of this seemingly small deviation from recommended procedures only became apparent after the event. Unfortunately, the identification of contributing interaction prior to an event becomes increasingly more difficult with system complexity.

As an example of emergency events within the offshore O&G industry, Table 1 identifies some of the fatal events that have occurred over the last 54 years. Within the table, the events have been grouped by decade. The table also indicates the type of event as indicated by investigation reports. For clarification, a blowout event includes situations in which material contained within the drill pipe is rapidly forced back out of the well by sub-surface pressures. This sudden discharge of drilling fluids can lead to a release of flammable gas or liquid that could be ignited by static electric discharge created by the rapid movement of the material through the pipe. Although not an exhaustive list, the table highlights the fact that an extensive increase in fatalities occurred during the 1980s. While not examined statistically, these incidents appear to correspond with an increase in overall offshore activity and availability of installations.

Table 1. List of fatal offshore incidents from 1956 to 2007.

Rig/Well Name	Year	Location	Fatalities	Type/Event/Comments
SedcoNo8	1956	GOM	4	Sinking/Under construction
Qatar I	1956	Arabian Gulf	20	Sinking/Collapse
Mr Gus 1	1957	GOM	1	Sinking/Tilt/Capsize
C. P Baker	1964	GOM	22	Blowout/Explosion/Fire
Seagem	1965	UK	13	Collapse/Jack failure
Little Bob	1968	GOM	7	Blowout/Fire
South Timbalier 26	1970	GOM	4	Blowout
Gemini	1974	Egypt	18	Punch through/Leg failure
Ekofisk A	1975	Norway	6	Fire
Deep Sea Driller	1976	Norway	6	Grounding/Storm
Ocean Express	1976	GOM	13	Sinking/Bad weather
Bohai 2	1979	China	72	Sinking/Storm
Ranger 1	1979	GOM	8	Collapse/Fatigue

Alexander Kieland	1980	Norway	123	Collapse/Fatigue fracture
Bohai 3	1980	China	70	Blowout/Fire
Hasbah Platform	1980	Persian Gulf	19	Blowout/Major release
Maersk Endurer	1980	Gulf of Suez	3	Blowout/Derrick collapse
Ron Tappmeyer	1980	Arabian Gulf	19	Blowout
Ocean Ranger	1982	Atlantic	84	Sinking/Storm
60 Yrs of Azerbaijan	1983	Caspian Sea	5	Sinking/Seabed failure/volcanic
Byford Dolphin	1983	Norway	5	Explosion/Diving accident
Glomar Java Sea	1983	S. China Sea	81	Sinking/Storm
Nowruz Platform	1983	Persian Gulf	20	Fire/Major release
Enchova Central	1984	Brazil	37	Blowout/Fire/Lifeboat fell to sea
Getty Platform A	1984	GOM	1	Explosion
Zapata Lexington	1984	GOM	4	Blowout
Glomar Arctic II	1985	UK	2	Explosion/Pump room
Penrod 61	1985	GOM	1	Sinking
West Vanguard	1985	Norway	1	Blowout
Ocean Odyssey	1988	UK	1	Blowout/Fire
Piper Alpha	1988	UK	167	Fire/Explosion/Sinking
Viking Explorer	1988	Borneo	4	Blowout/Explosion/Sinking
Al Baz	1989	Nigeria	5	Blowout/Burned/Sank
Cormorant A	1989	UK	3	Explosion/ Gas leak
Seacrest	1989	Thailand	91	Sinking/Typhoon
Sedco 252	1989	Indian Coast	3	Blowout/fire
DB29	1991	S. China Sea	22	Sinking/Typhoon
Rowan Odessa	1994	GOM	1	Fire/Leg struck pipe
Ubit Platform	1996	Nigeria	18	Fire/Explosion
Glomar Arctic IV	1998	Scotland	2	Explosion
Mighty Servant 2	1999	Indonesia	5	Sinking/Collided with rock
Al Mariyah	2000	Persian Gulf	4	Collapse/Jack failure
Petrobras P36	2001	Brazil	11	Sinking/Explosion
Arabdrill 19	2002	Persian Gulf	3	Collapse
Parker 14-J	2003	Indian Ocean	8	Collapse/Capsize
Mumbai High North	2005	Atlantic	22	Fire/Boat impact
Bourbon Dolphin	2007	GOM	8	Sinking/Capsize
Usumacinta	2007	GOM	22	Fire/Explosion/Riser failure
Total Fatalities			**1069**	

Figure 4 identifies the trends in offshore incidents and shows a clear increase in frequency for the 1980s followed by a rapid decline in the 1990s. During the 1980-90 decade a total of 745 individuals (70% of the total fatalities) perished in 23 incidents, of which almost half (11/23 – 48%) were the result of blowouts. Based on the these results, and that training policies and safety regulations were adjusted to meet some of the recommendation made by Lord Cullen, it could be argued that the Piper Alpha incident fundamentally changed the way in which offshore safety was viewed by the oil and gas industry and the world in general. After the Cullen (1990) inquiry was published, it was clearly no longer acceptable for offshore organizations to meet the previous bare minimum safety guidelines and training requirements without understanding how compliance could affect survival rates. New safety training standards and operational guidelines were established and the Offshore Petroleum Industry Training Organization (OPITO) began to investigate and document required qualifications of individuals working in the offshore. Unfortunately, it appears that it is only after major events such as the Piper Alpha takes the lives of numerous individuals do we see directed changes in standardized practices.

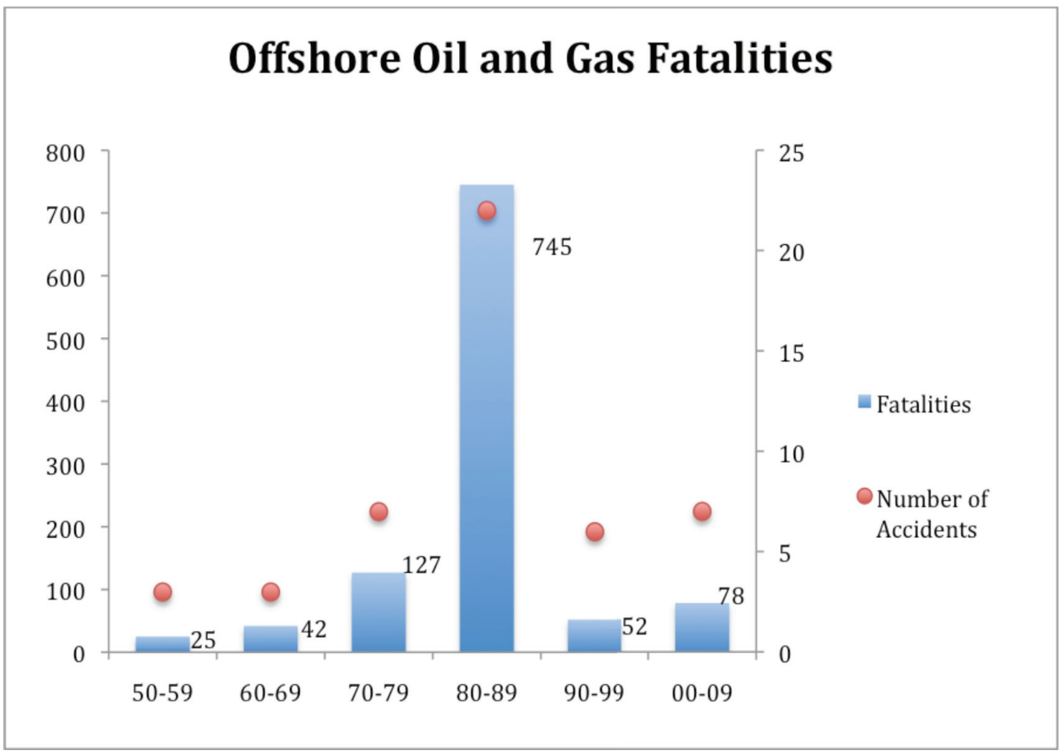

Figure 4. Offshore fatalities based on number of incidents.

Figure 5 shows the relationship between worldwide rig availability and fatalities. From the figure it is clearly apparent that after the Piper Alpha incident, fatalities decreased to a considerably lower level. The figure further shows that although fatalities appear to follow the rig availability trends, there are periods (1988 - 1989) during which the number of installations available does not directly correspond with the number of fatalities and is primarily due to Piper Alpha and the Seacrest platform sinking off the coast of Thailand.

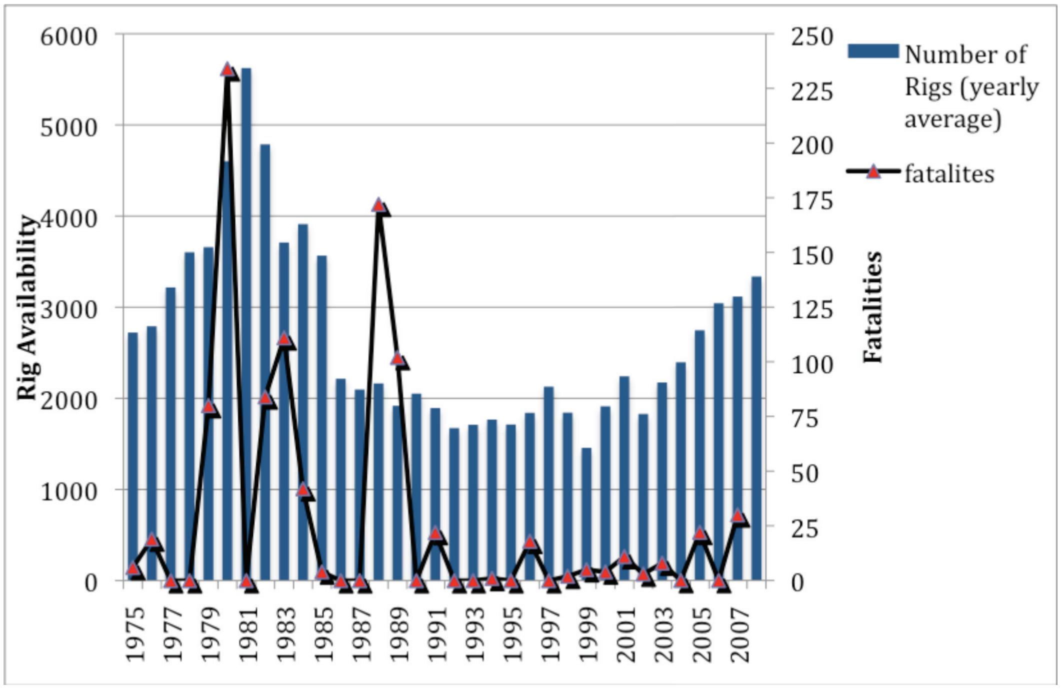

Figure 5. Offshore fatalities based on number of rigs available.

2.4 Emergency Event Summary

From emergency event descriptions like those outlined above, it is possible to conclude that within the aviation, marine, and offshore industries, training individuals to interact effectively with their environmental surroundings as well as within the constraints of organizational safety cultures is an important and complex endeavor. For example, in the MK 1602 flight, the pilot and other crew members had no indication that the total weight of the aircraft and its contents had been entered incorrectly, and in the Exxon Valdez grounding, the proximity to shore and its effect on possible ship movements was not displayed to the ship personnel on duty. Finally, in the case of the Piper Alpha oilrig, it was clear that a number of factors such as training, corporate safety culture, and standard operating procedures contributed to the overall outcome of the event.

Being aware of underlying conditions aids individuals in maintaining an understanding or grasp of a situation. The greater this understanding, the more likely individuals are able to predict how changes to the system will affect the future status of the situation (Endsley, 2000b; Wickens & Hollands, 2000; Wickens, Lee, & Liu, 2004). Endsley (1995a) suggests that by distinguishing the specific level of understanding that an individual or team has of a situation it is possible to identify how these individuals will perform during a real-world event. It has further been suggested that there are three specific levels of awareness: perception, comprehension, and prediction that can be used to categorize the level of understanding that is often called situation awareness (Endsley, 1995a). As the concept of situation awareness is a central component of this thesis, I have included a more detailed framework in Part II.

The emergency events outlined above describe situations in which the amount of information available at any given time varied, depending on system constraints. However, the processing of this information may also differ depending on the amount of experience and the level of understanding each person had about the desired system state. Research results have indicated that automation of systems may reduce the requirement for attentional resources needed during decision making. However, it has been argued that as a result of the automation, individuals often lack the experience to make decisions related to critical systems during an emergency (Reason, 2002, 2004). The paradox that exists between automation and maintaining a sufficient amount of situation awareness to respond to an emergency is a major challenge for operators of critical systems (Reason, 2002). During an emergency situation not only is it paramount that individuals had been trained to manage the incoming information, it is also important that the individuals are able to construct a clear mental image (situation awareness) of the factors that will have an affect on the outcome. Within each of the events discussed above, it is apparent that key aspects such as incorrect input of information in an onboard weight and balance computer, fatigue and violation of safety standards, and lack of safety training combined with changes to safe work practices leading up to the events contributed to the final outcomes. Without examining training and performance assessments used by organizations, as well as factors such as fatigue or failure to follow standardized safe work practices, it becomes difficult to identify where improvements can be made. Although it is relatively easy to retrospectively identify potential problems, it would be more beneficial if these shortfalls were identified prior to an emergency event. As with the pilot from MK flight 1602, it was apparently that MK Airlines had unofficially or incrementally implemented a policy of approving certification of individuals without ensuring a complete assessment of performance. Only after the emergency event was it revealed that this form of unsafe cultural practices might have led to deficiencies within the safety management system (Aerosafe Risk management, 2010; Cox, & Cheyne, 2000).

The remaining portion of Part I of this thesis suggests that if error mitigation is to be directly addressed, there is a need to standardize the manner in which incidents are viewed. In addition, I propose that by using an interactive format of representing relevant information, it may be possible for individuals to develop a more clear understanding of how complex systems are affected by their actions. Thus, by displaying the pertinent information, both individual and team awareness may be enhanced.

CHAPTER THREE
IMPORTANCE OF DISPLAYED INFORMATION

3.1 Interactive Representation of Information

As mentioned in Chapter 1, the use of a Critical Incident Technique (CIT) to examine prior emergency events may help to identify future potential problems prior to an undesirable event occurring. In addition, a CIT may aid in understanding how deviations from the key aspects of the normal operating procedures influence one another. In each of the events outlined above, it could be argued that had the personnel a way of visually piecing together the critical information related to the influence of their actions (i.e. weight and balance information based on aircraft design requirements, lack of qualified and alert personnel standing watch during the passage of a ship through a narrow channel, or gas pump status on the oilrig), it may have been possible to prevent or at least reduce the effects of the emergency events. Presentation of information in such a manner may have considerable relevance to those individuals involved in system failure, in that operators could be kept in-the-loop prior to the emergency event occurring. In addition, the inclusion of visuospatial information may reduce the difficulties associated with conceptualization of an abstract set of rules and regulations. Tesone and Goodall (2007) indicate that by using visual displays to consolidate information from large datasets, situation awareness is enhanced "by allowing the user to readily see the big picture" (p. 72). Working from a data management perspective, Tesone and Goodall (2007) indicate that users of complex systems often need to have intimate knowledge of the available information before attempting to obtain an answer to a particular query; however, if the system is designed to identify possible links within the dataset, search parameters can be reduced to a manageable level. Similarly, I argue that the identification of a clear link between separate safety - related factors that could be displayed and their relative importance should be considered paramount if individuals are expected to appreciate how human/system interactions influence the overall situation. For instance, if the captain and crew of MK flight 1602 had been able to visually verify the discrepancy in the weight and balance data as it related to the overall safe operation of the aircraft prior to initiating the take off sequence and how this difference to the actual or expected weight would affect their flight path, it is doubtful they would have proceeded without conducting a more detailed examination of the overall numbers. In other words, if the aircrew could have seen a display that depicted the aircraft performance based on expected and input weight and balance information, collectively, they may have had an increased level of situation awareness related to the missing totals. Additionally, it is important that a capability exists to signal or warn individuals who there is a potential problem in the system's operation. This will ensure that potential emergency prompting is not ignored, considered unimportant or simply missed.

Displaying critical information that is predictive in nature and is assumed to be important to the safe operation of any system or human/computer interaction is vital if individuals are expected to manage an emergency situation (Folmer, van Welie, & Bosch, 2006). Clearly, there is a difference between alerting the individuals to a potential problem and indicating what is required to mitigate the problem. In some cases, identifying the problem may be all that is needed, particularly if the individual can easily rectify the potential upset. However, if the potential problem requires an operator to conceptualize how specific complex aspects of a system need to be integrated into one combined effort, the way in which the information is presented needs to make sense to the person. Without identifying controlling factors, it is difficult for individuals to conceptualize the connections between their input and the impact that those changes may have on system functioning. Training individuals to identify and manage system upsets may offset some of these limitations of visual displays; however, in an emergency situation the display needs to be designed in such a way that critical information is easily accessible and can be integrated into an understanding of the interrelated components.

Unfortunately, when a system is extremely complex the information describing its state is difficult to display and if all of the information is displayed, the cognitive load associated with comprehending it all may exceed the capacity of the typical operator. The challenge is to compile key components of the system that shape safe operations into a cohesive, meaningful display that can be utilized by individuals prior to and during an emergency.

3.2 Human Factors Visual Display Design Principles

The consideration of human factors design principles when developing a visual display is key to ensuring that users are able to understand what information is available and how to locate relevant cues that will aid in task completion. Addressing design principles is important during normal operating conditions: however, this basic step is paramount under emergency conditions. For example, a user may be able to compensate for design deficiencies when there is ample to time to consider alternative sources of information, whereas, during time critical situations, a user may only have the opportunity to check a display once before making a decision. Moray (1997) outlines specific visual display development criteria that should be considered to ensure positive human-machine integration. Wickens, Lee, Liu, and Becker (2004) further identify important human factors design principles that should be utilized when developing a visual display. From the standpoint of an emergency situation, information should be easily recognized as being salient and should be contained within a useful field of vision for the users (Wickens, & Hollands, 2000; Wickes, et al., 2004). It is further suggested that visual noise (i.e., excessive distractor information that is not relevant) should be kept to a minimum, as this will reduce the amount of time it takes to locate the most critical information (Yeh & Wickens, 2001).

Wickens, et al., (2004) propose four distinct categories that should be considered when developing displays: 1) perceptual; 2) mental model; 3) attention, and; 4) memory. Within these four categories, 13 separate principles are outlined. Generally, the principles contained within the category of perceptual guidelines suggest that displays need to be legible in regard to visual angles, contrast, and illumination. It is further suggested that perceptual aspects related to judgment, expectations, redundancy, and the ability to easily discriminate between similar elements will ensure that users do not become confused (Wickens' et al., 2004). Mental model principles suggest that pictorial realism (i.e., the display should look like the real-world object), and all moving parts within a display should be compatible with users expectations. Attentional principles suggested by Wickens, et al. (2004) indicate that accessing information from one display area to another should not add unnecessary time, similar information should be located in close proximity, and the use of multi-modal information (e.g., visual and auditory) need to be considered when developing a display. Finally, memory principles suggest that knowledge in the head should be replaced with knowledge in the world (i.e., writing something down reduces the need to remember it later), multiple displays should have consistent organization and structure, and displays should aid in predicting what will happen (Wickens, et al., 2004).

By using the principles suggested by Wickens, et al., (2004) and Yeh & Wickens (2001), displays could aid in the ability to develop and maintain situation awareness. In order to address the goal of creating interactive displays, this thesis represents the first step in a much larger process. I believe that as part of the assessment and training of emergency response safety personnel, it is important to ensure that the displaying and management of incoming information is identified as being critical to team situation awareness.

By creating a visual representation of the critical factors, it becomes considerably easier to identify how specific actions can ultimately lead to better emergency response performance in the offshore. In order to further argue this point, I have examined the training and assessment of offshore oil and gas personnel assigned to command and control positions onboard O&G installations in the North Atlantic. Specifically, I discuss the Management of Major Emergencies and Person in Charge training programs provided by a Canadian Transport Approved course provider. By examining the specific components of the assessment process, I developed and tested interactive (touch screen) emergency response focus board (ERFB) templates that were used to visual display interconnected aspects of a particular situation. The ERFB was designed to ensure that the entire emergency response team located in the control room had a visual representation of what the installation manager knows to be true of the situation at any given moment. This study is important, in that it is the first of its kind within the

Canadian oil and gas industry. Additionally, the ERFB templates can be used both as a training and assessment tool during emergency simulations and as a technology to help manage actually emergencies in the O&G industry.

CHAPTER FOUR

HUMAN PERFORMANCE AND EMERGENCY RESPONSE

The research results detailed in this chapter were selected for their specific relevance to human performance testing. This chapter begins with a brief outline of an industrial event to illustrate that emergency events continue to occur in highly reliable organizations (i.e., an organization that has succeeded in avoiding events despite the level of risks associated with the work environment). This is in spite of considerable effort by industrial and other research efforts being directed at explaining how to reduce human error. Additionally, this particular incident demonstrates that even after recognition of an inappropriate organizational safety culture and the identification of training deficits, very little was done to change the situation. It was only after political and public pressure increased to a “tipping point” that the organization became sufficiently energized to change. Following a brief discussion of the incident, this chapter details the link between several sub-components of a Human Systems Integration (HSI) framework while considering offshore emergency management at both an overarching (macro) and focused (micro) level. At a macro-level, systematic reviews include HSI, situation awareness, information processing, and expertise in order to outline a general understanding of human performance. To expand on previous human performance research, this chapter discusses the effect that related factors (that are sometimes overlooked during incident investigations) have on human performance outcomes (Hopkins, 2004; Reason, 1990, 1997; Vincente, 2003). At a more focused micro-level, I have included reviews of accident investigations involving human performance, training, and user interface. Specifically, as the focus of these reviews becomes narrowed, I outline a need to consider the visual presentation of emergency response information in a more standardized manner for training and assessment of emergency response process for offshore Emergency Response Team (ERT) members.

4.1 Current Emergency Response Assessment Practices

On March 23, 2005, the American oil and gas industry, and more specifically, British Petroleum (BP) experienced one of the most catastrophic industrial explosions in their history. This emergency event at BP's Texas refinery resulted in the deaths of 15 individuals with more than 175 others being injured, along with significant economic (estimated to be approximately 1.5 billion dollars) and ecological damage (unknown at the time of the investigation). During its investigation, the U.S. Chemical Safety and Hazards Investigation Board (CSB) (2007) cited issues related to poor communication among operators, malfunctioning instrumentation, poor computerized control displays, ineffective supervision, insufficient staff, operator fatigue, and inadequate training. Each of the Texas City refinery issues identified above has been thoroughly examined by researchers involving human factors engineering, cognitive psychology, and organizational psychology methods.

Interestingly, the CSB investigation team noted that the safety culture at BP's Texas refinery was indicative of many corporations across the United States (U.S. Chemical Safety and Hazards Investigation Board, 2007). Reason (1997) suggests that safety culture "is the engine that continues to propel the system towards the goal of maximum safety health, regardless of the leadership's personality or current commercial concerns" (p.195). Based on this definition, it would appear that many investigators are indicating that monetary gains are held in higher regard than safety in many of the U.S. corporations. Investigators further noted that the lack of response to previous incidents (considered to be of a serious nature) at the refinery might have created an environment in which the safety management system of reporting, policy, and accountability appeared to lack support from BP's upper management. In fact, it was stated that "despite numerous previous fatalities at the Texas City refinery (23 deaths in the 30 years prior to the 2005 disaster) and many hazardous material releases, BP did not take effective steps to stem the growing risk of a catastrophic event" (U.S. Chemical Safety and Hazards Investigation Board, 2007, p. 19) and that "the refinery experienced two additional serious incidents just a few months after the March 2005 disaster" (U.S.

Chemical Safety and Hazards Investigation Board, 2007, p. 18). The apparent lack of direction from upper management as well as the inability to learn from past incidents, perhaps due to the complexity of the reporting system, undoubtedly influenced decisions made by key individuals prior to and during the incident.

Previous aviation and nuclear power industry research has examined several of the key components related to how humans integrate equipment into the environment in which they work; however, considerably less work has been carried out within the O&G industry, as is evident in the CSB report of the BP refinery incident. Specifically, the interrelated components of personnel selection, training, safety, health, human factors engineering, and survivability have not been examined within in the O&G industry to the extent seen in commercial aviation, National Aeronautics and Space Administration, and U.S. and Canadian military Human Systems Integration (HSI) research. The integration of these components has shown to be effective in increasing human performance outcomes and mission success (Booher, 2003).

In a proactive step to address possible limitations in training and safety related to human performance, Survival Systems Training Limited (SSTL), a Transport Canada approved emergency management training provider, has identified the need to validate current training procedures currently used to assess Offshore Installation Managers (OIMs) and Persons in Charge (PICs) against established criteria (personal communication with SSTL's CEO/Owner). Based on an absence of studies examining offshore emergency management training effectiveness, SSTL management believed there was a need to empirically study the manner in which these training courses are developed and evaluated. The primary interest for SSTL was to identify how subject matter experts (SMEs) develop "best practice" training over several decades, and how this development might influence future performance in a real-world setting. SSTL's focus was also directed at a concern that by using an untested "best practice" approach, SMEs could, under certain circumstances, induce error into a training system. This is because the SMEs are not always able to articulate which behavioural or psychological attribute makes for a desirable response to a particular emergency and may use unproven assumptions based on personal experience to decide the accuracy of a particular response (Hinds, Patterson, Pfeffer, 2001). It may be possible to approach a situation from many different perspectives that could ultimately influence the strategies used to complete the same goal, thereby leading to arbitrary or ill explained assessments of performance. Consequently, at this time, there does not appear to be empirically validated processes, involving established criteria, which are specifically used for offshore operations. However, the majority of organizations currently providing emergency management training to operators in the international offshore industry utilize the criteria established by Cogent/Offshore Petroleum Industry Training Organization (OPITO) (CAPP, 2005). OPITO is an international safety training organization that provides emergency response training courses to "more than 120,000 people across 30 countries" (http://www.opito.com/international/about-us/news.html).

Through multiple research studies associated with personality profiling, surveys and performance outcomes, Cogent/OPITO certification criteria has been based on six global factors (Flin & Slaven, 1994) that had originally been derived from an earlier Untied Kingdom Offshore Operators Association (UKOOA) guideline (1991). It was also believed that by selecting particular individuals, it can be assumed that training would be most beneficial for those who appear to be capable of handling the stress associated with emergency events (Flin & Slaven 1994). Based on selection criteria suggested by 26 organizations such as NASA, British Airways, and United States Navy, Flin and Slaven (1994, 1995) outlined criteria believed to be most appropriate for the specific and unique requirements of working in the isolated environment of an offshore installation. The criterion for selection was based on requirements typically used in aviation, military, marine, academia, and business, as it was thought that these domains require leaders to manage a diverse set of parameters that resemble those that are present during an emergency (Flin & Slaven, 1994, 1995). In a survey of desirable individual characteristics used in these domains, Flin and Slaven (1994, p. 36) reported the following common attributes:

- Leadership ability
- Communication skills, especially briefing and listening
- Delegating
- Team working
- Decision making, under time pressure, especially under stress
- Evaluating the situation
- Planning and implementing a course of action
- Remaining calm and managing stress in self and others
- Preplanning to prepare for possible emergencies

Within the list of desirable characteristics, it becomes apparent that the ability to develop and maintain situation awareness is not explicitly mentioned. As well, the term situation awareness is not used anywhere in the selection or training suggested by Flin and Slaven (1994). However, many of the criteria used for the selection of crisis managers include aspects of situation awareness. In fact, Flin and Slaven (1994) indicate that during the training and assessment of OIMs, situation assessment is a key factor that must be demonstrated by individuals before they can be certified to hold the position of person in charge for an emergency response team. This identification of a situation assessment is important to the understanding of the OIM’s performance in that the ability to be aware of what is going on is a fundamental requirement of attaining higher levels of SA. Furthermore, the UKOOA 1991 guideline (as cited by Flin & Slaven, 1994) suggested that as a minimum, OIMs and ERT members should:

1) have a good working knowledge of the installation operations;
2) be well versed in the installation's emergency systems and procedures;
3) be aware, on a day to day basis, of particular operations and special circumstances approved under the permit to work system which may affect the ability of the installation to respond to emergencies;
4) be trained and be able to assess and to control developing emergency situations with the objective of safeguarding personnel and the installation;
5) be able to act as coordinator between the installation and the onshore and offshore responses to the emergency; and,

6) be able to act as on scene commander where a serious incident occurs on a nearby installation (Guidelines for the Management of Emergency Response for Offshore Installations TRN 02, 2004)

Given that OIM's are responsible for the overall management of offshore emergencies, these requirements or guidelines essentially provided the groundwork for Flin and Slaven (1994) to identify their own six factors, which they considered to be basic requirements for effective emergency management. Unfortunately, terms like "good working knowledge" and "well versed" are vague and open to interpretations that allow them to be construed quite differently. My interpretation of these six global factors (Flin and Slaven, 1994) is represented in Figure 6 and identifies the expected behavioural assessment components (factors) of an OIM during an emergency. The first set of factors at the top of each column is meant to occur in a sequential order; however, it clearly is the ability to make decisions during an emergency that is considered the primary focal point.

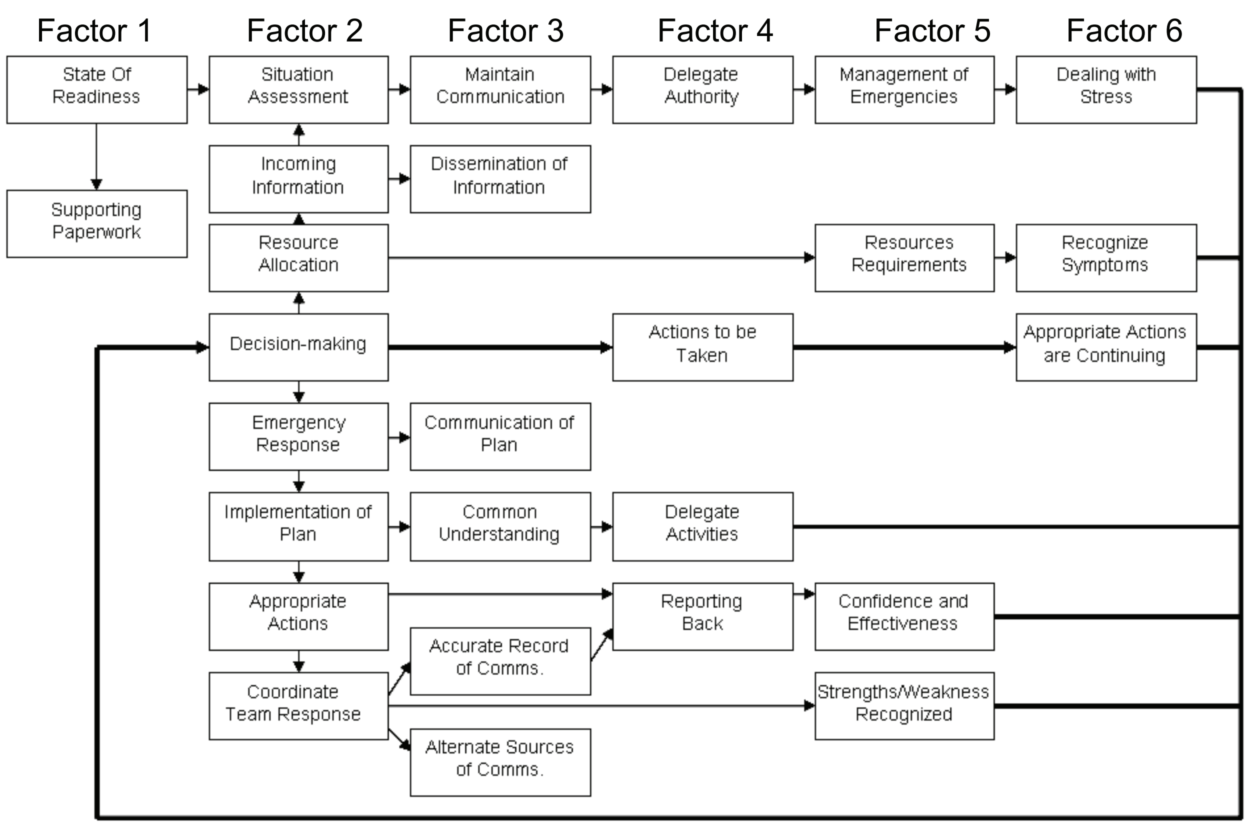

Figure 6. Outline of global assessment factors (adapted from Cogent/OPTIO and Flin & Slaven, 1994 OIM assessment process).

Although not discussed in detail in Flin and Slaven's (1994) original article, it should be pointed out that an interactive relationship was suggested to exist between and among the factors. In order to highlight the possible links, I have indicated the connections between factors (shown as connecting lines in Figure 6). This connection from one factor to another also needs to be considered in terms of its cyclical nature. Specifically, it is not sufficient that the OIM recognizes and deals appropriately with stress; it is the ability to understand the interrelatedness associated with situation assessment and ultimately decision making that affects the outcome. Within Figure 6, I have indicated the cyclical aspect of continually making decisions based on incoming information with thicker connecting lines.

Similar to the connection shown in Figure 6, Figure 7 outlines the Engineering Equipment & Materials Users' Association (EEMUA) (1999) depiction of an interactive relationship between each of the components that offshore operators need to deal with during an abnormal situation or emergency event. This figure highlights (as does Figure 6.) the notion that without appreciating the interrelatedness of each point in the figure, it is difficult to identify potential problems with operator's conceptualization of the structure of a particular system. This thesis examines the offshore emergency response training certification process by focusing on the information that is presented to the OIMs and ERT personnel, as opposed to focusing on control room operations specifically aimed at resolving abnormal production or drilling related emergency events. Figure 7 clearly demonstrates that an operator is expected to effectively and efficiently detect, comprehend, and correct an abnormal situation. This task may be different for each system anomaly; however, even under the most benign circumstances, the complexity of the incoming information may exceed the limits of what can be mentally processed by the individual.

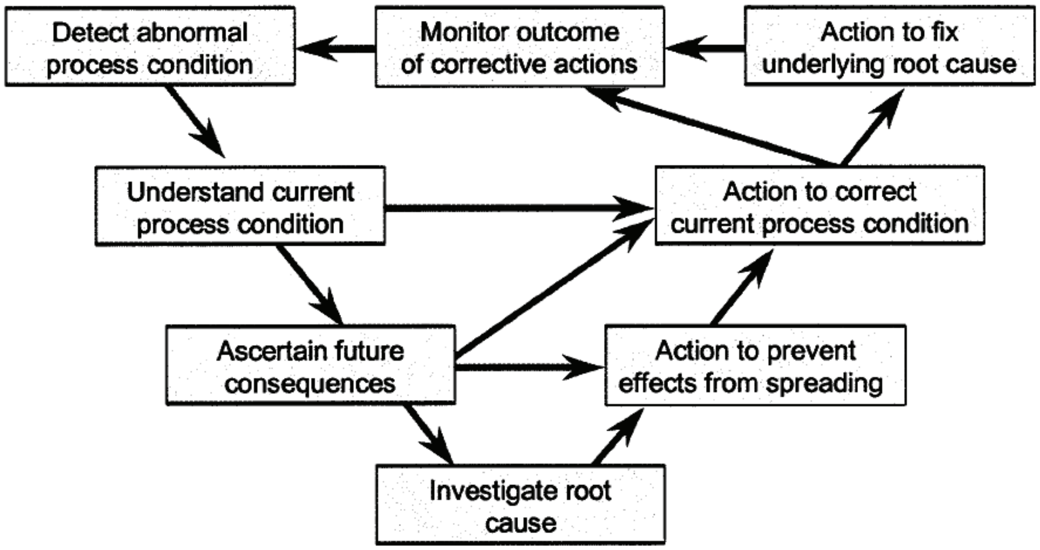

Figure 7. Operator response to an abnormal situation (from EEMUA, 1999, p. 3).

The following systematic reviews outline the current understanding of human performance and decision making related to information processing, expertise and previous training. For the purposes of this thesis, the following reviews represent research areas that are considered within the broader context of HSI and offshore emergency response management. In order to contextualize the reviews, an outline of Human System Integration frames the overarching paradigm through which I explore the interrelatedness of the human, environment, and technology components.

4.2 Human Systems Integration (HSI)

First developed by United States Army researchers (Booher, 2003), Human Systems Integration (HSI) (originally known as MANPRINT) framework was designed to systematically investigate human factors issues such as personnel selection and equipment design criteria in an attempt to decrease errors and increase mission success. Figure 8 identifies the components related to the integration of three primary components (Human, Environment, and Technology) as well as the influence of eight sub-components used to describe how each of the primary factors are linked to form an HSI assessment.

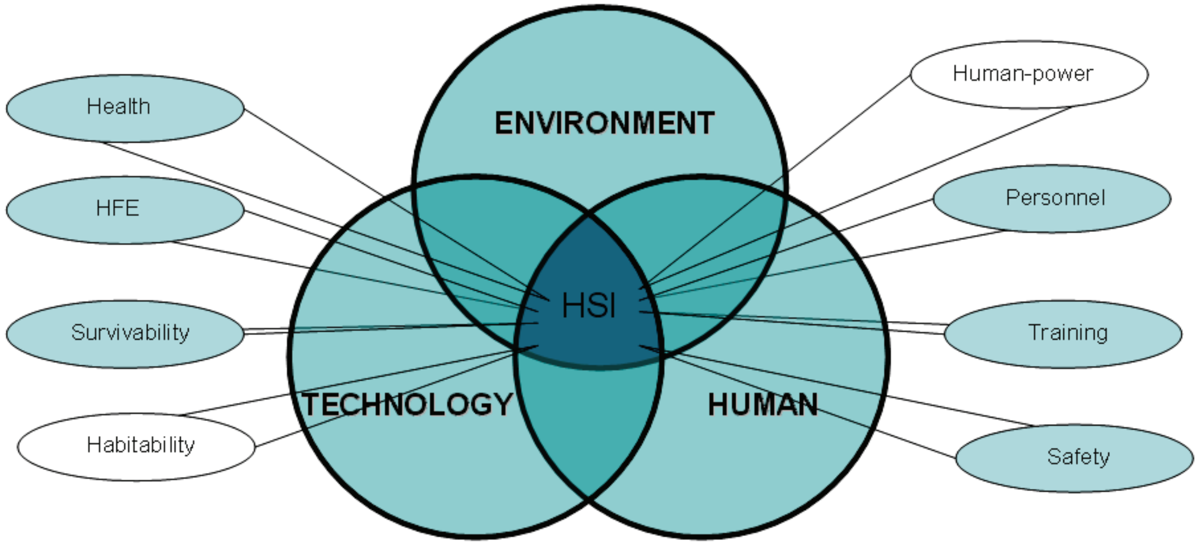

Figure 8. HSI components of interest (shaded), (adapted from Booher, 2003). **Note:** The two subcomponents of human power and habitability were not shaded as they deal with the number personal available to complete a particular task and the environmental conditions within a particular space and were not used to consider the emergency response management process for this thesis.

It is this systematic integration of key human factors, technology, and environmental issues that make HSI unique when compared to traditional human factors or health, safety, and environmental investigation techniques. Often the specialization of one domain (i.e. human factors engineering or human resources) limits its capability to fully examine influencing variables when identifying how an overall system will operate. MacDonald (2000) reported that without integration of all occupational health and safety (OHS) data within the Department of National Defence (DND) it is difficult to effectively reduce the incidences of task related injuries. As an example of the limited integration of several different aspects from OHS, MacDonald (2000) indicated that when asked about specific documentation that could potentially be added to a medical/injury incident database, only 15% of the medical staff interviewed knew that the document (CF98 - Report on Injuries or Immediate Death Therefrom) existed as well as knew how to use it. Greenley, Angel, Brooks, and Kamgi (1999) indicate that as a minimum, HSI investigation should incorporate analyses of missions and scenarios, concept of operation, and concept of support in addition to completing a task analysis that defines key roles and responsibilities (Annett, & Duncan, 1967). Ideally, HSI processes should be conducted early on in a project to ensure that potential deficiencies can be identified before an emergency event occurs; however, examination of existing process within an organization can be beneficial when attempting to mitigate future risk of system failure. Greenley et al. (1999) further point out that HSI analyses need to be validated through an iterative process to ensure that modifications stemming from previous investigation can be incorporated into new system designs. Validation of the HSI analyses occur by examining existing procedures within an organization against known standards of practice such as human-machine interface or workspace design criteria. Table 2 outlines the basic requirements used to conduct a full HSI assessment. However, it must be pointed out that conducting every assessment and analysis as indicated in Table 2 may not be appropriate or necessary for a given situation. It is therefore, the investigator's task to identify which of the requirements within the overall HSI framework is best suited to the conditions of interest while maintaining a holistic view of the macro-environment. That is, by envisioning how an ideal system would operate if all aspects of an HSI frame where included, an investigator can maintain a "big picture" view of which aspects will have the greatest impact on achieving the desired goal. Within this particular thesis it is proposed that components from Personnel, Training, Human Factors Engineering, Environment, and Safety can be used to consider aspects of Manpower, Occupational Health, and Survivability of offshore emergency response. The proposal to use selected HSI factors to consider aspects from other sub-factors is supported by previous HSI research and highlights the overlapping nature of integration (Greenley, et al., 1999).

Table 2. HSI requirements as outlined by Greenley et al. (1999).

Manpower
✪ Analyze organizational structure changes
✪ Determine system authorizations
✪ Determine type of personnel that will operate, maintain and sustain system
✪ Conduct manpower analysis
Personnel
✪ Develop, update, maintain target audience descriptions
✪ Identify operators, maintainer, sustainers knowledge, skills, abilities, and aptitudes
✪ Determine recruitment and retention trends
Training
✪ Develop, update, and maintain training plan
✪ Identify, update, and maintain training strategies, plans, policies, and procedures from new systems
✪ Determine instructional methods, training content and aids
✪ Assess training effectiveness
Human Factors Engineering
✪ Develop human engineering plan
✪ Develop human performance criteria and principles
✪ Assess psychomotor, sensory, and physical workloads
✪ Validate human-machine interface and workspace layout
✪ Conduct HFE assessment
Environment
✪ Determine environmental risks
✪ Develop, update, and maintain Programmatic Environmental, Safety, Occupational Health Evaluation (PESHE)
✪ Conduct pollution prevention assessment
Safety
✪ Develop, update, and maintain safety plans
✪ Conduct failure-mode and effects analysis (FMEA)
✪ Conduct a safety assessment
Occupational Health
✪ Conduct occupational health hazard analysis
✪ Develop, update, and maintain occupational hazard plan
Survivability
✪ Develop, update, and maintain survivability plan
Habitability
✪ Conduct habitability analysis
✪ Assess physical environment and living condition for adverse impact on quality of life and morale

The idea of integrating multiple aspects of the same system or process is not a new concept to human performance measurement techniques. It is however, the combination of various influencing elements such as survivability, personnel selection, and training that is unique within the study of HSI. Specifically, it is the assessment of situation awareness and dynamic decision making of emergency response team members in an offshore setting that is particularly novel to the examination of human performance within the simulated training environment used in this thesis. Furthermore, it is the integration of individual variables (shaded sub-components in Figure 8 above) that ensures a holistic investigation. If for example, specific human factors methodologies such as human error probability or functional task analyses are used to investigate how ERT members utilize incoming information, influencing factors related to personnel selection and survivability may not be explored or even considered. Moreover, contextual settings associated with the safety culture within an organization may play a less significant role in a human factors engineering study than they might in a health, safety and environmental investigation. These specific components, however, are ultimately affecting how well the human can integrate information so that appropriate decisions can be made at the correct time. Therefore, in order to consider an integration of human performance related to decision making, individual and team level situation awareness is used to explore how people make sense of what happening in a given situation.

4.3 Situation Awareness (SA)

The term situation awareness (SA) can first be seen in references during World War I where it is described as a necessary component of understanding a situation involving military air operations (Press, 1986 as cited by Endsley, 2000a). However, the concept of how humans use available information to construct the reality around them can be traced as far back as Sun Tzu's Art of War (Tzu, 6th cent. B.C./1988). In fact, it was Tzu that suggested the use of assessments (available information) to gauge tactical advantages before making a decision regarding a likely outcome (Tzu, 6th cent. B.C/1988). In this case, it was the basic understanding of what information related to an opponent is necessary during the decision making process.

In a more modern context, the term situation awareness (SA) has been conceptualized in diverse domains such as aviation, nuclear power (Ceuvas, Fiore, Caldwell, & Strater, 2007), medicine (Wickens, 2008; Gorman, et al., 2006), driving (Kaber & Endsley, 2004; Ruiqi & Kaber, 2005), risk assessment (Glendon, Clarke, & McKenna, 2006), air traffic control (Alfredson, 2007), assessments of expertise

(Endsley, 2004, 2006; Vincente, 2000), and emergency preparedness (Artman, 1999; Prince, Ellis, Brannick & Salas, 2007). SA has also been shown to be extremely important in sports activities (Weinberg & Gould, 2003). As the term situation awareness is used in such a large variety of domains, it would be reasonable to assume that there is a definition that has generally been agreed on by a majority of researchers. However, this is not the current state of this frequently used concept. In fact, definitions from each domain in which the concept is used appear to have slight variations in what is included in the understanding of situation awareness. Some theoretical frameworks use broad definitions to include all possible aspects associated with this term while others use a more focused definition. Criticisms for and against a broad definition abound. For example, it can be argued that if the definition is narrow in its acceptable parameters, it limits the application of similar concepts from multidisciplinary domains. However, if the definition is unnecessarily broad, it risks being too general to be useful. Situation awareness appears, for the most part, to be plagued by the latter and to support this, Sarter and Wood (1991) point out that SA is a critical although ill-defined construct.

For example, several researchers from diverse domains have agreed to use Endsley's (1995a) definition, which identifies that SA is 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*," (p. 36) pointing out that it addresses several levels of human information processing that affect decision making in dynamic situations (see Durso & Sethumadhaven, 2008; Kaber, Perry, Segall, McClarnon, & Prinzel, 2006; Tenney & Pew, 2006; Wickens, 2008).

Alternatively, however, Klein (2000) describes SA as the "*perception of reactions to a set of changing events*" (p. 51).

Adams, Tenney, & Pew (1995) indicates that SA is the "*up-to-the minute cognizance required to operate or maintain a system*" (p. 85).

Smith and Hancock (1995) define SA as "*adaptive, externally directed consciousness*" (p. 137).

Bell and Lyon (2000) cite the definition given by U.S military Air Staff who indicate that from a pilot's perspective, SA is the "*continuous perception of self and aircraft in relation to the dynamic environment of flight, threats, and mission, and the ability of forecast, then execute tasks based on that perception* (Carrol, 1992, p. 5)".

The U.S. Marine Corps field manual (2004) suggests that situation awareness is "*knowledge and understanding of the current situation which promotes timely, relevant and accurate assessment of friendly, enemy and other operations within the battlespace in order to facilitate decision making. An informational perspective and skill that fosters an ability to determine quickly the context and relevance of events that are unfolding" (p. 1-171).*

Sneddon, Mearns, and Flin (2006) indicate that SA involves having a "*high level of awareness of task and environmental conditions, and judging how these may change in the near future to predict how the situation will develop*" (p. 255).

And finally from a global perspective and detailed review of definitions, the Enhanced Safety through Situation Awareness Integration in training (ESSAI) project (2000) suggests that SA "*draws upon all the processes an operator brings to bear on a task, such as their goals, perceptions, attention, dynamics, temporality, prediction, automaticity, processing, motor skills, pattern recognition, training, motivation, experience, encoding skill knowledge acquisition, retrieval, storage and execution* (p. 37).

The listed definitions within the SA research literature clearly show the diversity of conceptual frameworks and domains in which SA has been studied. It is this diversity however, that makes it difficult to determine whether SA should be considered a specific or general characteristic related to understanding and decision making. For clarity and consistency within this thesis, Endsley's definition is used to examine the application of situation awareness in regard to emergency response. The rationale to use Endsley's definition stems from the fact that she specifies differences within the overall aspect of understanding what is going at a particular point in time. The temporal component of the definition allows for a greater examination of why particular decisions or choices are made in lieu of others. Furthermore, to outline how Endsley's SA theoretical framework is used in this thesis, Figure 9 identifies a flow diagram that I designed to illustrate how SA is affected at several levels by environmental/situational cues.

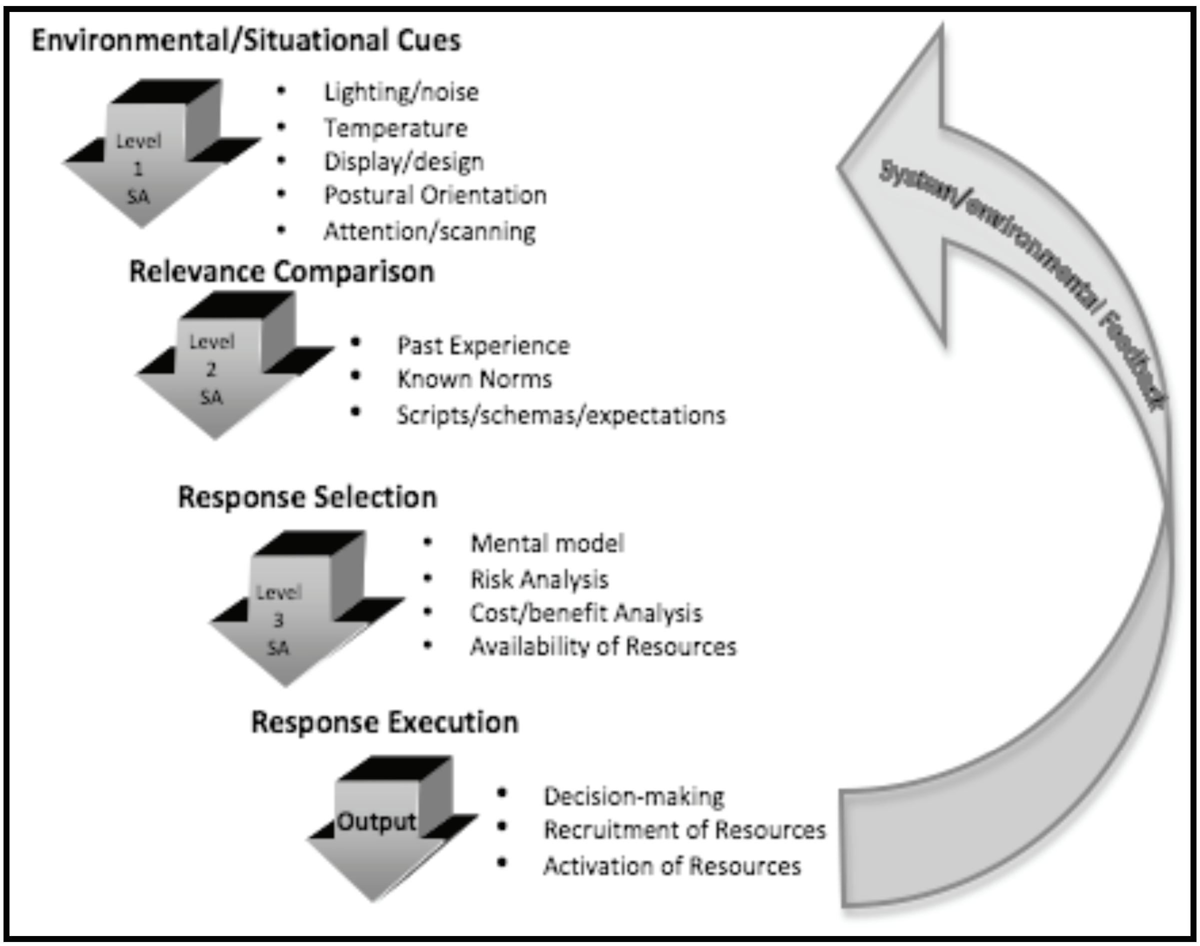

Figure 9. Components of situation awareness.

4.3.1 Level 1 SA

Figure 9 is a combination of information processing theory related to motor control and aspects of three levels of SA suggested by Endsley (1995b). Based on Endsley's definition of SA, the three levels (perception, comprehension, and prediction) indicate discrete points of understanding. At level 1 SA, Endsley (1995b) reports that "a person needs to perceive relevant information" in order to make a decision about what is happen around them (p. 65) (Figure 9). Without perception of cues or information, it can be assumed that an individual has no specific level of SA regarding a particular situation. Endsley does not however, describe an SA *level 0* (zero) in any of her work (also see Endsley, 1990, 1995a, b, 2001, 2004, 2006). Rather, Endsley (1995a) suggests that if an individual performs a particular task to the point of automation, thus reducing the cognitive load, the person may complete the required skills unconsciously. Endsley (2004) further suggests "people can have *level 2* and *3* SA, even when they do not have complete or accurate *level 1* SA" (p.320). This proposition by Endsley implies that individuals may be able to skip *level 1* SA and move directly to *level 2* or *level 3* SA given sufficient experience and practice. Figure 10 demonstrates that Endsley situates SA between environmental/system cues and decision making. Figure 10 also indicates that SA as well as decisions and performance are influenced by factors such as individual differences, system design criteria, experience, and goal directed behaviour. From the model depicted in Figure 10 it is difficult to identify where or how an individual might be able to skip a level of SA and move to decision making or performance of action as it appears that SA levels are embedded within a single overarching construct.

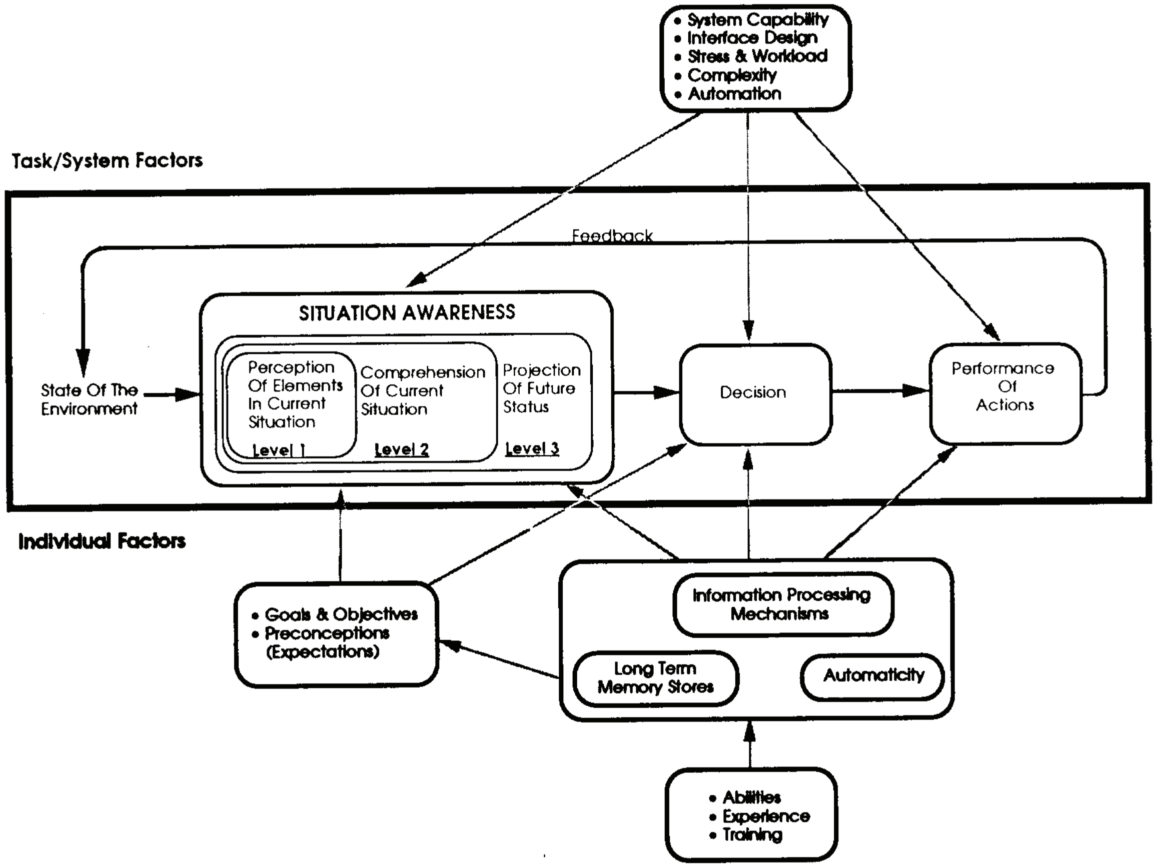

Figure 10. Model of situation awareness in decision making (from Endsley, 1995a, p. 35).

Research results have demonstrated that individuals considered to be experts in a particular domain (e.g., chess or hockey) are not always aware of the information that they are utilizing and often cannot articulate what aspects are of the greatest importance when making key decisions (Charness, 1981; Grabnar, Stern, & Neubauer, 2007; Saariluoma, Karlsson, Lyytinen, Teräs, & Geisler, 2004). Likewise, experts are particularly adept at the skills necessary for specific tasks; however, they may not be highly skilled at performing a similar task while under different environmental constraints (Endsley, 1995a; Ericsson & Kintsch, 1995). This would suggest that the level of SA that can be achieved might be influenced by the context in which a skill is performed. For example, Kontogiannis (1999) reports that "even when the required tasks seem familiar, emergencies would require devising different sequences of tasks, attending to multiple cues, sharing tasks due to time pressure, coping with frequent interruptions, sustaining performance for prolonged hours and reassigning tasks to team members" (p. 7). Given the circumstances of the Piper Alpha event described above, it can be assumed that the individuals who chose to jump into the sea rather than burn on the deck waiting for rescue, were, at least at a basic level, perceiving the environmental/situational cues and knew what was going on around them (i.e., they were at level 2 SA). It could also be argued that they were able to predict what would happen if they remained on the deck of the installation (i.e., they were operating at level 3 SA).

Figure 10 (above) further identifies that at the second level of situation awareness – described by Endsley (1995a) as requiring comprehension or extracting meaning from the system/environmental cues – *level 2* SA highlights the need for previous experience. Clearly, without having any prior knowledge of a particular environment or system state, it is difficult to fully understand what is occurring and what might be the most appropriate actions to take. Unfortunately this example is clearly demonstrated by some individuals when they are caught in novel or emergency situations (Fakhru'l-Razi, Shaluf, & Aini, 2003). When placed under highly demanding conditions such as time-stress, high cognitive workload, and limited resources, inexperienced individuals may make decisions that endanger rather than save their lives. Worse still, some individuals will completely freeze and become apathetic making no effort to save themselves or others (Leach, 2005; Leach & Griffith, 2008). It could be argued that an inappropriate response in an emergency is primarily an issue of anxiety or stress management; however, lack of experience may compound the situation and given sufficient time, unlimited resources and reduced cognitive demands, an inexperienced individual may be able to discover a reasonable solution.

4.3.2 Level 2 SA

As noted by Endsley (1995a), *level 2* SA is dominated by the constraints of working memory and as such, limits the amount of information that can be processed at any give time. Wickens (2008) points out that if given sufficient experience, individuals may be able to mitigate working memory constraints through the retrieval of information from a storage location described as long-term working memory that allows for greater comprehension of the environmental cues through the use of mental models stored in long-term memory (see also Ericsson & Kintsch, 1995; Wickens & Hollands, 2000). Expertise and long-term working memory will be discussed in further detail below; however, it is worth identifying at this point that both Endsley (1995a) and Wickens (2008) suggest that it is the situation and the number of times a person has experienced the environmental cues that best predicts how an individual or team will perform. Thus, it appears that attending to specific cues (while ignoring others) pertinent to the particular situation is of the greatest importance to maximize performance. Therefore, it can be assumed that individuals involved in the offshore incidents described above have not only perceived the environmental cues, but may also have incorporated them into a fairly coherent understanding of what is happening around them. The decision to jump into sea swells instead of remaining onboard the burning/exploding platform can be used as clear evidence that the individuals comprehended the gravity of the situation.

4.3.3 Level 3 SA

The final stage or level of situation awareness proposed by Endsley (1995a) consists of the capacity to project what will happen to the system state or environment in the near future. By its very nature, *level 3* SA requires an intimate knowledge of the situation or system, as it would be impossible to predict what will happen to a particular system if one has never had the opportunity for prior interaction. As a specific example, it would be difficult to predict how an individual's actions would affect a situation in the near future if the person has never before experienced the dynamic forces of an impact or practiced the necessary skill set need to survive an emergency. An individual can still make a decision in a novel situation; however, as pointed out above, the possibility of formulating an appropriate plan under possible time constraints in a situation that has never been experienced before may prove to be very difficult and which can possibly lead to apathy and inaction (Lehner, Seyed-Solorforough, O'Connor, Sak, & Millin, 1997). Endsley (1995a) suggests that the third level of SA is "achieved through knowledge of the status and dynamics of the elements and comprehension of the situation" which needs to be integrated in a coherent manner in order to project "future states of the environment that are valuable for decision making" (p.36). Endsley (1995a) clearly points out that although automaticity is of some benefit under specific conditions, she also warns of situations in which automatic reactions to environmental cues may "leave the individual susceptible to missing novel stimuli that can negatively affect SA" (p.49). Endsley (1995a) further cautions that two "external issues" (i.e. information acquired by an operating system and the display interface) will ultimately influence the level of SA obtained by the individual (p. 50) (see also Borst, Suijkerbuijk, Mulder, & Van Paassen, 2006). The Piper Alpha incident clearly highlighted that the novel cues of the situation (i.e. loss of internal communications, lack of safety training, and breakdown in chain of command) were not incorporated into the decision process of the individuals waiting to be told what to do.

Although the final investigation report of Piper Alpha does not include an assessment of situation awareness, it seems likely that the platform manager was at an SA *level 1* (perceiving environmental/situational cues such as the loud noise of the initial explosion) in regard to the particular situation. It seems unlikely that the manager was at *level 2* SA in that the available cues (e.g. massive explosion, smoke, and multiple alarm bells) were not utilized to project (*level 3* SA) possible consequences associated with his subsequent actions taken. At no time prior to the incident can it be assumed that the manager ever reached *level 3* SA. If the manager had reached *level 3* SA, it is likely that he would have been able to use his knowledge, of where the explosion occurred and the fact that the deluge system was in manual mode, to predict that the smoke and fire might be concentrated near the helideck. As the primary means of escape was expected to come from a rescue helicopter, the information regarding the location of the fire could have then been passed on to the individuals inside the accommodation block and plans to move to a safer location could have been implemented. Based on the Cullen Report (1990), the organizational conditions within Occidental Petroleum and employed onboard Piper Alpha relating to the requirement of safety training leads one to believe that the ability to project and/or predict (*level* 3 SA) what would happen if an explosion occurred directly under critical areas did not enter into a decision making process about risk mitigation. It should be noted, however, that the assessment of the actions taken by both the manager and rig personnel is clearly a function of hindsight bias, as it is only after the situation has completely unfolded do we truly have the chance to assess the observable behaviour that is a consequence of one's situation awareness (Bradfield, & Wells, 2005). Using Jones and Endsley's (1996) classification taxonomy, Sneddon et al. (2006) point out that in a study of 135 offshore oil and gas incidents that occurred between January and October of 2003, 90 (66.7%) were the result of failures in perception. In order to identify precise aspects of perception, Sneddon et al. (2006) examined incident reports related to drilling and production operations and separated the events into five distinct components: Data not available; Hard to discriminate or detect data; Failure to monitor or observe data; Misperception of data, and; Memory loss. Each of the identified components of perception related to *level 1* SA and of the 90 events, it was reported that 76 were related to detection, monitoring, observation, and misperception of data. These results clearly show that improvements in SA should be directed at the basic level of identifying what data are relevant to the situation and how they should be presented to the individuals.

4.3.4 Measuring SA

Measuring SA can be qualitative, through self-report estimation of performance on a Situation Awareness Report Technique (SART), as well as quantitative through the use of observations made by subject matter experts (SMEs) who rate performance on a scale of 1 to 10. Measuring SA is often conducted by freezing (i.e., stopping the task performance) the test scenario so that an individual can be asked specific questions (cognitive probes) about their environment and events that have occurred (Situation Awareness Global Assessment technique – SAGAT). This technique has raised questions and considerable criticism about how the probes may influence an individual's SA in subsequent testing (Wickens, 2008). Based on the criticisms of conducting cognitive probes alone, the Situation Awareness Rating Scale (SARS) (Bell & Lyon, 2000; Endsley, 1995b) was developed as a way of measuring SA through SME ratings. However, questions remain as to the ability of an expert to accurately rate other expert's performance, and highlights the extent to which an observer's biases might influence a final rating (Bell & Lyon, 2000; Shanteau, Weiss, Thompson, & Pound, 2002).

An individual's performance is considered central to how SA may be understood, in that without first perceiving environmental cues or system feedback, it is difficult to allocate attentional resources from both long-term and working memory. It is also difficult to identify mental schemata that can be used for decision making. SA is used as a central component of this thesis to highlight the relationship that exists between an individual's level of experience within a particular setting and their ability to predict possible outcomes. Based on past research, it is reasonable to argue that without SA, decision making would be severely hampered. Therefore, it is important to ensure that a system is designed in which relevant cues are perceived by individuals who will be able to comprehend the relevance of the information and have the capability to predict what might occur in the near future.

4.3.5 System Design Effects on SA

System design criteria affect the development and maintenance of SA in several ways. First, SA is limited by the amount of system information presented to the individual. If the system collects and analyzes millions or even thousands of bits of data per minute, it is evident that an operator will not be able to perceive or comprehend all of the internal information. Therefore, a system should be (and most often is) designed to provide the operator with the most relevant bits of information to ensure that human comprehension and perceptual limits are not exceeded. Second, the level of system control given to the operator affects SA. If the system is designed to merely present the operator with all possible options and wait for a response, it only directs attention without offering any advice or solutions. At this level of automation design, the system is considered to be complete manual control as the operator makes all decisions related to actions performed by the system. The development and maintenance of SA is limited by the need to attend to all incoming information while trying to decide which is most important. At the other end of the automation continuum, a system that presents pertinent information as well as offers a solution and executes that option without input from the operator is considered to be complete automatic control (Wickens et al., 2004). The level of automation may also impair an individual's ability to develop and maintain SA, in that there is no need to invest cognitive resources in a system that will automatically monitor and adjust a system as needed. This level of automation would be analogous to operating a motor vehicle; the driver is not required to monitor the internal operation of the motor while navigating. By limiting the amount of engine performance information presented to the driver, primary focus can be directed at ensuring that the vehicle is operated safely.

Elements of situation awareness related to human/system interface are at a point at which Endsley (1995a) posits that errors may occur when information is transferred from the environment to the system and then passed on to the individual. If, for example, a system collects vast amounts of information from the environment (i.e., a petroleum processing facility similar to those positioned offshore of Nova Scotia and Newfoundland) and presents this data in its raw form to the operator at a rate beyond the capacity of the individual, much of the incoming information may be missed. If the operator does not perceive the information, the level of SA (perception in this case) is dramatically affected. If, however, the system is designed to only involve the human at a point in which a malfunction has occurred, it is less likely that in a complex system with limited time to make a decision, the individual will be able to comprehend (*Level 2* SA) the situation enough to formulate a correct response. It is even less likely that the individual will be able to predict (*Level 3* SA) how his or her response action will influence the situation in the near future. Although training might mitigate some of the difficulties associated with out-of-the-loop designs, individuals may not assign sufficient attention to monitor a system that is completely automated. Table 3 outlines the possible levels of automation proposed by Endsley and Kaber (1999).

Table 3. Level of automation (LOA) (based on Endsley and Kaber, 1999).

Level of Automation	Human/System Contribution
Manual Control	Human makes all inputs and decisions
Action Support	System supports human actions
Batch Processing	Human can turn control of actions over to system while maintaining ultimate control
Shared Control	Human and system generate options that are selected by human and implemented by system
Decision Support	Human makes all inputs and decisions based on system feedback
Blending Decision Making	Shared action (human and system) implementation of tasks
Rigid System	Human selects an option for the system to perform automatically
Automated Decision Making	System generates possible options that are next approved by human
Supervisory Control	System performs all actions and is monitored by human. Human can input when deemed necessary
Full automation	System performs all function without input from human. Human cannot intervene

The level of trust an individual places in the reliability (actual or perceived) of a given automation (Figure 11) should also be considered when examining SA (Cuevas et al., 2007; Liu & Hwang 2000). If for instance, an individual explicitly trusts the system to execute all necessary aspects of a particular job, it may be more difficult for that person to understand what is happening within the system when something goes wrong. However, an individual that does not trust the automated system to complete the required tasks without input (pilot of MK flight 1602 detailed above) is more likely to be involved in every step, which may or may not increase the level of preparedness to intervene if needed.

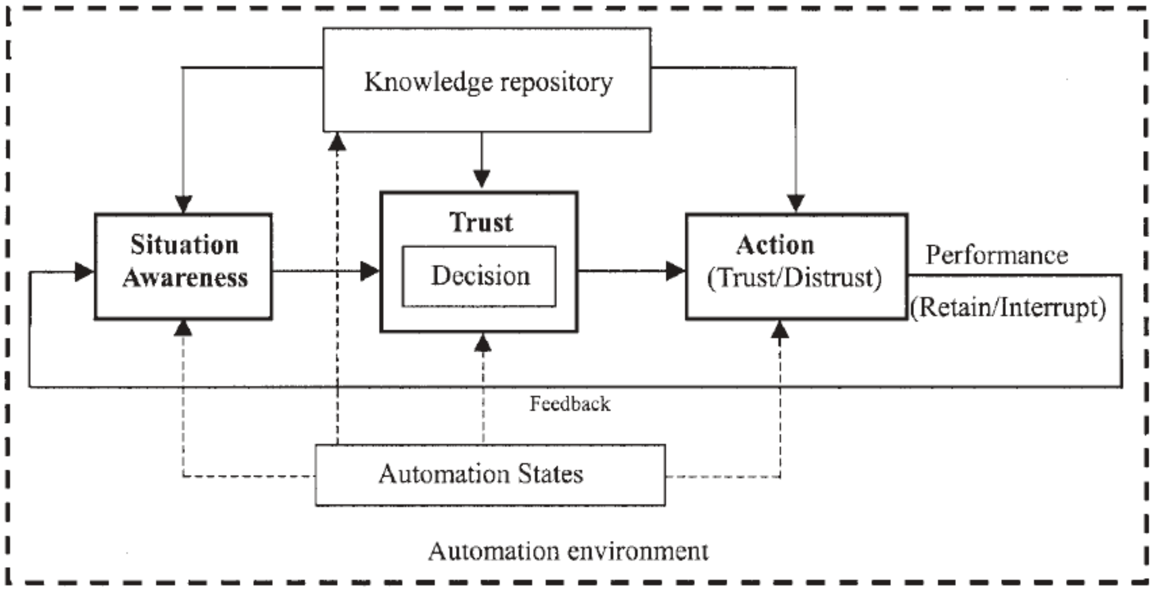

Figure 11. Conceptual relationship between trust in automation and SA (from Liu & Hwang, 2000, p. 128).

Figure 11 indicates that the level of automation affects an individual or team's knowledge repository and that performance will be affected by an individual's decision to trust or distrust system information. However, figure 11 does not consider that the level of situation awareness achieved in a given situation could also influence the quality of one's knowledge repository. One final effect of automation on SA has been identified by exploring the possibility of a reduction in skill acquisition as well as an inability to maintain those skills already acquired. It has been suggested that as the operator becomes more reliant on the automation of the particular system, the skills that were once needed to understand the operating aspects and mode configuration are neglected (Endsley & Kaber, 1999; Kaber, Riley, Tan, & Endsley, 2001; Liu & Hwang, 2000). This reduction in skill further complicates an emergency situation in which the system is reliant on the operator to initiate corrective actions. If the actions are rarely practiced, the operator may not be capable of fully understanding the situation. The operator may also form an incorrect mental model of the situation, based on tasks that were only required before the automation was implemented (Carley, 1997). The accuracy of this mental model may influence not only the individual's action, but it may also be extended to an entire emergency response team if the operator's actions appear to indicate little or no concern related to the situation. The Piper Alpha emergency event provides an excellent case study, in that the majority of rig personnel waiting for direction were told to remain in their muster station until given further instructions and thus presumably thought that everything was under control (Cullen, 1990). Without a clear understanding of the situation, it is far less demanding to diffuse responsibility to someone who appears to know what is occurring than to try and piece together the missing bits of information. Moreover, having limited access to equipment (e.g., due to the position of muster station) that would have indicated the magnitude of the fire on the platform, it could be argued that the personnel overestimated their ability to perform evacuation tasks based on their subjective appraisal of the situation. Therefore, by placing a significant amount of trust in an automated deluge system (which had actually be turned to a manual mode), individuals may have reduced their perceived need for practical emergency response skills.

4.3.6 Equipment Positioning Effects on SA

The location of equipment in both industrial settings and aviation has been shown to affect an operator's performance as well as SA. For example, Paris, Salas, and Cannon-Bowers (2000) noted that when considering team SA, the location and integration of communication systems might influence the ability of individuals to integrate information into a cohesive understanding (see also Cooke, Gorman, Duran, & Taylor, 2007). One of the concerns when designing a workstation for emergency command and control is to ensure that all necessary information (auditory and visual) is available to the individual who is in charge of the situation. If for instance, the installation manager of an offshore platform cannot see or hear all of the information coming in from emergency response team members who are located both within close proximity as well as outside the control room, it may be difficult for the manager to make an informed decision about how to approach a particular situation. As a further example of how important it is to consider even the smallest aspects of equipment placement, Wood (2001) suggests that within a control room design, it is important to ensure that the operators have sufficient space to push their chairs away from the multiple screens they will be viewing. This is in contrast to the parameters that would be set for individuals viewing a single monitor, which may require a considerably closer proximity. Several software programs have been designed specifically to address problems related to equipment placement and to consider the natural flow of workers within a particular space (e.g., Locate by SOS Products, http://aimdc.ca/sosproducts/LocateInfo.html and <Virtual Environment> by Integrated Environmental Solutions Ltd. http://www.microsolresources.com/cad/ies2.cfm).

Within the context of this thesis, the proximity of emergency response team members to the OIM and the location of the visual stimuli were considered to be of considerable importance, as all decisions stem from the information placed on the ERFB. Specifically the location and size of the ERFB was selected to ensure that a similar system could be implemented into an offshore setting. Additionally, the physical size of the ERFB was selected to ensure that all important response information could be input by the individuals recording all incoming emergency response information (scribes). Detailed information about the ERFB is located in the methods section below.

4.4 Information Processing

Wickens and Hollands (2000) identify that individuals make decisions based on their ability to process incoming information and are influenced by cognitive limitations. For instance, if the incoming information is compatible with or similar to an existing mental schema, the individual will typically be able to accommodate this new data and develop a plan of action. However, if the incoming information is unrelated to an existing mental model or considered to be novel, it may not be assimilated quickly and individuals will require more time to formulate a plan. Unfortunately, emergency situations rarely offer individuals extended periods of time to deliberate over which course of action would most beneficial.

Wickens and Hollands (2000) propose a model of information processing which indicates that even before information is perceived it is influenced by selective attention in the form of cue selection. Once the cues have been perceived and processed through working memory, the information is influenced by attention, metacognition, choices, and associated options or risks (Wickens & Hollands, 2000). Wickens and Holland's model (Figure 12) further demonstrates the importance of considering not only perception of external cues, but also the information that is retrieved through internal mental representations within the different levels of memory.

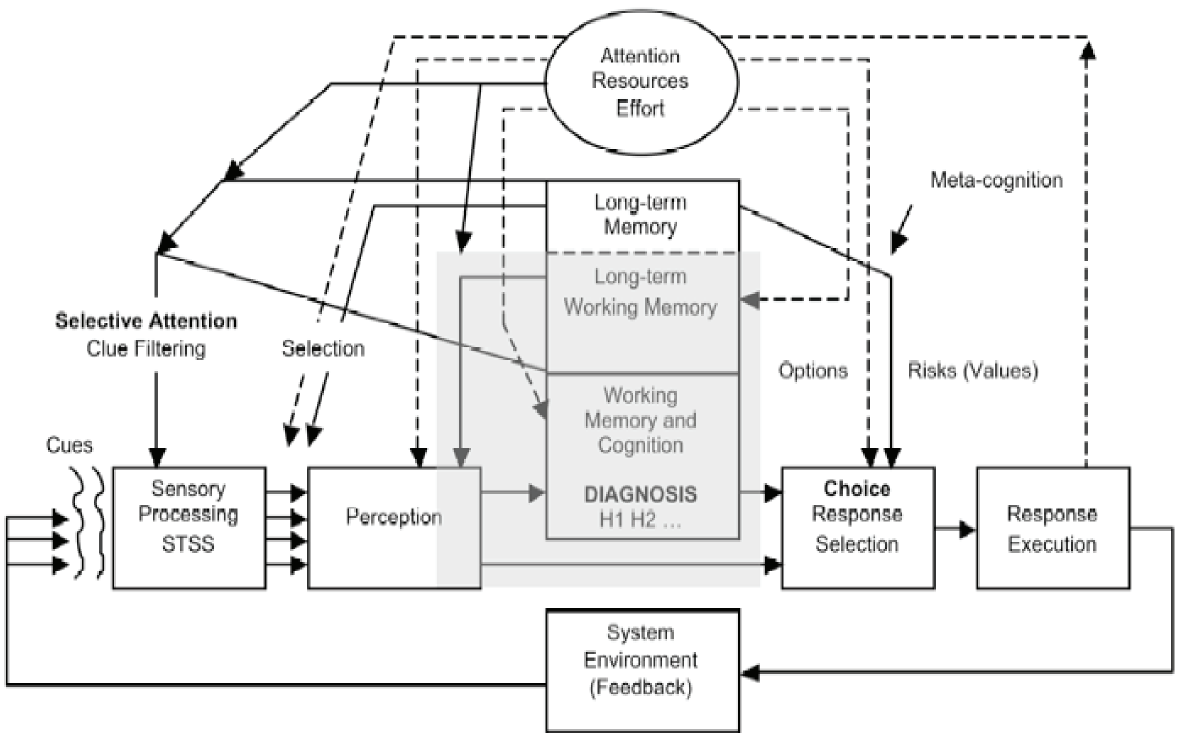

Figure 12. Information processing model proposed by Wickens and Hollands (2000, p. 295) (shaded area represents where situation awareness occurs in this model).

Within this information processing model, it is clear that the link between perception, long term and working memory, and attentional resources are required to maintain situation awareness (shaded area). However, when considering situation awareness, the Wickens and Hollands (2000) model does not appear to include a component of system or environmental feedback. When taking into account the influences needed to complete response selection and execution phases of decision making, it is difficult to imagine a situation in which feedback is not used to aid in SA. It could be argued that the proposed area of SA could be extended to include not only system/environment feedback, but could also include choice response selection. In support of this suggested expansion of SA, Schmidt and Lee (2005) point out that knowledge of results is extremely important to modifying human performance (response selection and execution), thus being important to decision making.

4.5 Decision Making

Individual differences related to decision making have been well documented in such domains as psychology, human factors, neuroscience, risk analysis, nursing, and human computer interaction (to mention only a few). Although examined in great detail, differences remain in theoretical perspectives regarding individual differences and the contributions of specific decision making strategies. For example, Endsley (2001) suggests that:

> Situation awareness (SA) can be thought of as an internalized mental model of the current state of the operator's environment. All of the incoming data from the many systems, the outside environment, fellow crew members, and others (e.g., other aircraft and ATC) must all be brought together into an integrated whole. This integrated picture forms the central organizing feature from which *all decision making and action takes place.* (p. 3, *italics* added).

However, Endsley does not indicate from which perspective the decisions should be viewed. Nor does she describe whether this integrated picture can be sufficiently developed under significant time constraints. The following section, therefore, outlines only the most relevant of decision making theories in order to maintain the focus on their influence in regard to situation awareness and Human Systems Integration.

4.5.1 Classical Information Processing and Decision Making

Classical information processing theorists suggest that decision makers rely primarily on their ability to mitigate limitations in working-memory (Wickens & Hollands, 2000). That is, decision makers reduce the amount of information that needs to be processed by combining data into chunks (Miller, 1965, 1994). The use of a decision making tree indicates that an individual employing a classical information processing paradigm would follow the nodes of the tree by using *YES/NO* criteria until reaching a desired outcome. Both Bayesian probability and multi-attribute utility theories suggest that by identifying specific hypotheses related to a situation, individuals can assess the possibility that their assumption are true (Cohen, Freeman, & Thompson, 1998). By developing particular rules associated with known situations, decision makers can reduce the amount of time and cognitive effort allocated to familiar situations.

Related to the notion of internal mental assessments of specific situational components, Sandom (2001) suggests that SA, as it relates to decision making, should be considered through a cognitive as well as interactionist perspective. From a cognitive perspective, SA can be thought of as "yet another black box component or sub-process within the human information-processing model" (Sandom, 2001, p. 52). Wickens and Hollands (2000) model of information processing (Figure 12, above) situated SA between perception, working memory and cognition, and long-term memory, thus suggesting that the process of developing and maintaining SA is not directly observable and must be implied through observation of behaviour in cases when self-reporting is possible. Additionally, from the model, SA and decision making do not overlap although it must be assumed that some interaction does to occur. When citing available research from an interactionist perspective, Sandom (2001) indicates that SA is considered "a useful description of a phenomenon that can be observed in humans performing work through interacting with complex and dynamic environments" (p. 54). It is, therefore, the observable performance of the interaction that is of considerable interest to the present discussion, in that information processing of environmental/situational cues is completed within the individual's central nervous system and not directly observable. Only through observation can it be assumed that an individual understands what is occurring in the environment. Furthermore, it can be assumed that if performance is carried out in accordance with a specific set of norms for a given situation, the individual must have perceived (short-term sensory stores), comprehended (working and long-term memory), and selected correct responses. It can also be assumed that the ease with which the individual completes necessary tasks is a reflection of the amount of experience an individual has for a given set of cues.

Unfortunately, observation of performance in isolation does not indicate the intricacies of the underlying process. As previously implied, it is the combination of performance (procedural knowledge) and the ability to articulate (declarative knowledge) which skills or procedures are necessary in a given situation that should be used to indicate an understanding of what is happening or what is about to happen. Consider, for example, the performance of a novice bowler and the first time the bowling ball is thrown down the alley. In this situation, the skill is performed without significant appreciation of how to adjust for possible error. If the skill is performed perfectly on the very first attempt, the individual may have achieved this perfect performance without having complete situation awareness. Conversely, individuals may perceive and comprehend environmental/system cues as well as be able to predict what will happen next (*level 3* SA) without having the capacity to perform a skill that will alter the outcome (passengers in a helicopter that is about to crash into the ocean).

4.5.2 Skill, Rule, Knowledge-based Decision Making (SRK)

Although Endsley (1995a, b; 2006) does not discuss decision making in detail, Wickens, et al. (2004) suggest that integration of different models related to decision making should start with Rasmussen's Skill, Rule, and Knowledge-based (SRK) model of cognitive control. Reason (1990) further points out that modern accident investigation is based primarily on the work of Jan Rasmussen and that without the compartmentalization of decision making into distinct stages, system design criteria would lack an understanding of "the shortcuts that human decision makers take in real-life situations" (p.43). As an example, Rasmussen (1982) points out that information processing of trained individuals is biased by their "experience and immediate expectations" (p. 316). Rasmussen (1982) makes a further distinction between the types of operator behaviour/decision making by addressing whether an error occurred in skill, rule, or knowledge-based processing (Figure 13 below). The SRK model is broken into three separate stages in order to demonstrate the different processing techniques. For example, at the "S" or skill-based level of decision making, individuals have gained sufficient experience so that they fully understand how a system works without having to rely on written procedures. At this level, individuals respond automatically to environmental cues. As with signal detection theory (SDT), Rasmussen (1982) indicates that individuals perceive environmental cues as signals. Therefore, those individuals who have gained extensive experience performing a particular skill set or tasks dominate this level of decision making and would presumably have the capacity to attain *level 3* SA. It can further be presumed that individuals operating at the skill-based level of decision making are better at recognizing and utilizing specific environmental/system cues. An offshore CR operator performing at this level of decision making could be thought of someone that would not only perceive environmental cues and comprehend current system states, decisions would be based on what the situation would be like if particular adjustments were made. Errors that occur at the skill-based level could be attributed to misguided attention related to non-relevant elements in the environment, as well as misreading system feedback due to influences such as a confirmation bias (Burton, Shadbolt, Rugg, & Hedgecock, 1990; van Swol, 2007). Skill-based (S) performance is also described as information processing that occurs at the subconscious/automatic level.

Rule-based (R) performance in contrast to skill-based relates to familiar situations in which the individual has begun to create mental models that help augment limitations in working memory. At the rule-based level of decision making individuals require procedural documentation to perform skills with which they have had little experience (such as the shutdown or startup of a complex system). Individuals performing at a rule-based level of cognitive control utilize *IF/THEN* rules during a conscious process of decision making. According to Endsley's three levels of SA, an individual operating at a rule-based level would be able to perceive relevant information as well as comprehend its importance; however, be unable to use this information to predict what actions would be most beneficial in rectifying a problem (*Level 2* SA). Therefore, it becomes necessary for individuals to refer to written procedures to ensure that correct actions are taken based on the situation. Errors occurring at this level of processing are related to misunderstanding of environmental and system information.

Finally, at the "K" or knowledge-based level, individuals have to rely heavily on information that is provided through written procedures and checklists as they lack any experience related to a particular situation (Rasmussen, 1982). At this level, individuals may attempt to assimilate incoming environmental cues into existing mental models within working memory; however, when none conform to the situation they must consult other sources of information. Within Endsley's model of SA, individuals at the knowledge-based level would have the capacity to perceive environmental/system cues, but lack the capacity to comprehend the relevance of these cues and would not be able to project future states (*Level 1* SA).

During the operator's progression from knowledge to skill-based decision making, it is important that all aspects of an operating system are understood. This is extremely important if individuals are expected to make specific links between complex system interactions as well as use this information to create shortcuts that save time and cognitive resources. Additionally, if certain skills are not practiced regularly it becomes difficult to rely on previous knowledge to perform at a level that will benefit the operator. The same can be said of SA in that, if the individual lacks the capacity to perceive and comprehend the desired system states, it becomes difficult for them to predict what will happen next.

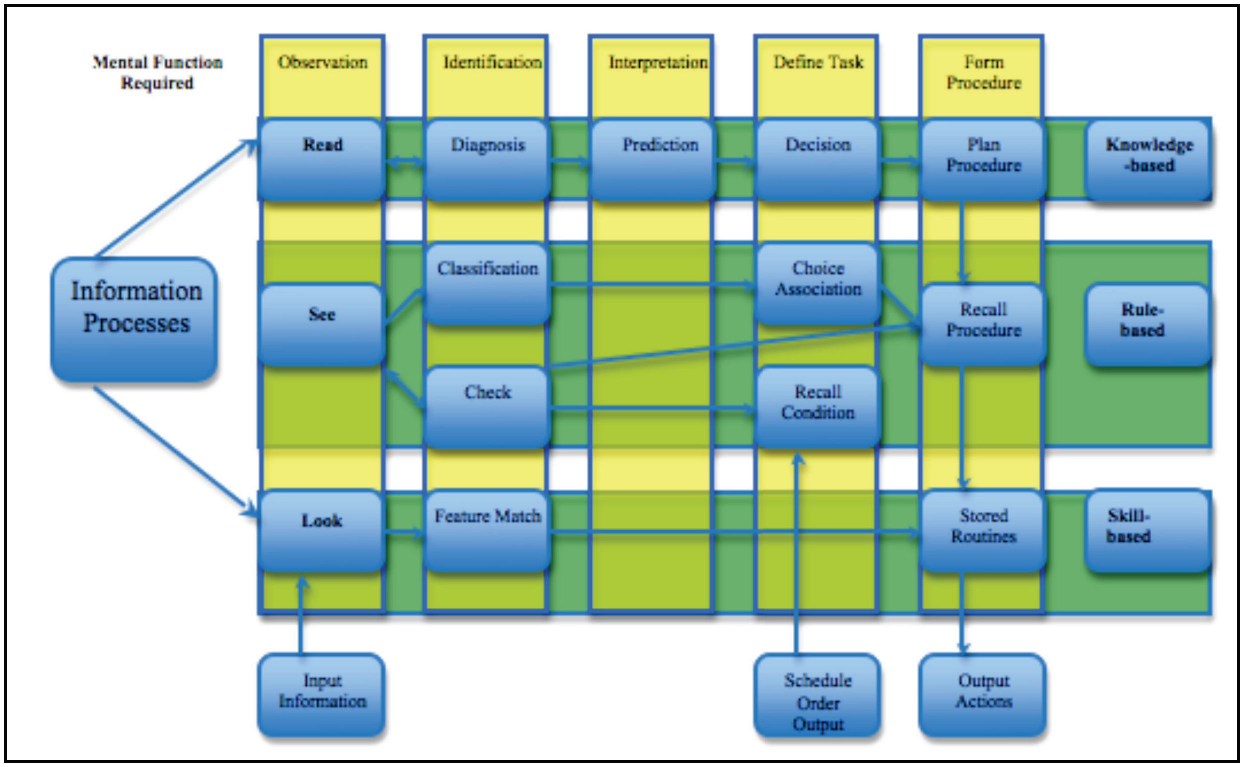

Figure 13. A model of cognitive control (adapted from Rasmussen, 1982).

4.5.3 Naturalistic Decision Making (NDM)

From a different theoretical perspective than the process of comparing all possible options (expected utility theory, see Durbach & Stewart, 2009) and making the most logical choice, given enough time and resources, naturalistic decision making (NDM) theory suggests that individuals will quickly categorize situations and select the most viable option rather than wait for more detailed information (Klein, 2008; Ross, Shafer, and Klein, 2006). This selection of appropriate actions is based on a rapid understanding of the current situation; however, formulated in relation to known schemata bearing the closest resemblance (based on past experiences) to available system/environmental cues. Klein (2008) indicates “from this perspective, making a decision means committing oneself to a course of action where plausible alternatives exist, even if the person does not identify or compare these alternatives” (p. 457). Klein (2008) has identified that some individuals are better at mental simulation than others and that this form of satisficing (Simon, 1955) allows individuals to play out a possible option without comparing other choices. Typically

NDM research involves observation of experts in a dynamic setting that includes time constraints, uncertain conditions, and vague or competing goals (Falzer, 2004).

Within NDM, Klein, Calderwood, and MacGregor (1989) developed the recognition-primed decision (RPD) model to incorporate intuitive and analytical aspects of decision making. The RPD model suggests that individuals will utilize the rapid nature of pattern recognition while tempering the possible faults and biasing of this method with the slower process of analyzing the option for consideration. This implies that at an individual level, projection (*level 3* SA) is affected by experience that shapes the general abilities of the person being tested. Figure 14 outlines the basic flow of decision making within the RPD model. As can be seen from the figure, individuals experience some change in the environment and compare the new stimuli to pre-existing situation models (schema/mental model) in relation to goals and expectations. This pattern recognition (*YES/NO*) and assessment is then followed by *IF/THEN* processing step in which the individual selects a course of action based on goal directed behaviour and initiates the response selection that appears to be the most correct given the set of circumstances. Given the fact that the RPD model takes into account external cues from the environment (e.g., pattern recognition) and an individual's decision making process (e.g., information processing), it could be used as a basis to improve the way in which individuals develop and maintain SA while in an emergency situation. Also, the inclusion of cues and expertise is important when considering the method of displaying visual information to emergency response team members. This is because by minimizing the possible solutions to the problem will likely reduce the amount of time required to make the decision, while at the same time reducing the possibility of making an error.

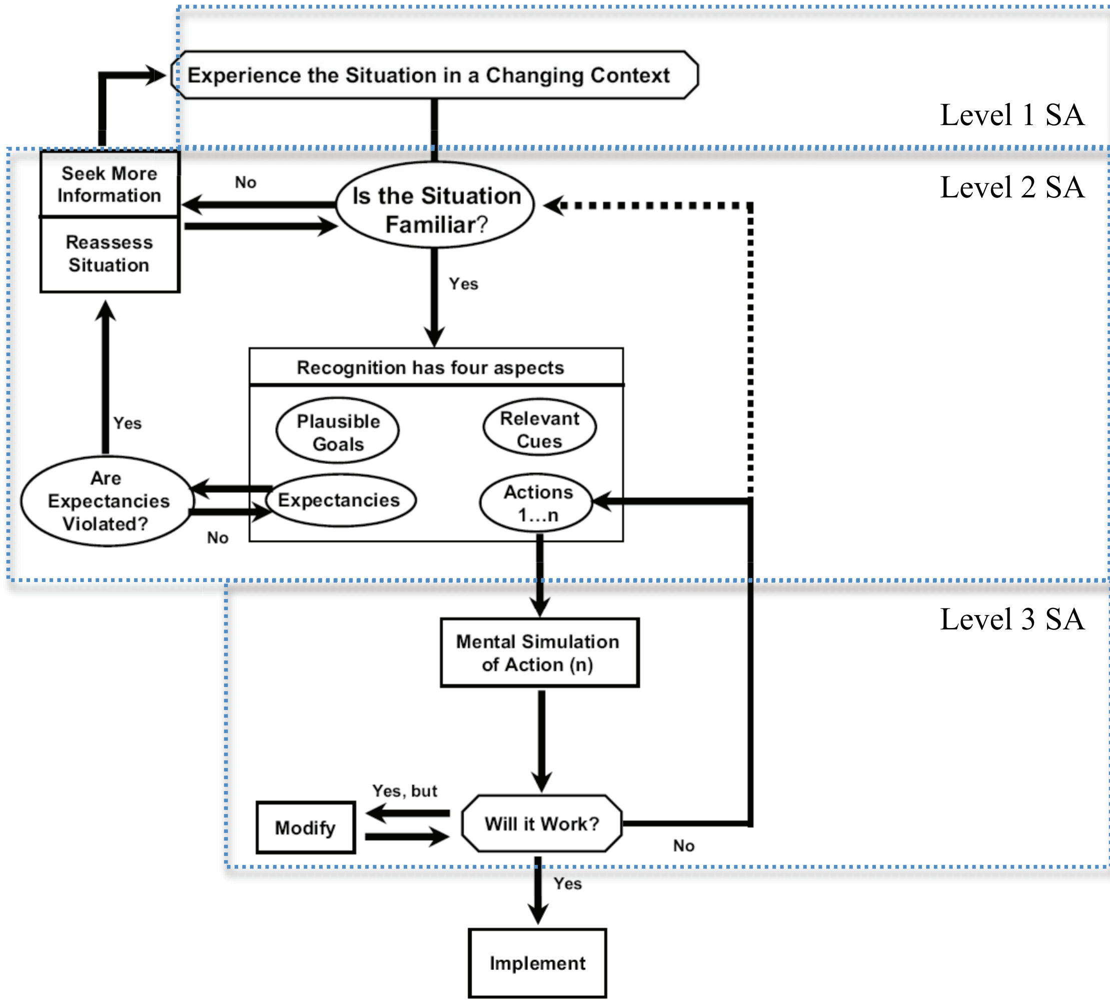

Figure 14. Recognition-primed decision model as it relates to SA (modified from Klein, Calderwood, & MacGregor, 1989).

4.5.4 Cognitive Continuum Theory (CCT)

One of the most intriguing decision making theories that relates to situation awareness and Human Systems Integration in general, is that of the cognitive continuum theory (CCT). Within this framework (Figure 15), it is proposed that decisions are made based on *intuition* and *analysis* that falls somewhere along the continuum between the two extremes (Hamm, 1988). If the situation is perceived to be novel and has considerable time constraints (i.e. an emergency), individuals will use intuitive knowledge to rapidly make a decision. However, if the situation is familiar and there is ample time, individuals will analyze available options in order to select the most appropriate course of action. Although used primarily in medical settings (Offredy, Kendall, & Goodman, 2007), the notion that decisions are not based solely on a detailed analysis of all available options (expected utility theory) or completely skewed by goal-directed behaviour allows for the possibility of influencing factors stemming from interactions occurring at a situational and individual level of decision making. CCT is intriguing in that when completing a situation assessment, individuals undoubtedly use a combination of intuitive and analytical reasoning. Additionally, CCT assumes that every situation has the potential of combining time related aspects as well as structural influences related to a specific task that may include a multidimensional continuum of direct/indirect and internal/external influences.

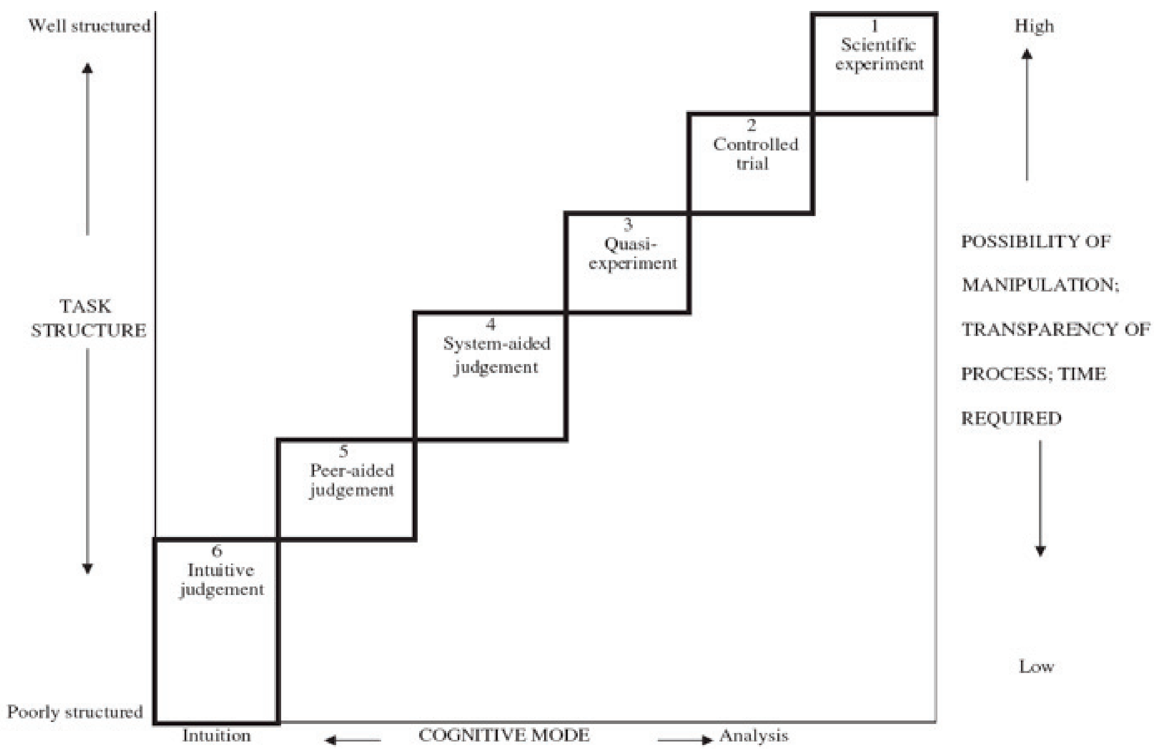

Figure 15. The cognitive continuum matrix (from Offredy et al., 2007).

Based on work carried out by Hammond (1955), Hamm (1988) and Hammond, Hamm, Grassia and Pearson (1997), Offredy et al. (2007) suggest that after testing 25 nurse prescribers on how they would evaluate and make decisions in four different scenarios, it was noted that as task structure decreases, individuals used more intuitive decision processes. This shift between intuitive and analytical cognitive modes is also seen when the situation moves from one of high possibility of manipulation (such as that experienced in scientific experimentation), transparency of process, and time required to complete the process. That is, if the individual has unlimited time to complete a task, the task is well structured and elements of the task are easily manipulated, it is more likely that an analytical approach will be used to make decisions. The cognitive continuum theory further highlights the possibility that if the situation is ill structured and there is little time available, an intuitive approach will be used and that this type of decision making favours individuals who have extensive contextual knowledge.

It is in the last level of SA that many researchers have suggested that experience and training accounts for the performance differences between novices and experts. It is also important to add (as does Endsley, 1995a) that expertise could be considered both a benefit as well as a detriment when making future predictions of system states (see also Carretta, Perry, & Ree, 1996). It could be said that one of the greatest downfalls of expertise in a dynamic systems is that when presented with novel environmental cues, experts may stop looking for alternative information that does not support their initial assessment of the situation. Known as confirmation bias (Johnston, 1996; Van Swol, 2007), individuals may easily find information that supports their initial assessment, where it is more difficult (particularly under conditions of high cognitive workload and time constraints) to continue searching for alternate solutions not supportive of the first choice. This strategy is effective under some circumstances when time constraints are short; however, in an emergency, alternative possibilities may arise from similar initiating cues. If an individual automatically assumes that the initial cues represent a particular situation and acts according to a preset schema or mental model (intuition), the potential for making an error increases. Without considering at least some alternatives, the resulting outcome may be considerably different than expected, even if the initial aspects of the situation are similar to those previously experienced under different circumstances.

In the Piper Alpha platform incident, confirmation bias and intuition were clearly acted on by those who chose to jump into the water. From a survival standpoint it is not difficult to imagine that when faced with explosions and fire, most individuals will rapidly decide to move to an area that does not contain as many perceivable hazards. Unfortunately, jumping into the water is not always the best option, particularly in conditions where there may be debris or flammable material on the surface or the temperature of the water is sufficiently low to induce cold shock and/or swimming failure (Stocks, Taylor, Tipton, & Greenleaf, 2004).

4.5.5 Dynamic Decision Making in a Microworld

Dynamic decision making (DDM) is designed to study decision making processes while in a complex situation/environment (Gonzalez, 2004; Gonzalez, Vanyukov & Martin, 2005). High fidelity production simulators in the aviation and nuclear power industry (often called microworlds (Gonzalez et al., 2005)) are currently used to assess an operator's ability to process information during systems failures. However, as more complex and automated systems are added to an existing processing framework, the operators need the cognitive ability to not only process the incoming information, but also to identify which items are relevant and which are irrelevant. It has been suggested that the operators of highly automated systems may lack the understanding of what a supervisory control system is doing and what it will do next (Itoh & Inagaki, 2004; Sarter & Woods, 1995). This lack of understanding reduces the ability of the operator to predict what will happen next or how system input may affect subsequent system states that may lead to a failure.

Alternate theories, such as signal detection theory (SDT) indicate that a relationship exists between an individual's signal detection performance and the strength of the signal, the operator's response bias, and the amount of external stimuli (noise), have also suggested that studying decision making under real-world conditions is essential to being able to predict how individuals will response in an actual situation (Wickens & Carswell, 1997). Thus, decision making ability may be impaired when a large amount of interference occurs (Masalonis & Parasuraman, 2003; Wickens & Hollands, 2000). March, Hicks and Cook (2005) note that interference related to cue detection may be influenced by transient thought, such as the consequences of making an incorrect decision. Therefore, in a dynamic environment, decisions need to be recognized as being dependent on previous responses and that any errors made during the initial stages of an emergency will most likely increase the probability of a system failure and loss of life.

4.5.6 Decision Making during an Emergency

Leach (1994) reports that individuals respond to similar amounts of information differently during an emergency than during a normal state and that this difference is based on the level of experience within a specific situation. In fact, Leach (1994) indicates that approximately 75% of individuals will become "stunned and bewildered" during and following an emergency (p. 540). During a review of accidents from several industries, Reason (1990) identified that inappropriate actions by those designated to be in charge were the result of both intentional acts, which were based on a faulty understanding of the situation and inadvertent slips in which an incorrect button was pressed.

Figure 16 demonstrates some of the information that may need to be processed by a control room operator during an emergency situation. Since this figure only displays one small section of the larger processing system it can be assumed that during a system upset, the operator and emergency management team members need to know what information is most relevant and which information can be disregarded. Further, Figure 16 adds support to the suggestion that operators and ERTs need to be trained in an environment that will help integrate incoming information into a concentrated mental model that resembles real-world settings in order to predict their responses during an actual situation. For example, if individuals are trained on a generic system that does not emulate well the information that would be experienced during a true emergency, it may be difficult for them to perform at a level attained during simulation based training.

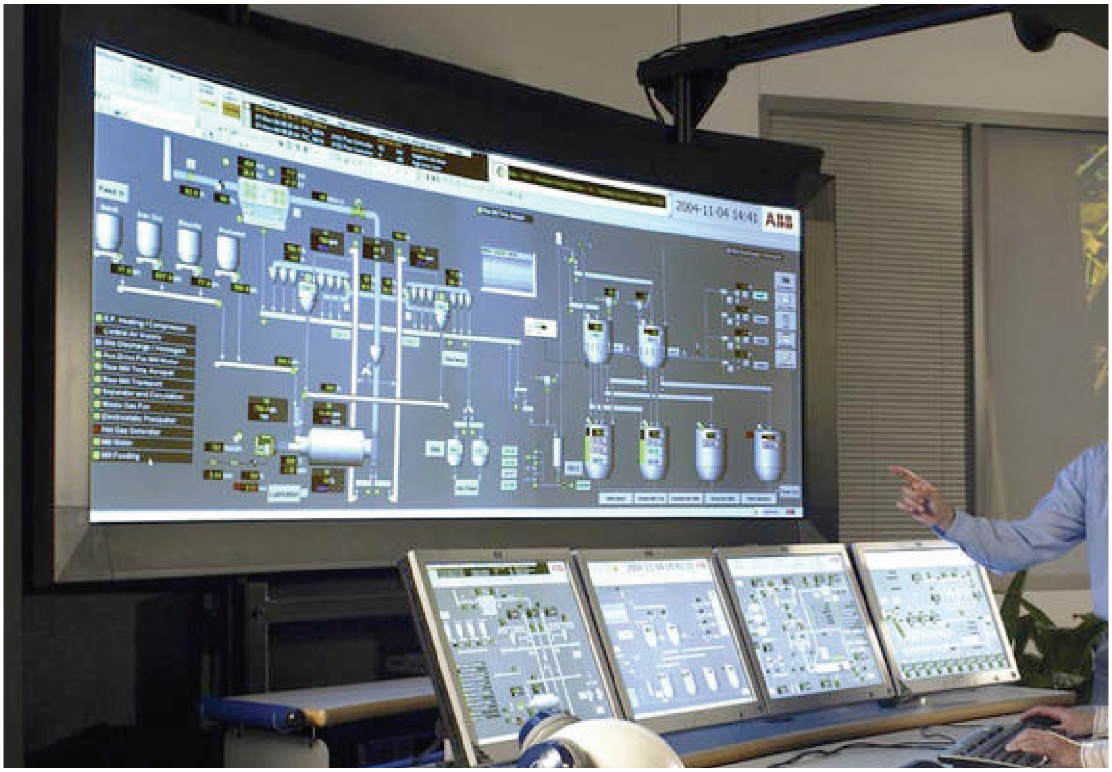

Figure 16. Existing control room operator's screen display.

Currently offshore MEM/PICA training conducted in Nova Scotia is conducted in a classroom setting at SSTL and does not resemble any of the offshore installations operating off the Atlantic coast. Under these circumstances of low fidelity, the operators and ERT members must conceptualize information that is presented to them by the assessment team. For example, it may be difficult for control room operator or OIMs to mentally simulate the amount of alarm information that could be associated with particular scenarios such as a helicopter crash on the helipad or a collision of a stand-by vessel used during this low fidelity training. Deficiencies in alarm and emergency management may represent a significant reduction in situation awareness. However, in an offshore environment the ERT members have the benefit of using system information and external cues to enhance their situation awareness, whereas during training, extra cognitive resources must be allocated to create an internal representation of the situation. Therefore, one of the applications of this thesis is to identify the quantity and quality of information that can be processed during an emergency situation. As well, how that information should be presented to ensure that the entire emergency response team shares a similar understanding of the situation (Cooke, et al., 2007).

The large body of research related to information processing clearly supports the notion that humans are limited in their capacity to identify which information will help them as well as how reliable that information is during an emergency (Gonzalez, Lerch & Lebiere, 2003; Rasmussen & Svedung, 2002; Wickens, 2002). In an offshore environment, the amount of information that is available during an emergency may overwhelm some of the individuals who are responsible for making appropriate decisions. However, it could be argued that it is the quality or manner in which the information is presented to the emergency response team that makes it difficult to comprehend the various aspects of the emergency.

The inability to make decisions and focus one's attention on a specific task is known to be linked to time constraints (Wickens, 2002) and age (Howard, Howard, Japikse, DiYanni, Thompson & Somberg, 2004). Senior rig personnel (Offshore Installation Manager, Drilling Supervisor, etc.) often comprise the majority of individuals designated to be on the ERT as they have gained many years of experience and seniority in their specific field. These years of experience could be considered a benefit in some aspects (Cooke, et al, 2007); however, it could also be argued that the older an individual, the more likely difficulties will arise when processing and adapting to the incoming information (Smith, Geva, Jonides, Miller, Reuter-Lorenz & Koeppe, 2001). Therefore a further aspect of this research is to identify whether personnel selection criteria for senior positions within an ERT needs to be focused on decision making performance of experts or if the presentation of information can mitigate some of the difficulties associated with information processing and integration.

4.6 Expertise

Ericsson (2006) formally defines expertise as "characteristics, skills, and knowledge that distinguish experts from novices and less experienced people" (p. 3). Although somewhat imprecise, when examined in greater depth this definition can hold considerable merit. Experts display superior performance when tested in their specific domain and this expertise is identified as being advantageous during decision making in that it offers the individual specialized knowledge that can quickly be utilized. It has also been proposed that experts may be able to use information stored in what has been termed *long-term working memory* (Ericsson & Kintsch, 1995). Wickens and Hollands' (2000) model of information processing (Figure 12 above) identifies that situation awareness includes perception, long-term memory, working memory and cognition. Based on this theoretical position, it is reasonable to conclude that an expert in a particular area of interest would not only perceive more relevant environmental cues, but would also comprehend the information in qualitatively different ways than a novice, which allows the expert to predict how this information might influence the systems' future status.

Research results have convincingly shown that experts are able to chunk information into larger and more meaningful blocks that require less cognitive or attentional resources during processing (Subotic, 2007; van Gog, Ericsson, Rikers, & Paas, 2005). Based on Ericsson's (2006) definition of expertise, it can also be argued that experts should have an increased level of SA, as they would have more experience in assessing the effects of sensory information related to environmental cues, as well as be better able to use this information to make informed decisions. Unfortunately, during times of emergency, it is sometimes difficult to recognize relevant cues that will improve human performance due in part to the fact that SA, decision making, and expertise are influenced by time constraints and available resources. Previous research further indicates that experience in emergency situation management may mitigate the negative influences of a situation (Glendon, Clarke, & McKenna, 2006; Leach, 2004; Meichenbaum, 1985; Orasanu & Backer, 1996; Salas, Driskell & Hughes, 1996). The relationship between practice and improvements in human response appears to support the need to include higher fidelity simulations that match, as closely as possible, the environment in which individuals will have to perform during an emergency. This is particularly true for situations in which a team effort is required to ensure that all tasks are completed in an effective and efficient manner.

4.6.1 Expertise, General Intelligence, and SA

The Piper Alpha event clearly demonstrates the need for individuals to be prepared for rapidly changing conditions. Although a complete exploration of expertise is beyond the scope of the present discussion, it is worth noting the contributions of gaining expertise in a particular domain. It can be assumed that experts have refined their mental models and schemata to the point of automaticity, thereby circumventing or mitigating limitations in working memory. In addition to long-term working memory (LTWM), Horn and Masunaga (2006) suggest that experts also have the added benefit of information available in what they have termed expertise working memory (ExpWM). It is proposed that ExpWM, when compared to short-term memory, retains considerably more information, is less affected by interruption and distraction, more easily resumes processing of information after an interruption, has a more flexible order of recall, and encodes information to long-term memory better (Horn & Masunaga, 2006). If an individual were able to utilize both LTWM and ExpWM during dynamic situations, it could be assumed that performance would be enhanced. Unfortunately, it appears that to gain the benefits of these desirable individual differences, it is generally agreed that one needs to deliberately practice a particular skill set on a frequent basis for at least 10 years (Ericsson, Krampe, & Tesch-Romer, 1993; Ericsson & Lehmann, 1996). Ericsson and Lehmann (1996) point out however, that once deliberate practice has decreased, many of the anatomical and physiological differences indicative of experts diminish to a level that can be considered average. From the overall perspective of the various factors affecting situation awareness, it may be reasonably assumed that many individuals will never attain the highest level of expertise, due to a variety of limitations in both cognitive and physiological capacities.

Further to the discussion of expertise, Hunt (2006) points out that any discussion related to “talent versus experience has to begin with an analysis of the role of intelligence” (p. 31). Although not explicitly stated as such, Fleishman’s (1972) research attempted to explore the link between human performance and specific abilities needed to form an overall view of psychomotor abilities or general traits used in the performance of specific tasks. It has been noted however, that general intelligence does little to explain the obvious differences in abilities with regard to math, science, and verbal skills (Cattell, 1963; Weinberg, 1989). However, based on the work of Fleishman and others, it can be hypothesized that those individuals who are more proficient at performing specific tasks (whether in math, science or other domains) will have a propensity to select these tasks and may have an underlying general ability that influences a type of self-selective process. That is, when an individual is considered above average at performing a particular skill and is rewarded according to that performance, it is more likely that the individual will select tasks closely related to that skill in the future.

Weinberg (1989) indicates that when asking the general public, intelligence consists of three main components: 1) practical problem solving ability; 2) verbal ability, and; 3) social intelligence. Weinberg (1989) further points out that these identified abilities are relatively similar to those suggested by cognitive researchers. These three aspects of intelligence also appear to be important when considering the individual differences associated with situation awareness. As mentioned in discussion on SA, it is the ability of individuals to understand what is going on around them (through the general acquisition of knowledge) that is used during decision making in a given situation. Being able to take into consideration the social context (working environment and safety culture of a given organization or environment), the required forms of communication, and appropriate decision making strategy may equate to a higher level of general situation awareness.

A distinction between fluid (Gf) versus crystallized (Gc) intelligence suggests that the two are separate subcomponents of general intelligence. Fluid intelligence is thought to be responsible for “the ability to reason abstractly in novel environments” as well as abilities in problem-solving and pattern recognition (Heitz, Unsworth, & Engle, 2004, p. 62). Crystallized intelligence, on the other hand, is said to be responsible for the use of skills gained through acquired knowledge and experience (Cattell, 1963; Van Lehn, 1996). Within the present discussion, crystallized intelligence refers to expertise in a particular situation, whereas fluid intelligence refers to the general capability of making sense of what is going.

In regard to sense-making generality, it has been suggested that automation of control systems may be used to reduce cognitive loading of less skilled and/or experienced individuals (Cuevas et al., 2007; Endsley & Kaber, 1999; Wickens & Hollands, 2000). This suggestion however, has been tempered with research that shows this intervention may also reduce operator situation awareness (Endsley & Kaber, 1999; Endsley and Jones, 1997; Liu & Hwang, 2000; Wickens and Hollands, 2000). Furthermore, Endsley and Bolsted (1994) found that spatial abilities significantly contributed to pilot situation awareness; therefore, it can be assumed that automation of spatial navigation systems may pose out-of-the-loop circumstances for pilots using this type of system. Clearly, spatial information that can be visually represented to the entire emergency response team (ERT) would aid in the formation of a shared understanding of where equipment and personnel are located throughout an emergency.

4.7 Emergency Event Investigation of Human Performance Failures

Investigation of accidents within the petroleum industry identifies numerous examples of inappropriate actions of personnel during critical moments of an emergency. Yule and Flin (2007) suggest that the management and safety climate can play a significant role in reducing risk-taking behaviours. Furthermore it has been pointed out that safety management practices have been linked to accident rates (Mearns, Whitaker, & Flin, 2003). After reviewing the explosion and subsequent shutdown of the Longford gas plant, near Victoria Australia, Hopkins (1999) suggests that an increase in the complexity of controls and display panels in the oil and gas industry may amplify the probability of an error occurring. The information available to ERT members during an emergency needs to be pertinent to the management of personnel, equipment, or resources in order to actually aid the development of SA. The information provided to the CR operators who are managing the production process is crucial to the entire ERT as it relates to the current system state; however, being able to sift through the myriad of information on multiple display screens becomes more difficult as system complexity increases. As an example of poor SA within a complex control room setting, Hopkins (2000) pointed out that operators at the Longford gas plant could not attend to the more than 1500 system alarms typically received during a single 12 hour shift in the days leading up to the incident and elected to ignore or silence them prior to the explosion.

4.7.1 Emergency Response

Problems with SA and decision making during emergency situations are potentially more serious when the individuals have not had extensive experience with the information available to them. Leach (1994) argues that there are three distinct behavioural responses associated with emergency situations. He indicates that only 10 to 12% of the individuals involved in an emergency react in a positive manner. These individuals are allocated to what he calls a "spontaneous leadership" category and are identified by their capacity to formulate a decisive plan of action under adverse conditions. Leach (2004) further indicates that spontaneous leaders often have previous experience performing in stressful situations.

The second category in Leach's (1994) hierarchy of emergency response is that of being "stunned and bewildered," in which he suggests that 75% of individuals will react inappropriately to the situation (p. 540). Reduced attention to relevant cues and inability to make a decision are described as the major obstacles for individuals within this category (Leach, 2004). Lack of experience in dealing with the environmental cues as well as understanding what skills are needed to improve the situation further hampers an individual's ability to respond (Leach, 2004). Here it could be argued that individuals may comprehend environmental cues but are unable to incorporate this information into a clear plan of action.

The final category of emergency response includes approximately 10 to 20% of individuals who Leach calls "paralyzed anxiety." These individuals are so overwhelmed by the information being presented to them that they simply "freeze". They lack experience in a similar situation; therefore, they may not have created a mental model or schema to help with an appropriate response selection. These distinct categories proposed by Leach (1994) are based on interviews with individuals who have been involved in emergency situations as well as reviews of reported responses. However, Leach does not report qualitative data obtained through traditional analyses (axial coding or illustrative method). The lack of empirical data to support his categories suggests that the associations are anecdotal and may not represent a true quantification of the emergency responses. This point is not meant to reduce the implications of Leach's findings; it is merely used to highlight the need to empirically investigate emergency response data in a holistic Human Systems Integration approach.

4.8 Training

One of the final Human Systems Integration components, and perhaps the most important for the purposes of this thesis, is that of training and evaluation. Without establishing a clear understanding of what information is necessary during a real-world emergency, it is difficult to formulate an effective training strategy. Process control and emergency management is a team endeavour and, therefore, requires that ERT members, the Installation Manager, and external emergency response personnel interact in a manner that utilizes their individual technical skills while creating a shared understanding of what is occurring around them. In addition to the technical skills, emergency response members need to be able to communicate effectively with all other team members; including process technicians, and onshore support members. Crew Resource Management (CRM) and Stress Inoculation Training (SIT) have been used effectively to train individuals how to work in a cohesive manner during an emergency (Meichenbaum, 1985; O'Connor & Flin, 2003; Orasanu & Backer, 1996). By distributing the cognitive loading of a particular situation across the resources of an entire response team, CRM and SIT identify points at which performance degrades. After repeated exercises in a particular situation, it is believed that team members begin to gain a better understanding of their role as it pertains to completion of goals (Orasanu & Backer, 1996; Sexton, Thomas & Helmreich, 2000). Ideally, if the team is exposed to repeated simulation of a specific emergency, it is thought that performance will increase to the point of automation. (Leach, 2004; Orasanu & Backer, 1996).

However, the ability to fully understand what is happening and how each team member can contribute to the efforts of managing the emergency can be difficult to conceptualize. If team members are able to visualize the collective understanding of the emergency (i.e., see how they fit into the overall plan), it may be possible to increase the development and maintenance of team situation awareness. Therefore, the potential outcomes of this thesis provide an innovative approach to evaluating and assessing the training effects of MEM/PICA course delivery techniques. Thus, training interventions could be developed to improve performance outcomes by systematically examining the ERT members' responses to simulated emergencies while using an interactive emergency focus board through an iterative process similar to those used for in-practice CRM training procedures.

4.8.1 Enhancing Interface Design

In order to properly evaluate user responses, it is also important to identify which aspects of the user interface contribute to performance (Jones, Endsley, Bolstad, & Estes, 2004). Usability of the control room visual display interface clearly influences operator performance and can contribute to error and the risk of failure. The ease and speed at which the operator can identify upsets in the process is critical to efficient day-to-day operations and is vital for handling process disturbances under time constraints. Currently there is anecdotal evidence that suggests that some control room operators are overwhelmed by alarms during a process disturbance and that this will significantly limit the operator's ability to manage the incident in an attempt to return the system to a safe state (personal communication with MEM/PICA SME assessor). Although there is appropriate guidance on alarm management (EEMUA, 1999) available to operators, it is sometimes difficult to implement these guidelines in practice. For example, Mayer and Moreno (2003) highlight the need to ensure that cognitive load is kept to a minimum and suggest that this reduction can be accomplished by utilizing different sensory modalities. For instance, by presenting important information visually, the cognitive loading on the auditory system is reduced (Mayer & Moreno, 2003). The challenge is in determining which information needs to be presented to the team to ensure that each member fully understands the overall situation and how they can contribute their own knowledge. Furthermore, without conducting a test of the product/process, it is difficult to gauge the ease with which the potential user can navigate from one component of the system to the next.

Due to the complex nature of petrochemical process environment, control room operators need to know the relationship between parts of the process both spatially and functionally (Eastman Kodak Company, 2004). Furthermore, Wickens (2002) indicates that depending on levels of experience, different displays result in explicitly different responses. Based on these suggestions, it is also important to understand how new and innovative technologies can aid in the development and maintenance of ERT situation awareness. If designed with the human in mind, interactive touch screen features may enhance SA by allowing team members to visually confirm or refute the OIM's conceptual understanding of the situation. If, for example, the visual display board indicates that a vessel or search and rescue helicopter is in a position that has not been updated recently, ERT members can quickly correct the board (and everyone's understanding of resource locations) by simply moving an icon to the correct location.

4.8.2 Performance Metrics

The effectiveness of the current comprehensive emergency response training and usability of recent MEM/PICA course improvements have yet to be judged in terms of performance. To date, no such testing metric exists; therefore, subject matter experts (SMEs) conduct subjective assessments only. For example, although the current training process conducted in Nova Scotia is based on the OPITO/Cogent standards used in the United Kingdom, several of the assessment categories (Appendix A) such as “makes valid decisions” are left to the subject matter experts' judgment. This judgment is based on a fundamental understanding of what decision seems most appropriate in specific situations as well as basic training that is completed through an OPITO/Cogent assessors training course. Additionally, the SME's assessments are typically based on years of offshore experience completed in a senior emergency response position (although this is not absolutely necessary). Surprisingly, this judgment is never audited by an external organization and rater drift is never assessed after the initial SME qualifications are completed. Rater drift has been described as the unintentional tendency of evaluators to shift or redefine their original assessment procedures over time (Polina Harik, Clauser, Grabovsky, Nungester, Swanson, & Nandakumar, 2009).

As part of this thesis, therefore, I have examined the MEM/PICA assessment process by exploring previous emergency exercise assessments, interviewing SMEs to gauge agreement of assessment processes, presentation of emergency information, and assessment of situation awareness within a Human Systems Integration methodology. Specifically, I explore the information that is used to gather physical evidence presented to assessors during the training and testing of offshore emergency response team personnel. I argue that without first identifying the information presented to the SMEs, it is difficult to identify how and where improvements can be made in the assessment process. Thus, making it difficult to predict how ERT personnel will react to real-world emergency situations. I further argue that without an understanding of situation awareness, human error, stress, expertise, environmental influences (organizational safety culture and/or physical), and appropriate training techniques such as CRM and SIT, it is difficult for assessors to fully understand why individuals make the decisions they make during an emergency. Finally, I argue that empirically tested performance metrics should be used to make these important SME assessments.

Performance metrics that include time to return the system to its normal steady state following an upset, time spent on task, number of errors made, or number of alarms handled correctly in a specified timeframe could be used to complete the assessment; however, none of these measures are currently utilized by the training and SME staff. The incorporation of specific performance metrics will ensure that subjectivity is reduced to an appropriate minimum level. However, it should be noted that testing and training of this nature will always have a certain level of ambiguity and not all individuals will require the same amount of time to completed the necessary tasks for each emergency. By combining objective performance metric with the subjective assessment of the SME in appropriate quantities, it may be possible to predict future performance.

4.9 Summary of Literature Review and Research Challenges

Based on the presented literature above, it can be reasonably predicted that without strong SA and without the ability to process the amount of information being presented at any given point, decision making will be severely hampered. Therefore, understanding system feedback within a particular environment is an important concept related to human system integration (Booher, 2003) as well as information processing (Wickens & Hollands, 2000), decision making (Rasmussen, 1982), and expertise (Ericsson, 2006). It is known that when using a rational choice model, individuals would presumably weight all options prior to making a decision (Keinan, 1987). However, during an emergency, individuals most often employ a naturalistic decision making (NDM) strategy, which narrows the decision options that are based on the information that is available to them at a specific time.

Examining MEM/PICA training standards through an HSI framework has not previously been attempted and represents a considerable advancement in knowledge related to offshore emergency management. Findings from this thesis could be used to evaluate existing control room designs and training processes as they relate to human/machine interface difficulties leading to errors. Beyond the scope of this project, SSTL plans to utilize the products/processes in future MEM/PICA evaluation.

CHAPTER FIVE

RESEARCH OBJECTIVES, PLAN, AND QUESTIONS

5.1 Research Objectives

The overarching objective of this multiphase research thesis is to reduce health, safety and environmental (HSE) risk by enabling Offshore Installation Managers (OIMs) and Emergency Response Team (ERT) members to effectively respond to system disruptions and emergency conditions. This objective has been approached through focused investigation of HSI components such as personnel selection, training, safety, health, human factors engineering, and survivability. These broad component categories were used to identify more specific factors related to an emergency response visual display interface, information processing integration, situation awareness, and emergency response training processes that ensure an understanding of how incoming information displayed on a central focus board will influence performance during a competency evaluation. By using a Human Systems Integration approach, factors that contribute to human performance are considered in combination rather than in isolation.

To accomplish the overall of objective of integration, the investigation of emergency response training and testing has been separated into five distinct phases of investigation:

1. Examination of previous emergency response training sessions;
2. Investigation of Subject Matter Expert's subjective evaluation standards of emergency response team performance;
3. Development of an Emergency Response Focus Board (ERFB) template;
4. Testing of an integrated Emergency Response Focus Board (ERFB), and;
5. End user testing of the ERFB under HSI-based assessment conditions.

These five phases were used to determine whether a newly designed emergency response focus board would increase accuracy of and speed of response while enhancing the emergency response team members' situation awareness. The first two phases were used to develop an understanding of how offshore ERT training has been conducted in the past four years. The objective of the third phase was to develop an ERFB that could be used by all ERT members during training. The development of the ERFB was directed by comments made by possible end users in a focus group setting. The last two phases were used to establish specific ERFB design criteria for future training courses. It is hoped that the research presented in this thesis can be applied to practical training strategies used during the evaluation of offshore ERT members.

5.2 Research Plan

The following hypotheses are based on the objectives of this thesis and the current offshore emergency response training process described in Section 6.3.1.

Phase 1 Hypothesis:

Transport Canada approved MME/PICA assessment processes will benefit from an analysis guided by Human System Integration principles. Specifically I hypothesize that an examination of existing training and evaluation protocols would aid in identifying possible improvements in standardization related to the display of incoming emergency information.

Phase 2 Hypothesis:

I hypothesize that Subject Matter Experts (SMEs) use different assessment factors despite having similar backgrounds and training experience. Using the six global factors (state of readiness, situation assessment, maintain communication, delegate authority, management of emergencies, and dealing with stress) outlined in Section 4.1, I hypothesize that SMEs would select different aspects of the OIM's performance to complete the assessment process.

Phase 3 Hypothesis:

As this phase was qualitative in nature and used to gather the opinions of OIMs regarding the emergency response focus board, no specific hypotheses were developed prior to the focus group discussion.

Phase4 Hypotheses:

I hypothesize that by standardizing the incoming emergency information display on an electronic touch screen whiteboard, ERT members (including the OIM) would be able to share a mental model of the situation created by the team and that this shared knowledge would improve situation awareness. During the testing of the electronic whiteboard templates, I hypothesize that those individuals with limited offshore experience (i.e., novices) would take longer to respond to event-specific questions than experienced offshore personnel in a simulated emergency. Similar to experts in other field (e.g., chess, tennis, and hockey) I hypothesize that experienced ERT members would focus on qualitatively different aspects of an emergency than novice team members. Finally, I hypothesize that when the simulation is stopped to ask situation awareness questions, individuals will take longer to response when the focus board is blanked out.

Phase 5 Hypothesis:

During this final phase, the primary objective was to observe how MME/PICA course candidates would interact with the newly designed ERFB template and to identify any difficulties associated with its use during the training/evaluation process. Therefore, no specific hypotheses were made prior to conducting the testing.

5.3 Research Questions

Based on the phase hypotheses outlined above, the following research questions were addressed through both qualitative and quantitative methodologies. Specifically, questions related to reaction time were investigated through quantitative data collection methods, whereas information related to cognitive strategies was examined through an interview process while discussing ERT responses associated with OPITO/Cogent global assessment factors used during simulation exercises.

Phase 1 Questions:

- Based on previous MEM/PICA training and evaluation processes, are there differences in how OIMs complete similar emergency response simulation?
- Is there a difference in the amount of time spent explaining the emergency situation to the entire ERT?

Phase 2 Questions:

- To what extent do MEM/PICA subject matter expert assessors use the same criteria to evaluate OIM and ERT member emergency response performance?
- To what extent do MEM/PICA subject matter expert assessors share a common understanding and agreed upon definition of situation awareness?

Phase 3 Questions:

- What aspects of an emergency are considered important to OIMs and what information needs to be displayed on the focus board?
- Where on the emergency response focus board should critical information be displayed?

Phase 4 Questions:

- To what extent does the visual display of emergency information affect situation awareness?
- Does offshore experience affect the accuracy of responses made to SA cognitive probes?
- Does the configuration of the focus board change the way in which participants answer self-rating SA questions?
- When assessing situation awareness (using the Situation Awareness Global Assessment Technique), do individuals respond quicker when the focus board information is visually available to them than when it is blanked out?
- Is vital response information retrieval faster on an existing focus board or a reconfigured (centralized information) emergency response focus board?

- To what extent does the visual display affect the amount of time required to ensure the ERT has a shared understanding of the emergency?

Phase 5 Questions:

- Will a change in the information delivery system (ERFB configuration) affect the amount of text (e.g., incoming emergency information) that a scribe writes on the focus board?
- To what extent does the final ERFB template aid the ERT in developing and maintaining situation awareness?

CHAPTER SIX
RESEARCH METHODS OVERVIEW

This chapter focuses on current Major Emergency Management/ Person In Charge Assessment (MEM/PICA) training and evaluation processes in relation to the use of an electronic Emergency Response Focus Board (ERFB) and situation awareness performance evaluations. The first portion of this chapter includes a brief outline of phases as well as an overview of the methods used in each phase. The chapter also includes information regarding fundamental emergency response components, a situation awareness checklist for a simulated helicopter crash on deck scenario, and SA measurement techniques.

6.1 Methodological Overview of Research Methods

The training of offshore emergency response personnel may have direct implications for safety and survival in a real-world situation, so it is important to fully examine factors that influence the evaluative processes related to certification of these personnel. To this end, it is important to ensure standardization of evaluation tools used during emergency management response training. While the need to establish a reliable measure has been recognized by training organizations such as Survival Systems Training Limited (SSTL) (personal communication with John Swain – company owner), finding an appropriate method of standardization for the evaluation of performance within a dynamic situation is in its initial phases of development. This thesis represents the first empirical examination of the MEM/PICA. By considering aspects of a Human Systems Integration (HSI) framework, the focus of this thesis is directed at combining aspects of personnel selection, training, safety, and human factors engineering. Based on these broad areas of research, several approaches to standardizing the assessment and training process could have been implemented. However, after examining previous MEM/PICA training sessions (Phase 1 of research detailed below), I noted that one of the main differences in course presentation and subsequent performance was associated with the way in which incoming emergency information was delivered and displayed on a centrally located focus board. Therefore, an assessment of the methods used to present visual information to Emergency Response Team (ERT) members during offshore emergency management simulations was used to offer a possible solution to mitigate concerns of assessment reliability.

The research plan for this thesis has been divided into five distinct Phases; however, each component builds upon the previous one in order to address the multiple factors associated with an HSI assessment. Although separated into Phases for discussion, Figure 17 indicates the data collection process and clearly shows the integrative approach that links each Phase. As the figure shows, HSI is considered during every Phase of the research and is central to the Phase evaluations.

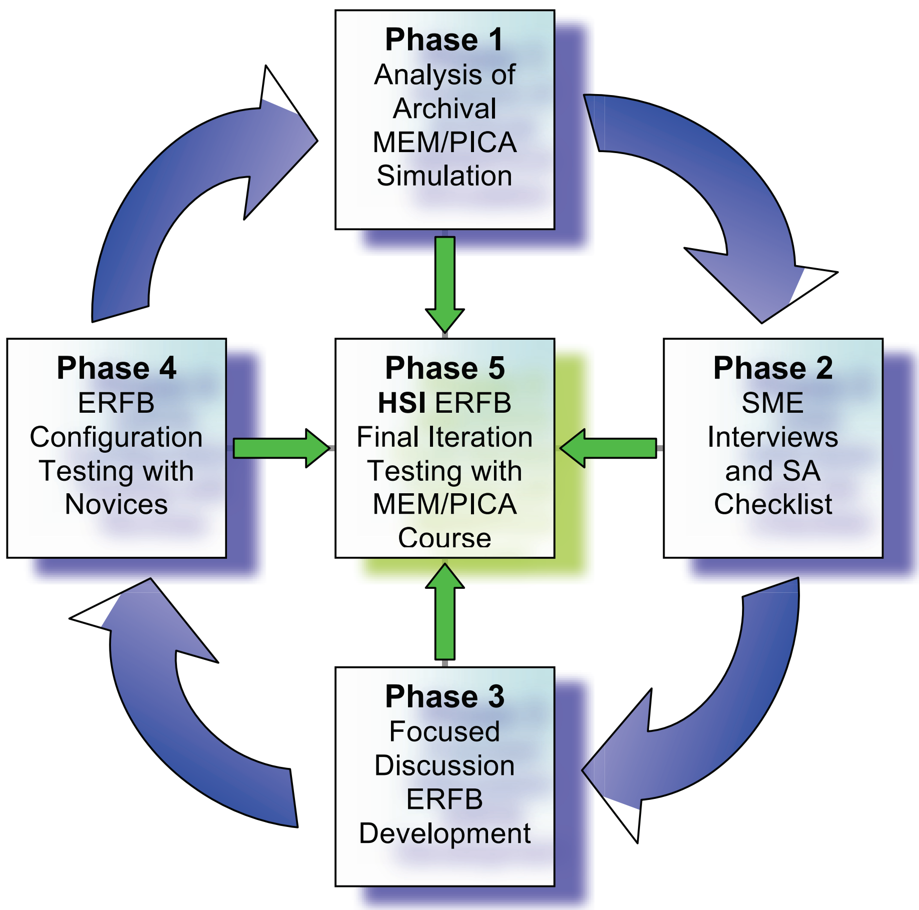

Figure 17. Interconnectedness of HSI data collection and documentation Phases.

All data collection Phases were approved through Dalhousie's Human Ethics Board and data collection was based on the fundamental idea that standardized MEM/PICA evaluation criteria related to ERT and Offshore Installation Manager's (OIM's) situation awareness performance do not currently exist. Based on this general focus, I have included a condensed summary of the methods used to conduct the research:

- **Phase 1** – The initial component of data collection and analysis consisted of examining archival videos from SSTL's MEM/PICA course folders in order to establish relevant cues that may be used by the participants when making decisions during a simulated emergency.
    - A list of relevant cues gathered from the archival videos were used to develop a situation awareness (SA) checklist that was then used to identify specific levels of SA during emergency response evaluations of both novice and experienced offshore personnel in Phase 4 and 5 of this study.

- **Phase 2** – Four offshore emergency management training evaluation subject matter experts were interviewed (structured and unstructured) in order to validate the SA checklist (developed in Phase 1) specifically designed for offshore emergency management evaluations. This process included an examination of inter-rater reliability of the SMEs while discussing transcribed components of existing OIM assessments (archival video data). SMEs' responses were used to develop informal cognitive maps related to the six global factors developed for the OPITO assessment process.
    - Once the SA checklist was approved by the SMEs it was then used to develop SAGAT questions for the assessment of individuals completing an MEM/PICA course at SSTL.

- **Phase 3** – After analyzing the interview data completed with the SMEs, a focused discussion was organized and completed with three OIMs in order to identify what emergency management information is necessary to make appropriate decisions and where this information should be located on a focus board during MEM/PICA training.
  - Three separate emergency response focus board configurations were developed. However, only two were used during SA and usability testing in Phase 4 and 5.

- **Phase 4** – In an effort to gauge the effectiveness of the SAGAT questions developed in Phase 2, simulated emergency testing was conducted with 32 individuals who were identified as novices with regard to offshore emergency management training. ERFB configuration performance was used as a measure of SA performance and usability responses were collected from 32 participants tested by using a helicopter crash on deck simulation. Two ERFB configuration conditions were tested to compare differences in the novice user responses to situation awareness queries.
  - Novice (no offshore emergency management experience) testing included SAGAT and cognitive probe SA testing, heart rate variability, SA self-rating, and usability data.

- **Phase 5** – In order to assess the usability of a final ERFB configuration, observation of an MEM/PICA course was conducted at SSTL during this final Phase of testing. In addition, documentation of the final ERFB iteration was used to explore the development and maintenance of SA.
  - This final Phase of the data collection included estimation of time on task, heart rate variability, SA self-rating, usability, and relevant participant demographic data (e.g., previous

emergency response training, age, years of offshore experience, years in current position, number of times involved in real emergencies, understanding of assessment criteria, and subjective assessment of the MEM/PICA training).

6.2 Fundamental Emergency Response Components

6.2.1 Real-Time Cognitive Probes, Reaction Times, and Cognitive Failure

Throughout this thesis, SA has been discussed in regard to an individual's ability to perceive, comprehend and predict the future status of a system. The decision to use this approach of measuring individual SA follows the current evaluation approach used by the offshore subject matter expert evaluators. This approach of aggregating individual SA performance to report team SA is not necessary appropriate since the various ERT members each have a different set of responsibilities, which might influence the OIM's understanding of a situation (Cooke, Kiekel, Salas, Stout, Bowers, & Cannon-Bowers, 2003) and is discussed in further detail in Chapter 12 of this thesis.

Within the SA literature, various measures (e.g., reaction time, accuracy of response) and techniques (e.g., SAGAT, SART, SARS) have been suggested as useful depending on the domain under investigation. Based on the available literature, the Situation Awareness Global Assessment technique (SAGAT) and Situation Awareness Rating Technique (SART) appear to be the most widely used and validated measures (Endsley, Selcon, Hardiman, & Croft, 1998). SAGAT requires that the simulation be stopped (frozen) and the available information is blanked out before SA questions are posed. However, it has been recently suggested that it is the visible information that is available to the individual which influences the accuracy and understanding of the situation (Durso, Hackworth, Truit, Crutchfield, Nikolic, & Manning, 1998; Durso, & Dattel, 2004; Jones & Endsley, 2004). Based on this acknowledgement of possible contributing factors, Jones and Endsley (2004) used a combination of SAGAT, real time probes, and SART to assess the validity of the probes. It was found that real time probes correlated with SAGAT and do measure SA at some level; however, not as effectively as SAGAT (Jones & Endsley, 2004). SART was not shown to correlate with SAGAT and it was suggested that this might have been due to the operators not being capable of rating their own performance. Endsley (1995b) indicates that self-rating of performance is related to a lack of understanding of what is not known and suggests, “ignorance may be bliss” (p. 68) (see also, Endsley et al., 1998). During their analysis of the issue it was noted that if probes are used to identify what information is needed to formulate an appropriate mental image in situations, and where the SAGAT could not be employed, the real-time probe technique might have some merit (Jones & Endsley, 2004). In particular, real time probes may be most useful in real-world settings where a stoppage in task performance is not possible. Furthermore, by identifying what information is extracted from the environment/system, it is possible to analyze the individual’s response as it relates to SA questions.

It should be noted however, that despite the wide use of SAGAT, individuals are required to respond to questions concerning situation awareness without having visual access to information that might be displayed on a computer screen or cockpit display. Therefore, individuals are required to maintain various amounts of information in working memory. With this in mind, Gonzalez and Wimisberg (2007) suggest caution when making a decision about which technique to use and found that if individuals have access to information on display systems, their SA will be greater than those of individuals who experience the standard form of SAGAT. It was further noted that if research is directed at knowledge acquisition and the effect of practice on SA, as opposed to working memory capacity alone, it may be possible to make suggestions related to better visual display system designs that will support dynamic decision making (Gonzalez & Wimisberg, 2007).

In addition to SAGAT and SART, Durso et al. (1998) used the Situation-Present Assessment Method (SPAM) to assess real-time probes in an air traffic control environment. It was found that those operators who responded more rapidly and more accurately to the *in situ* queries were subjectively rated as having better SA by SMEs (Durso et al., 1998). Although real time probes have not been used in many studies, their applicability to real-world situations such as an offshore emergency response make them an extremely attractive methodological approach to training for events where the operators can be asked a specific question about their SA without interrupting task performance.

Given the fact that ERT members and the OIMs use a central focus board to consolidate incoming emergency response information, and SA is developed and maintained by gathering relevant information from the immediate environment, I believed that it was important to consider how the information was visually displayed as well as how the SA questions were posed. Based on the non-standardized focus board setup that has been used during previous MEM/PICA assessment protocol, I decided that developing an interactive and standardized system for displaying the incoming emergency response information might increase SA performance. I also decided that it was important to consider a situation in which a real-world emergency in the offshore could not be stopped to ask the OIM questions about their SA. Therefore, I combined a SAGAT and real-time probe approach during the assessment of the ERFB and questions outlined in Table 5 (below) were posed at pre-determined times throughout a helicopter crash on deck simulation. The individual's reaction time to the real-time probes was interpreted as an index of the ability to recall information from working memory or to locate the information on the display.

6.3 SA in Modern Assessment Processes

One of the primary objectives of this thesis is to explore the use of a Human Systems Integration approach to emergency response performance by utilizing situation awareness assessment techniques. This research is carried out within a specific context of offshore emergency management training and with data collection focused on individual SA performance during a simulated emergency. Based on findings from previous research, I included aspects of the environment, technology, and human performance (i.e., the three main components of HSI) to ensure that a holistic view of situation awareness could be used to identify possible changes to future performance during training. By comparing individual and team performance against expected outcomes, established by MEM/PICA subject matter experts, SA assessments can be used to identify deficiencies in situational understanding. However, a clear understanding of what constitutes good or superior SA performance needs to be established before any links to the MME/PICA assessment can be made. For example, if the OIM directs the ERT members to complete all of the SME recommended steps required to extinguish a fire on the helideck, it can be assumed that the OIM's SA is at a sufficient level to successfully manage the situation. This understanding of what constitutes superior SA performance is crucial in light of the suggestion that an individual can perform simple tasks without having any idea of what is going on around them (Endsley, 1995a; Wickens, 2008). It has also been suggested that an individual can have excellent situation awareness yet perform well below an expected level because of an inability to react to specific cues (Endsley, 1995a). As the management of an offshore oil and gas emergency would undoubtedly require more than simple task performance, understanding the relationship between integrating specific cues and SA performance is essential to identifying what constitutes "good" SA. Therefore, accuracy of response and reaction time were used as a measure of performance and were based on what should be expected given the available information located on the focus board.

6.3.1 Assessment Processes in the Offshore Oil and Gas Industry

In a report of the Piper Alpha emergency event, Lord Cullen (1990) pointed out that the loss of life could have been minimized if the Offshore Installation Manager (OIM) and crew members had been better trained in emergency response techniques. In the years following the report, researchers in the United Kingdom (UK) focused on techniques for selecting and assessing individuals who would be responsible for the management of an emergency offshore (Flin & Slaven, 1994). Training and assessment processes for Emergency Response Team members and OIM in Canada are similar to the standards set out by OPITO. These standards are used to identify individuals who have the ability to develop and maintain a clear picture of what occurring in the situation as well as the possibilities of emergency escalation in the situation. As with the OPITO standards, the Canadian requirements are somewhat ambiguous in their description of what needs to be assessed and how specific quantification takes place. As an example, both the OPITO and Canadian standards indicate that a situation assessment includes the following components (SSTL Technical document, 2008 - Appendix A):

- Obtain, evaluate, & confirm information
- Interpret evidence validly
- Make valid decisions
- Identify contingencies
- Review potential outcomes

Without identifying what "make valid decisions" actually means in the context of an emergency, considerable interpretation of different measurements may lead to inaccurate evaluations of performance. In regard to SA performance, the listed assessment criterion does not indicate whether they pertain to perception, comprehension or projection, nor do they help distinguish which is most important. While examining errors in perception, Jones and Endsley (1996) reported that 76% of pilot SA errors stem from system design issues or cognitive processing. Additionally, in an investigation of offshore emergencies involving the performance of 200 OIMs in the UK, O'Dea and Flin (2001) found that "not thinking the job through" was considered the number one reason behind errors leading to an emergency event (p. 47).

6.3.2 MEM/PICA Specific SA Application

Based on previous offshore ERT performance findings, it is important to consider how the assessment criteria are incorporated into the MEM/PICA evaluations in that there should be no ambiguity in the evaluation of training performance. SMEs and OIMs should have a clear interpretation of each assessment criteria and how they related to performance in training as well as the real world. If, for instance, the assessment criteria are considered from an SA perspective and an individual is unable to attain *level 3* SA, it might be that the information being provided from various environmental cues is incorrect or difficult to understand, which will presumably have negative effects on performance. Within the criteria listed above, it can be assumed that, “obtain, evaluate, and confirm information” refers to perception (*level 1* SA), whereas “interpret evidence validly and make valid decisions” refers to comprehension (*level 2* SA) and prediction (*level 3* SA) respectively.

The situation awareness global assessment technique (SAGAT), first developed by Endsley, (2000b) was used to estimate one of three levels of awareness, as well as identify possible variables that enhance or decrease operators ability to process incoming information within the control room setting. In addition to the SAGAT, SA interview questions developed by Sneddon, Mearns, and Flin (2006) were modified and used during SME interviews (Phase 2) to establish how SA is understood and/or utilized during safety management evaluations in the offshore community. The SAGAT evaluation represents only one of the HSI components, however, it is crucial to understanding how the safety management system currently enables offshore workers to complete tasks while remaining safe.

The parameters that constitute high versus low SA during offshore emergency response need to be considered at two distinct levels (baseline and validation testing). This distinction is necessary because an SA assessment method has not as yet been utilized under the circumstances identified in this thesis. First, the baseline levels of SA were formulated by examining the archival videos and technical data (recorded MEM/PICA course documents) and were based on known criteria for aviation and nuclear power ERT responses, as well as the six global assessment factors (e.g., state of readiness, situation assessment, maintain communication, delegate authority, management of emergencies, and dealing with stress outlined in Figure in Chapter 4). This initial examination established a baseline against which subsequent simulated emergency SA performance collected in Phases 4 and 5 were compared. After establishing the SA baseline parameters, the archival data were then used to expand my understanding of performance criteria through SME agreement to ensure that the initial SA assessments had both content and ecological validity (i.e., the testing environment approximated that of the real world offshore conditions). Second, testing of the SA criteria checklist was used to gauge the performance of both novice and experienced offshore employees with regard to the information that was written on the ERFB. The SA checklist was used to formulate specific questions posed during “time-out” sessions in the simulated exercise. The time-out session in the MEM/PICA training range in duration and frequency and are typically only used if the OIM senses that the ERT members are losing focus or an important shift in the emergency has occurred. Time-outs are also used to aid in confirmation that the entire response team has a clear understanding of the present and future status of the situation.

A minimum of five SA related questions were asked during three predetermined *time-out* sessions. The SAGAT assessments gathered during Phase 4 were used as a basis of comparison for the MME/PICA participants and as a component of usability (e.g., efficiency and effectiveness) for the emergency response focus board configurations. The validation of the SA checklist questions was examined through reaction times, ability to elaborate on future situation parameters, and accuracy of response and based on the differences in ERFB configuration type.

6.4 General Data Analysis Overview

Data collection techniques differed for each of the Phase measures; however, they were also related to each other at least at a basic level. For instance, SA data collection was needed from Phase 4 and 5 in order to identify what constituted good situation awareness under specific circumstances. SA assessments were therefore needed to include a baseline description of each level as well as the input from SME interviews (qualitative) in order to arrive at a numerical (quantitative) value of awareness. This combination was in part due to the nature of how SA is defined. Endsley (2000) points out that the exact and appropriate amount of SA for each situation will be different and that one can never have too much SA. Therefore, quantifying good SA incorporated what SMEs believe to be a correct response for a given set of circumstances, as well as an identification of the steps that were required to achieve the correct response. Once established, this information was then used to examine the simulated assessments of the MEM/PICA course participants (Phase 5).

Both parametric and nonparametric statistics such as correlation coefficients, ANOVA, and Chi square analyses have been used to examine various aspects of SA and I used all options where applicable (keeping in mind post-hoc corrections for significance). Dependent variables of response times (sec), self-rated situation awareness, heart rate, heart rate variability, and usability assessment scores were used for each simulation to compare their performance effects under the three conditions (static, dynamic and EC2). For example, a 2 (with or without ERFB information visible) x 3 (board configuration) analysis of variance (ANOVA) was used to identify interactions and main effects associated with situation awareness rating (initial reaction time – RT). A similar ANOVA was used to assess the board configuration effects on heart rate variability standard deviation (HRV – SDRR). Correlation measures were assessed between SA rating (RT) and HRV (SDRR). Heart rate variability was also assessed to identify differences in pre-test rates versus those recorded during SAGAT testing in the emergency response simulation time-outs. Additionally, HRV was examined for differences in ERFB configuration.

Data from Phase 5 were compared to those generated during Phase 4 (static/dynamic ERFB offshore users). Therefore, a comparison between heart rate variability, self-rating situation awareness, reaction times, and usability data was used in the development of future emergency response focus board configuration guidelines. However, unlike the testing completed in Phase 4 (novice offshore personnel), the Phase 5 ERFB testing of the use and interaction of the emergency response board was carried out within a group setting. This methodology ensured that the testing protocols mirrored actual conditions under which the focus board would be utilized in an offshore setting, as well as the conditions that are used to conduct the Offshore Installation Manager's performance assessment (i.e., ecological validity).

6.5 Measurement Summary

As each Phase of data collection is unique in the type of information collected and analyses, Table 4 is offered as a quick summary of which measures were recorded during each Phase of testing. As can be seen from the table, the integration of this information is designed to aid in a better understanding of the HSI components necessary to improve emergency response management assessment procedures in the offshore oil and gas industry. Additionally, Table 4 provides a checklist of items that should be included in future ERFB development.

Table 4. Phase data collection checklist/summary.

Data Collected	Phase Number (number of participants)				
	1 (n = 6)*	2 (n = 4)	3 (n = 3)	4 (n = 32)	5 (n = 5)
Archival Video	✓				
Interview Responses		✓	✓		
Heart Rate variability (HRV)				✓	✓
SAGAT Responses				✓	✓
SA Real-time Cognitive Probes				✓	
SA Self-rating				✓	✓
Usability Assessment			✓	✓	✓
Audio Recordings		✓	✓	✓	✓
ERFB Video				✓	✓

* The number of different OIMs shown in the archival emergency response videos.

6.6 Phase Chapter Outline

In order to organize the Phases of research, the following outline of the Chapters, the following briefly notes the participants, data collection methodology, results, and discussion for chapter 7 through 11.

Phase 1 (Chapter 7)

- Participants - none were required
- Methods - video analysis of 8 MEM/PICA training sessions and examination of technical documentation
- Results - OIMs respond differently to the same simulated emergency

- Discussion - Lack of standardized emergency response board requires OIMs to compensate for deficiencies in event recording

Phase 2 (Chapter 8)

- Participants - 4 MEM/PICA evaluation subject matter experts
- Methods - semi-structured and unstructured interviews - transcription of interview - qualitative analysis (illustrative method) of SME responses - SA checklist development
- Results - SMEs use different global assessment factors to evaluate OIM MEM/PICA performance - no explicit use of SA measurement techniques - no inter-rater reliability
- Discussion - Based on the lack of standardized assessment procedures, considerable rater drift occurs as the MEM/PICA course is modified.

Phase 3 (Chapter 9)

- Participants - 3 OIMs currently managing an installation in the offshore
- Methods - Focused discussion about current MEM/PICA training evaluation process - Development of electronic ERFB
- Results - 3 ERFB configurations
- Discussion - ERFB 1 considered too complex and difficult to manage an emergency - need for a simple format

Phase 4 (Chapter 10)

- Participants - 32 MEM/PICA novices
- Methods - test 2 ERFB configurations (static and dynamic)- SAGAT - SA cognitive probes - SA self-rating - RT - HRV - SDT - usability assessment
- Results - confidence levels higher, faster RT, greater SA/accuracy with dynamic configuration - similar usability - visible information is better for SA - accuracy is affected by time-out session - no difference in HRV
- Discussion - dynamic ERFB better at developing and maintaining SA

Phase 5 (Chapter 11)

- Participants - 5 MEM/PICA course participants
- Methods - Observation task performance analysis
- Results - Final ERFB iteration effective and efficient - no difficulties interacting with configuration
- Discussion - Good overall design that seems to aid in critical factors of emergency response (e.g., personnel tracking)

CHAPTER SEVEN

PHASE 1

MEM/PICA ARCHIVAL VIDEO ANALYSIS AND SITUATION AWARENESS CHECKLIST DEVELOPMENT

This chapter outlines the methods, results, discussion, and conclusions related to the first phase of data collection. In order to cross-reference the research questions (Section 5.3 above) with each Phase, I have included the questions posed at the beginning of each Phase chapter. During this phase, MEM/PICA evaluation videos were examined for variation in emergency response performance. The specific focus of this Phase was to better understand how OIMs complete simulated emergency response and to develop a situation awareness checklist as a standardized evaluation tool that could be used by subject matter experts during future MEM/PICA assessments.

7.1 Phase 1 Methods

Research Questions:

1. Based on previous MEM/PICA training and evaluation processes, are there differences in how OIMs complete similar emergency response simulations?
2. Is there a difference in the amount of time spent explaining the emergency situation to the entire ERT?

These research questions were selected for their specific focus in relation to the standardization of evaluations. For example, by answering question 1, it is possible to identify particular differences in OIM approach to specific simulations and to explore the source of those differences. On the other hand, question 2 explores how much time is spent on particular tasks and whether those tasks aid in a shared understanding of the emergency, which could be used to predict the future status of the situation.

7.1.1 Participants

As this phase involved video analysis of previous MEM/PICA performance, Phase 1 did not require participants. However, a total of six different Offshore Installation Managers were depicted in the eight archival videos used to develop an understanding of MEM/PICA training and evaluation practices.

During this Phase of the thesis I completed systematic reviews of relevant technical literature, and analyzed eight archival videos that are used as evidence during MEM/PICA assessment at Survival Systems Training Limited (SSTL). While completing the systematic review of available technical documentation, it was noted that SSTL has conducted MEM/PIC courses for more than 200 individuals from more than 15 different companies over a period of seven years (2002-2009). During these assessments, ERT members' performance has been video-taped and stored at SSTL. In order to establish basic situation awareness requirements I conducted a qualitative observational analysis of archival MEM/PICA videos by examining OIM and ERT member responses to incoming emergency information. To capture key aspects of the training, I randomly selected two test videos from each of the four main scenarios (collision avoidance/abandonment, fire, person overboard, and helicopter crash on deck). As the archived videos do not have a specific coding system, it was impossible to know the order of simulations used to test each OIM candidate. That is, each OIM and team completed three to four simulations throughout their week-long training/testing period. Therefore, by randomly selecting the recorded scenarios from eight different simulations complete during one MEM/PICA course, the chance of selecting only initial or end testing sessions was limited and as all the individuals successfully completed the training, it was assumed that basic performance requirements had been completed during each simulation. Once selected, I transcribed the audio data and then analyzed the information through an illustrative method (Neuman, 2006; Roos, 2004). This qualitative approach to data analysis aided in identification of key aspects of emergency management attributes while in a simulated environment. As outlined by Neuman (2006), existing documentation (CAPP, 2004, 2005; Flin and Slaven, 1994, 1995; Survival Systems Training Limited, 2008; Transport Canada Marine

Safety, 2007) was used to gather evidence to support ideas related to emergency management techniques. Coded emergency response simulation video data were also examined for event onset information in order to identify information gathering and decision making aspects of the situation. Quantitative data (time on task) was then used to establish a hierarchical task analysis (HTA) (Mosleh & Chang, 2004; Shepherd, 2001; Stanton, 2006) that was used to identify objective differences in the way that OIMs address specific emergencies. The eight separate MEM/PICA video assessments represent approximately 15 hours of OIM testing and were considered to be typical of all other assessments completed during the last seven years.

7.2 Situation Awareness Query Checklist

The fact that situation awareness has not been used to conduct performance evaluations during the management of major emergencies course at SSTL makes it difficult to use as a baseline. However, the MEM/PICA course has very distinct criteria (albeit not well defined) that must be met by participants in order to gain certification; therefore, these set points in performance (e.g., assess situation, take effective action, maintain communication, delegate authority, manage self and team performance, and deal with stress) can be used to identify specific levels of SA. For instance, it is critical that an OIM passes pertinent information to all members of the ERT so that actions such as preparation for abandonment can be made. Any omission of key information could lead to a reduction in team SA and errors in judgment.

Taber, Plumb, and Jolemore (2008) suggest that “grey areas” of implicit knowledge, although not documented in standard operating procedures, are used by those having extensive experiential knowledge of how to manage an emergency (p. 277). By examining the archival videos, I identified distinct points in the simulation training during which implicit knowledge could influence the level of SA that could be attained by the OIM. Specifically, periods of time immediately following the movement of personnel from one location to another represented a critical point during which ERT members needed to ensure that the OIM understood the implications of this move. For instance, if personnel were moved to a new location that may impair communications or subsequent orders to abandon the installation, it is imperative that any ERT member who understands the implications of the move reports the information to the OIM.

During Phase 1 of this research, it was noted that four main emergency response scenarios (crash on deck, collision/abandonment, fire, and person overboard) are used in SSTL's training program. However, the helicopter crash on deck simulation was selected because it requires individual's to have a global understanding of several key aspects that may not be included in other scenarios. For the purposes of this thesis, I compiled the scenario information into a task list by using transcripts that I created from archival training videos (Phase 1) (Appendix B). The information contained in the task list was then condensed into a situation awareness checklist that was used to develop scenario specific questions that could be asked during testing of the ERFB (Phase 4).

While developing the checklist, I ensured that both OPITO (2005) and SSTL (2008) emergency response performance assessment requirements were considered. In addition, the following information outlined by Enhanced Safety through Situation Awareness Integration (2000) was used as a guideline for the SA checklist (p. 105):

> ***Performance of action***
> *In an emergency, the OIM and the command team are expected to deal with the immediate situation and to take any action required to ensure the safety of personnel on board and the integrity of the installation.*
>
> *Actions may include:*
> *- Shutting down production*
> *- Ceasing drilling operations*
> *- Mustering personnel*
> *- Deploying firefighting or rescue teams*
> *- Liaison with adjacent installations, onshore management, the coastguard,*

shipping and aviation

- Evacuation of non-essential personnel

- Total abandonment of the installation.

Communication

According to the OPITO (National (UK) Training Organisation (NTO) for oil and gas Extraction) Standard of Competence 'Controlling Emergencies' for Offshore Managers, the maintenance of communication entails:

- All essential people and organisations are immediately informed of the emergency

- Reports of the situation as it develops are provided to installation staff at suitable intervals

- Appropriate communications are maintained during the emergency

- An accurate record of all events and of key communications is maintained.

In order to incorporate aspects of the guidelines listed above, I divided the helicopter crash on deck scenario into 10 main components (listed below) that could be addressed during each SME evaluation. Information related to each of the list components is typically collected by SMEs as physical evidence during the assessment process. Because each OIM completes several scenarios during the week long MEM/PICA course, SMEs suggested that a full assessment could take more than one simulation to gather the required evidence before certification can be issued. In order to outline the methods used to test the newly designed focus board, the following information summarizes the specific tasks completed by OIMs during the MEM/PICA evaluation process (SSTL, 2008). In particular, the following information identifies the information that should be considered by an individual in order to successfully complete an evaluation of a simulated helicopter crash on deck scenario developed by MEM/PICA Subject Matter Experts (SMEs) at SSTL. To ensure that the listed items, keened from the archival video analysis, were appropriate for the situation checklist, I reviewed and discussed the items with SMEs. This discussion centered on identifying aspects of a helicopter crash on deck that were considered to be the most important during physical evidence gathering:

1. Location and total number of all installation personnel;
2. Location and status of fire team/emergency response personnel;
3. Status and location of nearest available emergency response equipment;
4. Status and number of personnel onboard the (crash) helicopter;
5. Position of helicopter on deck (upright, on its side, near the edge or close to the center, port or starboard side);
6. Status of the fuel on the helicopter;
7. Status of production or drilling (depending on mode of installation);
8. Location and status of standby vessel(s);
9. Overall awareness of information located on focus board; and,
10. Ability to predict future status of situation.

The 10 components are not explicitly listed in any SSTL assessment documents; however, they represent main aspects that an OIM should consider when managing a helicopter crash on deck. As the list was developed only for the ERFB testing in this thesis, the items are deliberately vague and were designed to prompt individuals rather than direct them toward a specific answer. For instance, the location and total number of rig personnel requires that there is an accurate manifest that is available to the OIM and the emergency response personnel. If the manifest has not been updated since the last helicopter or ship transfer, there may be names of personnel still on, or missing from, the list that have left or joined the crew. An OIM would further need to know that all personnel have arrived safely at their designated muster points.

As DiMattia, Khan, and Aymotte, (2005) point out, the gathering of all personnel in designated locations does not always go as planned and it may take a considerable amount of time before the OIM can be assured that all installation personnel are accounted for. Furthermore, in order to maintain a shared mental image of the situation, the gathering of information that can be used to make critical decisions needs to be represented in a manner that is accessible to the entire emergency response team. Based on the fundamental components of Endsley's *level 3* SA model (maintain an overall understanding of the situation so that predictions can be made), the focus board must incorporate all of the information necessary for the OIM and ERT personnel to make predictions of what might happen next.

7.2.1 Helicopter Crash on Deck Situation Awareness Checklist

In an effort to further outline the 10 components listed above, Table 5 details the tasks completed by the Radio Operator (RO) during the time just prior to a normal helicopter landing on deck. This same information should be gathered prior to an emergency event and although the RO performance is not being assessed by the SMEs, the RO's role is critical to the development of the ERT's situation awareness and ultimately affects the performance of the OIM. Therefore, the information contained in the table identifies the need to gather and share specific information with the entire ERT team. Portions of this list were also used to better understand which information is needed to answer SA questions posed during the testing of the ERFB. For instance, if the RO did not check the wind direction and weather status before an emergency event, this information would not be placed on the focus board and the ERT members (including the OIM) may not be able to answer SA questions related to the future status of a fire located on the helideck.

Table 5. Radio Operator (RO) task list used during a simulated helicopter crash on deck.

Task	Time Started	Time Ended	Did Not Complete
Make contact with approaching helicopter			
Ask pilot to confirm status of helideck			
Check status of standby vessel and any other ongoing activities (e.g., pumping or drilling)			
Check for and record radar traffic in the area			
Ensure cranes are properly positioned for approaching helicopter			
Check and record wind direction			
Check and record weather related information			
Notify pilot of any problems			
Notify OIM of any problems			
Monitor situation			
Confirm number of personnel onboard helicopter			
Confirm status of helideck crew and fire team members			
Check on passengers waiting in the heli lounge			
Ensure that manifest is updated (arrivals and disembarkation)			
Check on fueling requirements			
Comments			

7.2.2 Helicopter Crash on Deck Transcript

As the task list only details the requirements to be carried out by one of the ERT members before the scenario occurs, it can be seen that without completion of necessary tasks (e.g., call the pilot, call fire team), it would be difficult to have a clear understanding of how a situation might be affected by information that is not placed on the focus board. The transcription of the entire helicopter crash on deck simulation (Appendix B) is not normally used during the MEM/PICA assessment of an OIM's performance; however, I believed that this information is required to highlight the times when an OIM attempted to update the ERT members' situation awareness. I colour coded the information in Appendix B to identify the different personnel involved in the emergency response simulation. Each of the ERT members has a specific role to play in the emergency simulation and based on the information presented in Appendix B it is clear that the Radio Operator (RO) is extremely busy answering radio and phone calls throughout the scenario. It is also clear that the on-scene Fire Team Commander (FTC) is not as taxed by radio calls. However, the FTC is considerably more involved in the emergency response decision making process than is the RO and his or her ability to identify critical information has a greater influence on the OIM's situation awareness. Appendix B also shows the times when the scribe (person writing information) is updating the focus board. These entries only indicate specific times that it was obvious that emergency response team members were checking the information, however the focus board updates and modifications occurred throughout the entire scenario.

7.3 Phase 1 Results

This Phase of data analysis consisted of reviewing eight emergency response training videos that had been collected as physical evidence to support MEM/PICA evaluations. A total of six different OIMs were involved in at least one of four separate simulations (helicopter crash on deck, fire, collision avoidance, and MOB) used during the MEM/PICA training program. During the observational analysis of the archival videos, I recorded the number of time-out sessions, public announcements, radio communication, and telephone calls made by the OIM. In addition, I recorded the length (in seconds) of each task. The number of time-out session ranged between 4 and 6 with an average length of 467 seconds (7.8 mins). Public announcements (PAs) ranged from 1 to 9 with an average length of 77.4 seconds (1.3 mins). Radio communications and telephone calls were combined into one category and ranged between 0 and 11 with an average length of 17.3 seconds (0.3 mins).

7.3.1 Emergency Response Comparison

Overall timelines of the simulation types varied between 3115 seconds (51.9 mins) and 2040 seconds (34 mins); however, each of the scenarios contained aspects of the 10 main components listed in the methods section above and were considered to be critical to successful emergency response. Table 6 outlines some of the differences in OIM responses from two separate but identical helicopter crash on deck simulation scenarios in an effort to highlight the need to consider both individual perception of key elements and the situation itself. Additional archival video analysis information associated with time on task is included in Phase 5 testing (Table 19 and 20 below) as it is compared against that of OIMs using the final ERFB iteration.

Table 6. Comparison of OIMs' time on tasks for helicopter crash on deck scenario.

Response Task/Element	OIM 1 (seconds) Time spent on Task	OIM 2 (seconds) Time spent on Task
Discussion about current operations concerning pumping operations	7	6
Decision to halt pumping	2	2
Decision to allow helicopter on deck	N/A	12
Decision to launch FRC following heli crash on deck	9	N/A-ship's captain makes decision without prompt
PA (1) made to all personnel (muster)	N/A- this is carried out by radio op	14
Decision to call JRCC	N/A this is carried out by radio op	2-after prompted by radio op
OIM requests first situation update	4	N/A- Fire Team Commander carries this out without prompt
Time-out 1	109	169
PA (2) made to all personnel (crash on deck)	N/A- this carried out by radio op	20
OIM on phone to JRCC	N/A- this carried out by radio op	79
OIM asks for fire team situation update	N/A	25
Time-out 2	104	220
OIM on phone to shore	N/A	82
PA (3) made to all personnel (remain at muster stations)	N/A	64
OIM on phone to shore	N/A	60
Time-out 3	93	116
PA (4) made to all personnel (update)	N/A	30
Time-out 4	125	53
OIM on phone to shore	N/A	44
PA (5) made to all personnel (update)	34	28
OIM on phone to office	N/A	59
Time-out 5	78	100
Time-out 6	109	N/A
Total time of exercise	3090 (51.5 min)	2718 (45.3 min)
Total Time for Time-outs	618 (10.3 min)	658 (11 min)
Total time on PA	34 (sec)	156 (2.6 min)
Total time on phone	N/A	334 (5.7 min)
Percentage of time spent on TO, PA, and phone	21%	43%

7.4 Phase 1 Discussion

As Table 6 clearly shows, OIM 2 spent considerably more time talking on the phone and making PA announcements to the crew than did OIM 1. At first this difference may appear to be beneficial as it ensures that all crewmembers and onshore personnel are currently informed with the situation. However, it is the content of the updates that must be further examined to identify possible benefits. OIM 1's only PA announcement to the rig crew contained relevant information concerning the status of the personnel on board (the helicopter and the installation), status of the fire, and movement of casualties, whereas OIM 2's multiple PA announcements did little to update situation awareness of the crew and mainly repeated the request to remain at muster stations. Moreover, OIM 2 indicated only once that it was the OIM speaking during announcements in the initial onset of the emergency. The indication that the OIM is making the update is important in that installation personnel may use the OIM's tone of voice or hesitations to gauge the severity of the situation as well as the state of the emergency response process.

7.4.1 Time-outs

Time-out sessions within the current MME/PICA program are designed to aid in-group understanding of a particular situation (i.e., improve team SA). The SMEs suggest that the concept of using time outs to update situation awareness is new to many of the OIM's and may be difficult for them to integrate into an existing emergency response plan (personal communication with OPITO SME Assessors – Phase 2 interviews). Therefore, the time spent on briefing and updating other ERT members must be carefully outlined in detail before any assessment of the OIM's performance can be made. Therefore it is the SME's responsibility to ensure that the OIMs understand how and when to use a time-out. If, for example, the OIMs believes that a time-out can be used every few minutes during a 40 minute emergency simulation, there is a risk that the ERT members will constantly be focused on the OIM's update of the situation instead of gathering additional emergency response information from resources located outside of the command and control room. Currently there is no limit as to the number of time-outs that can be used, nor is there a set limit concerning the maximal length of time that can be spent in a time-out session. During SME interviews conducted in Phase 2, it was reported that time-outs are considered to be a “tool that is taught to the OIMs” and “expected to be used during the emergency response process” (SME interview quote). It was also reported that there is no requirement to use time-outs during the MEM/PICA performance evaluation nor would an OIM be penalized for not using them. However, if performance is deemed to be below the current MEM/PICA evaluation standard, OIMs are reminded that time-outs are valuable in updating the teams understanding of the situation. Furthermore, it was pointed out that the time-out “can be instigated by any one of the ERT members” when a “significant piece of information needs to be presented to the team” (SME interview quote).

By training the OIMs and their emergency response team members to the use of time-outs during the MEM/PICA course, SMEs indicate that it is more likely that the “tool” will be used in a real-world emergency event and was compared to a time-out used in profession sports. It was suggested by SMEs that there are times in a real emergency that necessitates a stoppage in task performance to ensure that specific response requirements are progressing toward a goal that is shared by the entire team. Without this break in the fast paced action of an emergency (or elite sporting event), it was suggested that OIMs and ERT members can lose focus of what tasks are most important to further ensure the safety of installation personnel.

Based on the nature of the four different emergency response simulations examined in this Phase, it would be reasonable to assume that OIMs using the time-outs should finish a particular type of evaluation session (e.g., helicopter crash or person overboard) in a similar amount of time and use a similar number of time-outs. Based on the review of the of the helicopter crash on deck simulation identified in Table 6, OIM 1 and OIM 2 initiate the first time-out after a very brief period of time (3 minutes, 26 seconds, and 2 minutes, 49 seconds respectively) to ensure that all ERT members have similar information to help create a team mental model of the events. However, OIM 1 requests a second time-out 4 minutes, 58 seconds after the completion of the first time-out, while OIM 2 waits more than 9 minutes before calling the second time-out. During this nearly 10-minute gap, a considerable amount of information had come into and out of the radio control room without a full team update. Table 6 indicates that OIM 2 required two full minutes longer to brief the ERT members on the second time-out than did OIM 1. This difference in time required to update crewmembers is likely due to the duration between briefings and represents a key difference in OIM MEM/PICA performance. Additionally, the time difference identifies a needed to better understand how time-outs are used in training and in real-world emergency events.

7.4.2 Use of Focus Board

One of the most obvious factors associated with the variability in performance appeared to stem from the lack of consistency in visually displaying the incoming emergency information. Moreover, it appeared that it was the ability of the scribe, who is typically the least qualified individual in an emergency response team, to not only decipher that information and distill it into usable data, but also must decide what should be placed on the focus board and where it should be placed that influenced the OIM/ERT performance. If for example the scribe missed or deemed a particular piece of information to be irrelevant, it was not placed on the focus board and required ERT members to maintain this information in their working memory.

From the archival video it was obvious that some of the scribes were particularly good at identifying and recording relevant information on the focus board. Similarly, it was obvious that other scribes were unsure of what information should be recorded and used a strategy of recording everything. As the focus board has limited space, the scribes who tried to record every piece of incoming information quickly ran out of space and needed to use flipchart paper. In the cases were multiple flipchart sheets were used, each of the filled sheets was torn off the chart and clipped to the bottom of the focus board or simply flipped out of the way. This strategy required the OIM and other ERT members to hold an excessive amount of information in working memory and appeared to affect performance and situation awareness. Based on the observational results from archival videos, as well as the fact that there is no formal training for scribes, and the focus board is not standardized from one MEM/PICA course to another, it was important to address the one aspect of the simulation that is used by all ERT member to create a shared understanding of the emergency.

CHAPTER EIGHT

PHASE 2

MEM/PICA SUBJECT MATTER EXPERTS

This chapter outlines the methods, results, discussion, and conclusions related to the second Phase of data collection. As with the previous Phase, I have included the research questions posed in Chapter 5. During this phase, MEM/PICA Subject Matter Experts (SMEs) were interviewed in order to identify specific evaluation criteria used in the assessment of Offshore Installation Managers (OIMs) during an emergency response simulation. Inter-rater reliability was assessed for SME agreement on which evaluation factor (i.e., OPITO global factors) is most important for MEM/PICA success. A secondary focus of this Phase was to discuss the situation awareness checklist that was developed in Phase 1 with the SMEs in order to identify items that should remain on the checklist. In addition to the situation awareness measures, subject matter experts (SMEs) were interviewed to gain access to their experiential knowledge of crucial performance requirements during emergency response. The involvement of the SMEs was critical, in that the qualitative criteria used to certify an OIM have not as yet been empirically evaluated.

8.1 Phase 2 Methods

Research Questions:

1. To what extent do MEM/PICA subject matter expert assessors use the same criteria to evaluate OIM and ERT member emergency response performance?
2. To what extent do MEM/PICA subject matter expert assessors share a common understanding and agreed upon definition of situation awareness?

The research questions selected for this Phase are designed to explore the consistency between evaluators. That is, do they consider similar factors when evaluating the OIM’s performance? If not, does this affect the reliability of the assessments?

8.1.1 Participants

The participants for Phase 2 of this research included four individuals who are currently certified to conduct evaluations of emergency response personnel during simulation training. To gain certification and therefore be considered subject matter experts, these participants have successfully completed an extensive training program in Aberdeen, Scotland in accordance with Offshore Petroleum Industry Training Organization (OPITO/Cogent) qualification standards. Typically, the subject matter experts have previously been employed as an offshore installation manager. This requirement is not absolutely necessary for this research; however the four available evaluators all had held senior oil and gas management positions prior to obtaining an assessor certification. All four individuals currently reside in Atlantic Canada. As the majority of offshore workers from Atlantic Canada are male (ratio of 11:1 – male to female) and range in age from 18 to 58 with a mean age of 37.1 (Kozey, Brooks, Dewey, Brown, Howard, Drover, MacKinnon, & McCabe, 2009), the sample of ERT evaluators are clearly in the upper end of this age range (mean age = 49.75 years, SD = 4.58 years). The MEM/PICA SME age range also reflects the apparent need for subject matter experts to have a considerable number of years of emergency response training and leadership experience in offshore environments.

8.1.2 Interviews

The interviews (structured and unstructured) were designed to establish which aspects of emergency management are specifically needed to gain MEM/PICA certification. Each SME was informed of the nature of the research prior to giving written informed consent and was encouraged to thoroughly read the informed consent forms prior to agreeing to participate in the research study. Each interview required approximately two hours of the SME's time. Interview questions (Appendix C) were designed to elicit verbal responses related to the cognitive aspect of certification.

SME interviews took place at SSTL's Dartmouth location, Dalhousie University, and through one teleconference. The interviews were audio recorded and saved to a password protected personal laptop computer. This audio data was also recorded onto a compact disc (CD), which was used during member checking and data analysis. The contents of the CD were only accessible to me to ensure confidentiality of the individuals completing the interviews. Once the data were used for analysis it was locked in a metal filing cabinet that only I have access. The CD will be stored for a period of five years post-publication, at which time a shredder will be used to destroy the CD.

As part of the HSI approach to investigating performance, the interviews were directed at addressing both personnel selection and training sub-components. Additionally, this Phase was designed to explore the preliminary aspects of understanding how subsequent sub-components such as safety and health are affected. Interviews were coded in ATLAS.ti (V 5.2.12) to identify and match subjective components used by the SMEs when making decisions about emergency response certification. Coded information was then examined for themes related to the six global assessment factors shown in Figure 6 above (Neuman, 2006). In a standard form of member checking, SMEs were given the opportunity to modify any statements (quotations) they believed did not truly reflect the qualitative meaning of their assessment process. The digital recordings of the interviews also aided in identifying standardized criteria used for certification and were used to check inter-rater reliability. SMEs' inter-rater reliability was determined by asking each of them to indicate which of the six OPITO global factors were considered to be the most important aspect of the emergency management process. Additionally, SMEs were queried about each sub-section of the global factors. The SME responses were also coded to examine links between similar ideas. Once coded, I used the data to develop informal cognitive maps, which indicate the interconnectedness of the six global factors and sub-sections used in Figure 6 (above). These cognitive maps were then used to develop SA questions that were posed to novice participants during the testing of the ERFB configurations. The illustrative method (Neuman, 2006) used to analyze the archival videos in Phase 1 was also used in this Phase to analyze the qualitative components associated with the six global assessment factors and aided in the documentation of subjective attributes that are used to perform the MEM/PICA evaluations. The SMEs agreement of which of the six global factors were most influential in their assessment of OIM and ERT member performance was then used to determine inter-rater reliability.

SMEs were also queried about their understanding of situation awareness and asked to provide a definition of what they considered to be important components of the MME/PICA evaluations. These definitions were taken into consideration while developing the ERFB configurations. For example, if an SME indicated that communication of information was the most important aspect of SA, the ERFB configuration reflected this statement by ensuring that sufficient space was provided on the board for event and communication tracking. ERFB configurations are outlined in further detail below (see Phase 3 and Phase 4 details).

8.2 Phase 2 Results

During this phase of research, four subject matter experts were asked to identify which of the six global assessment factors (state of readiness, situation awareness, maintain communications, delegate authority, management of emergency, and dealing with stress) were most important to MEM/PICA success. This particular interview question was designed to assess inter-rater reliability as it was expected that all (or most) of the SMEs would agree on the specific assessment factor needed to successfully complete the emergency management training. However, each of the SMEs indicated a different global assessment factor was used to assess overall performance during simulated emergencies. SMEs indicated that communication, situation assessment, a state of readiness, and a combination of all six factors is most important to the overall assessment. Therefore, without consensus among qualified assessors (inter-rater reliability of 0), I recognized that it would be difficult to identify agreement concerning a standardized set of situation awareness criteria. In addition, each of the SMEs had a slightly different, although similar, understanding of what constitutes situation awareness. For example, the following quotes were obtained during the SME interviews:

“Situation awareness, as I understand it is an understanding of the big picture of what’s happening around me as it is based on reality.”

“Within offshore emergency response situation awareness, it is the ability to know the main focus and being able to update that information.”

“Situation awareness is having the ability to take onboard the information that’s coming in, making sense of it, and then develop a game plan for action from that information.”

“Situation awareness is an understanding of the emergency as it’s evolving, and it’s an understanding of how the emergency or the incident that’s ongoing can affect the integrity of the facility and therefore life or the environment”

In order to examine the differences in how the SME conceptualize the MEM/PICA evaluation process, I examined their responses for interrelatedness and overlapping concepts. The goal of this examination was to identify where, if at all, the SME’s agreed on specific assessment criteria as well as where there might be differences. Therefore, I created informal cognitive maps (Swan, 1997) that represent each of the SME’s responses to the global assessment factors interview questions. These cognitive maps represent the final component of the illustrative method used to analysis the qualitative aspects of emergency response management evaluation. In order to identify the similar interconnectedness of the global assessment factors suggested by Flin and Slaven (1994), I have included an insert of Figure 6 next to each of the SME’s cognitive maps. The cognitive maps were developed in ATLAS.ti by first coding the specific SME responses to interview questions. These coded responses were then arranged around the central themes related to the six global assessment factors. Figure 18 through 21 show the individual cognitive maps developed from the SME interviews. The cognitive maps show that each of the SMEs link the overall factors in a different manner. The maps identify that there is a complex interaction of multiple factors regardless of which global assessment factor was chosen as a main focal point. Interesting however, the SMEs all believe that the management of emergencies included in the six global factors is actually an overarching theme of the MEM/PICA evaluation and not necessarily an assessment factor on its own. Based on the SMEs' comments, the cognitive maps do not include a management of emergencies node.

Figure 18 identifies that one of the SMEs believes that communication is the most important assessment factor. The links (yellowish-orange boxes) that were selected by this SME, include key aspects of record keeping, alternative forms of communication, incoming information, resource allocation, reporting back, and coordination of team actions and were considered to be "a part of" the overall communication requirements. Secondary to the main requirements of communication, the SME indicated that sub-components involve all of the aspects of an emergency response and are considered to be "associated with" ensuring that everyone knows what is happening (team SA). Finally, Figure 18 also shows that the SME believes that the OIM's personality plays an important part in the communication effectiveness and style that would be used by the rest of the team.

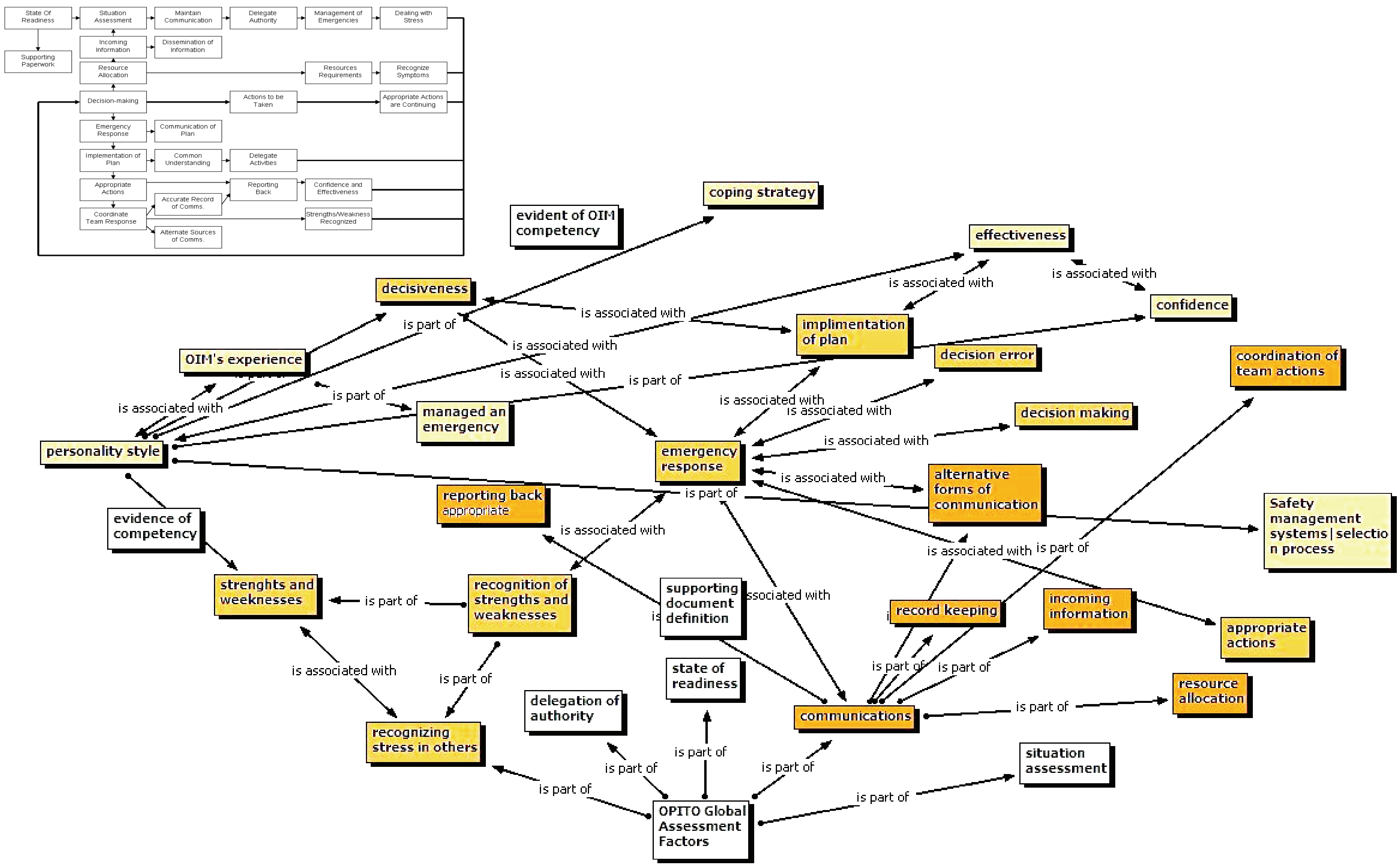

Figure 18. Communication OPITO global assessment factor (from SME interview) and Figure 6 insert.

The cognitive map shown in Figure 19 identifies the situation assessment components (pinkish-red boxes) chosen by a second SMEs. From the map, it can be seen that similar communication aspects that were highlighted by the previous SME were also considered to be important by this individual. However, this particular SME believes that only by conducting a situation assessment can an OIM actual start to establish good communication with the rest of the ERT members and the shore-based resources. It was suggested by this SME that if the OIM has no idea what is occurring, it is difficult to identify where deficiencies might affect communication. Similar to the previous cognitive map, it can be seen that this SME also believes that the OIM's personality style will play a part in the formulation of an emergency response plan and the effectiveness of that plan's implementation.

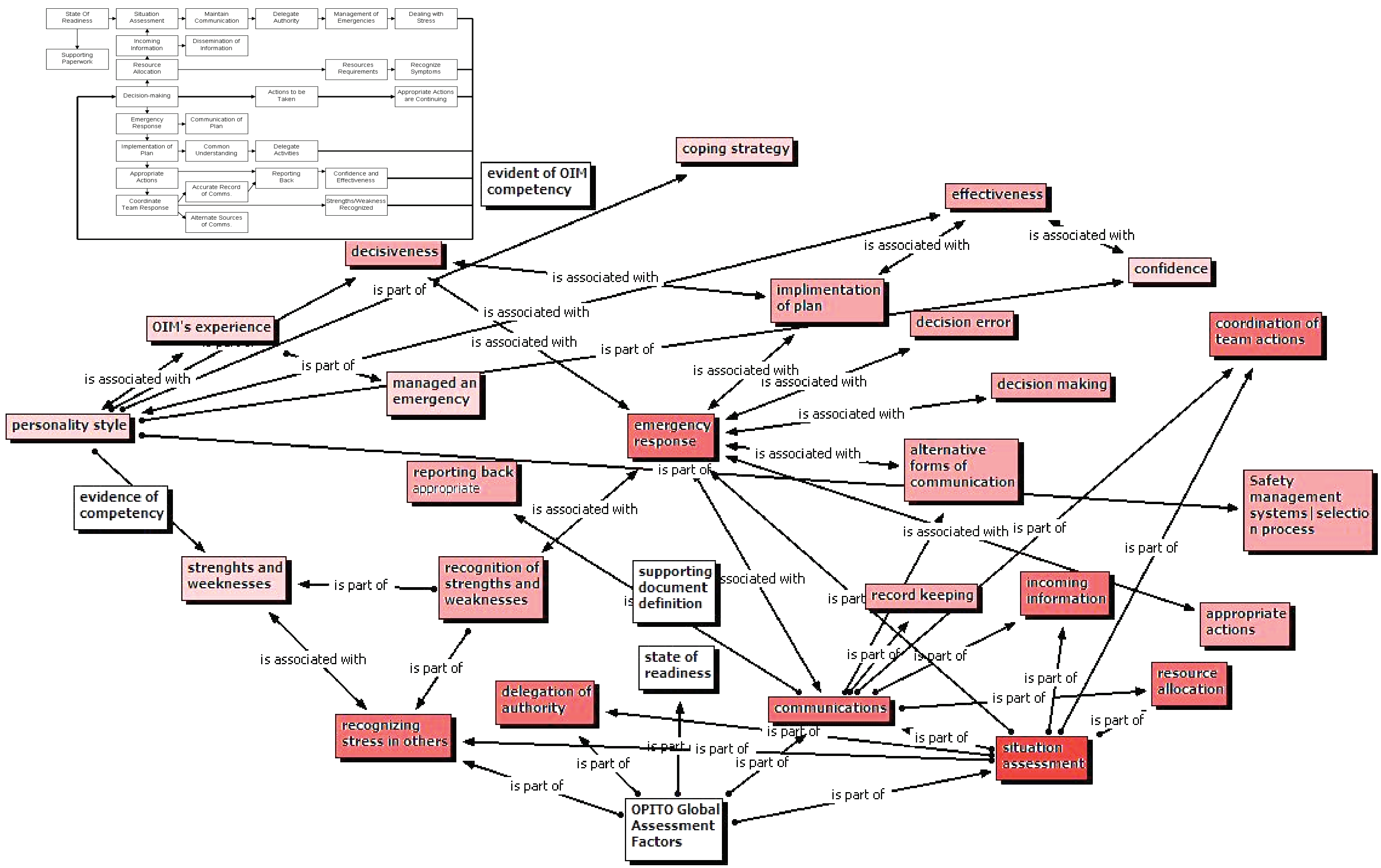

Figure 19. Situation assessment OPITO global assessment factor (from SME interview) and Figure 6 insert.

Figure 20 identifies that when asked to indicate which of the OPITO global assessment factors is most important to a successful assessment, this SME chose state of readiness (blue boxes). This particular assessment factor is similar to both “communication” and “situation assessment”; however, the global assessment factor of “supporting documentation” assumes that an OIM will perform at a basic level of competency based on previous training and experience. This SME believes that if individuals were recommended to attend an MEM/PICA course and undergo an SME evaluation, the individual would have been required to have successfully completed a certain amount of prior training and assessments that had been conducted under similarly stressful simulations. This includes an assessment of coping strategies, personality style, experience, and an agreement by industry peers that this individual is fit to complete the training.

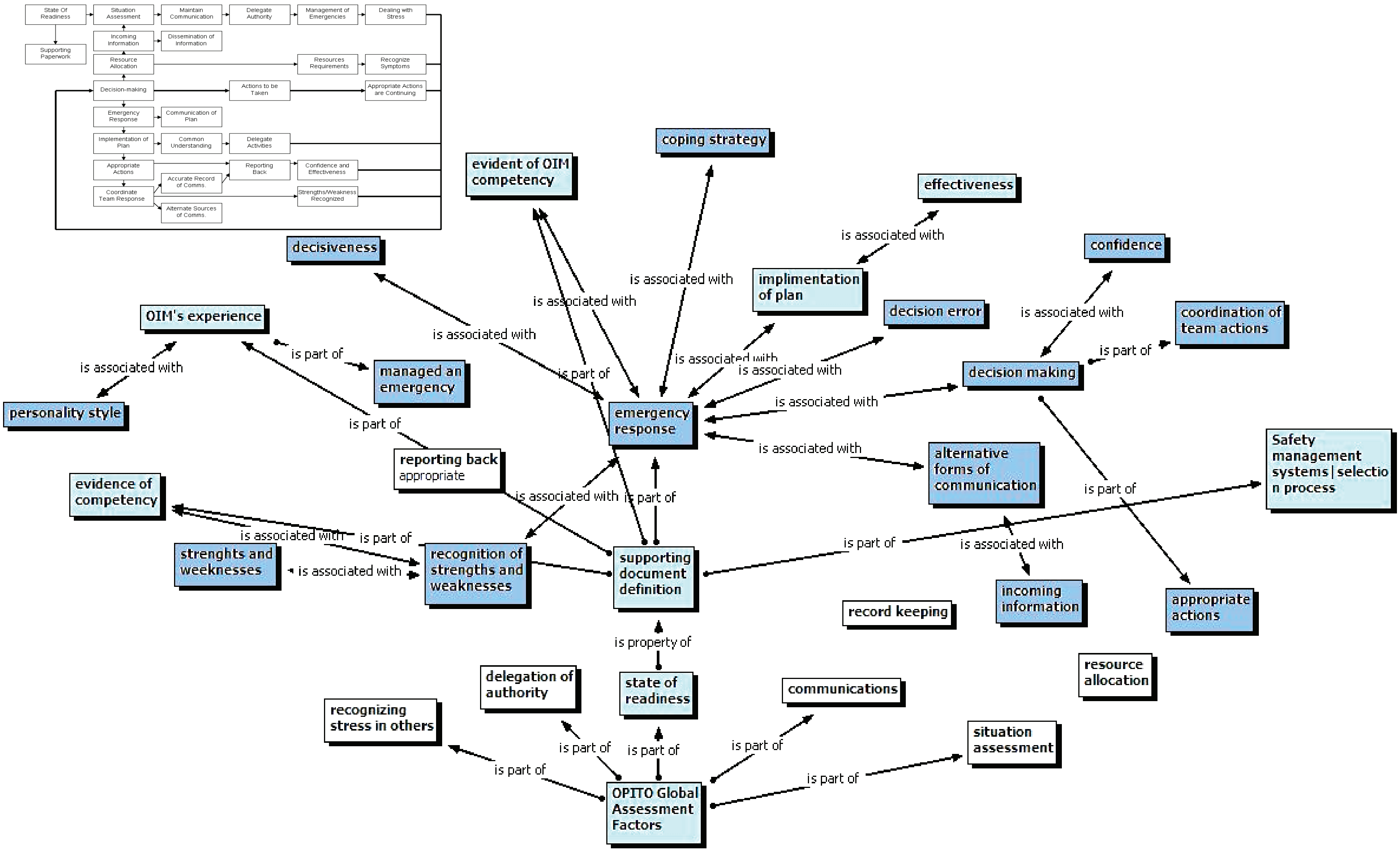

Figure 20. State of readiness OPITO global assessment factor (from SME interview) and Figure 6 insert.

The final cognitive map (Figure 21) shows the interactive nature of all six global and sub-factors used during the assessment of MEM/PICA candidates. This SME's cognitive map shows that all aspects of the assessment are important, thus suggesting that it would be impossible to separate the factors into individual levels of importance. Although this SME has suggested that all aspects of the global assessment factors are important, the figure shows the colours used in the previous SME cognitive maps to show how their selections differ. This figure also indicates that although each of the SMEs chose different global assessment factors (SME responses indicated by associated coloured boxes), their discussion of the topic overlapped considerably. For example, each of the SMEs indicated that the OIM's personality style (yellow boxes) was key to emergency management effectiveness. All SMEs suggested that if the OIM could not show confidence and decisiveness when making decisions, the ERT members and ultimately the rest of the installation crew, would find it difficult to follow orders and might not respond in a helpful manner. Additionally, all of the SMEs indicated that the MEM/PICA training is designed to expose possible weaknesses in the emergency management process, whether the weaknesses are an OIM's response style, communication, or team interactions.

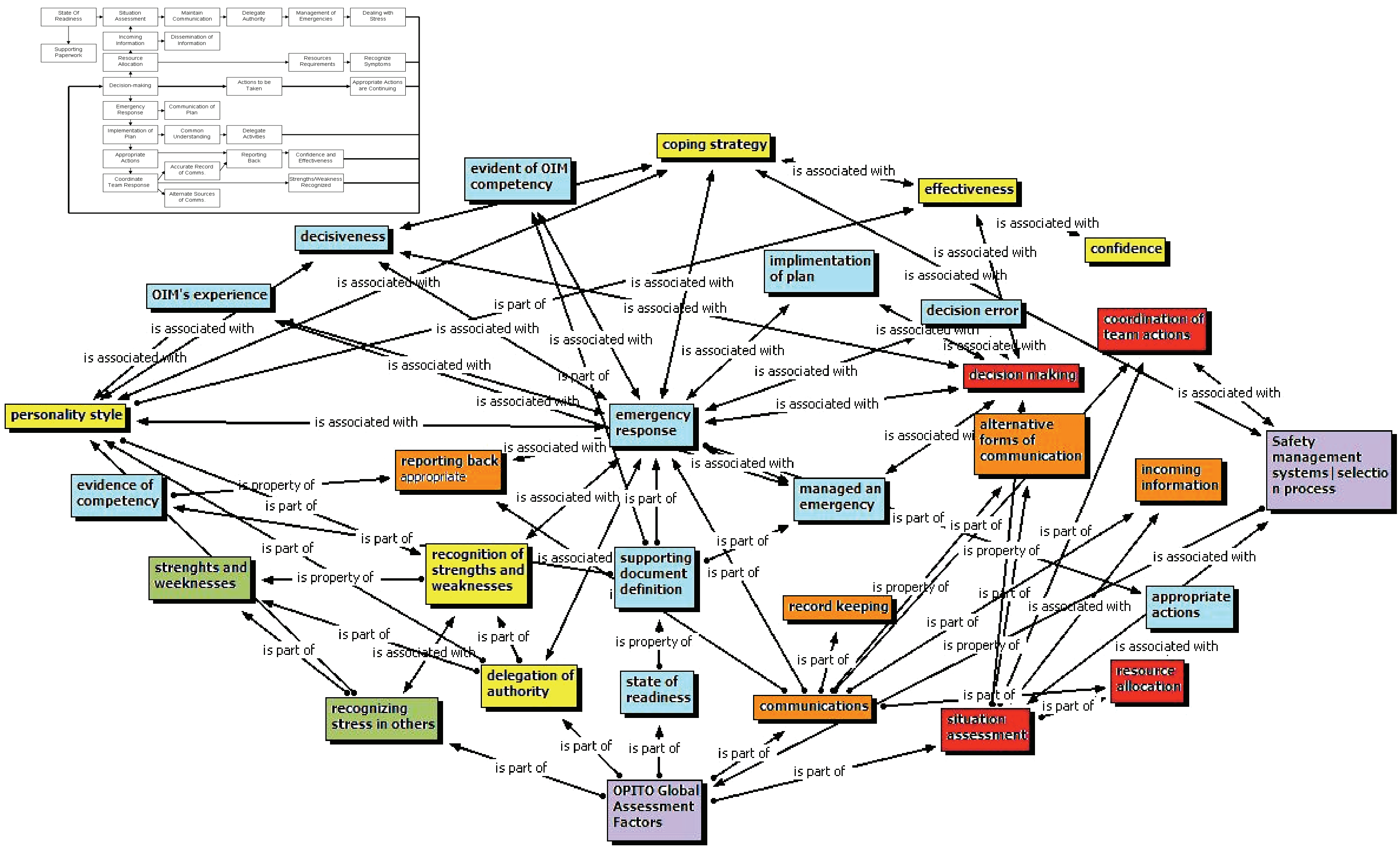

Figure 21. Interrelatedness of all OPITO global assessment factors and Figure 6 insert.

8.3 Phase 2 Results Summary

The following summary addresses each of the research questions posed during this phase.

1. To what extent do MEM/PICA subject matter expert assessors use the same criteria to evaluate OIM and ERT member emergency response performance?

Based on the SME interviews, it is clear that each assessor uses a slightly modified approach to conducting offshore emergency management evaluations. These slight differences do not appear to alter the overall assessment process, however without a standardized baseline of assessment criteria, there is currently no way to identify whether the SMEs are drifting toward or away from a better assessment process.

2. To what extent do MEM/PICA subject matter expert assessors share a common understanding and agreed upon definition of situation awareness?

The informal cognitive maps representing the SMEs' understanding of the OPITO global assessment factors clearly indicate that there is considerable overlap in the way that SMEs interpret OIM performance. The interpretation of which factors are most important to MEM/PICA performance appears to influence the SMEs' understanding of situation awareness. Each SME has a slightly different understanding of situation awareness. However, it should be pointed out that although the SMEs have had no formal training in SA, they all appeared to be able to articulate key aspects of the general concept.

8.4 Phase 2 Discussion

Based on the results of this study, it is clear that the MEM/PICA assessment process examines many factors of emergency response performance. Although the subject matter experts approach the assessment process somewhat differently when considering the OPITO global factors, they appear to have a similar view of what is necessary to gain certification. The fact that their discussion points concerning the global assessment factors overlapped to a large extent was encouraging when discussing the basic level of standardization (cognitive maps). However, when I examined the archival video simulations, it was also clear that there was considerable discrepancy in how the OIMs performed during similar emergencies. Discrepancies were seen in the use of time-outs, phone and radio communications, and public address system usage that did not appear to be reflected in the decision to grant certification. When asked about the differences in the approach to the simulated emergencies, the SMEs acknowledged that the display of incoming information and record keeping played a significant role. The SMEs further suggested that depending on the assessor's evaluation criteria (i.e., the internal checklist used to assess performance), the discrepancies in focus board use and time-outs may or may not affect the decision to grant certification.

Consistency between assessors is an important aspect of the HSI process in that personnel selection, safety and training are affected by the results of the MEM/PICA evaluations. It is worth noting that because all of the assessors have successfully completed OPITO/Cogent qualification requirements, there should be some level of baseline evaluation criteria. However, the OPITO/Cogent qualification does not appear to incorporate an auditing process for assessor performance after they have gained their certification and allows for considerable drift away from the original training requirements. Without some form of standardized procedure to check the assessment procedures it becomes difficult to judge the tolerance of the testing system (i.e., how many differences in the evaluation process will still result in a competent assessment of OIM performance). For example, the MEM/PICA course presentation process underwent significant upgrades to its simulation and recording system in 2005 (personal communication with SSTL Operation Manager – Joel Carroll); however this addition of realistic sound effects was not evaluated against the original testing scenarios to identify any benefits or changes to ERT member understanding of the situation. If additions are made to an existing program without an assessment of the impact to the training and testing, it is impossible to attribute future successes or failures to the interventions.

When considering a Human Systems Integration approach to examine the MEM/PICA assessment process, I believed that I would be focusing primarily on the SME's subjective rating of performance. However, I quickly realized after analyzing the archival video and interviewing the SMEs that I had to first establish a basic standard for presenting the incoming emergency information, as this was the only way to ensure consistency between repeated simulations. Only by standardizing one of the fundamental components used by all ERT members to create a shared understanding of the situation could there be some form of quantitative/object evaluation of MEM/PICA performance. Based on my personal experience within the emergency response domain, the first step in developing a standardized layout and design of a focus board that would be similar to those used at SSTL and many offshore installations was to identify the components that absolutely needed to be included on the focus board. By discussing these components with the individuals who would be assessing the performance of potential end users (Hall, 2001), I was able to ensure that usability aspects related to effectiveness and efficiency were addressed. In addition, by using guidelines suggested by Tesone and Goodall (2007), the emergency response focus board was designed to reduce the gap between "perception" and "explanation" (i.e., comprehension and prediction) to a manageable level (p. 68). Reducing this gap was important because it was noted during the SME interviews that rater-drift away from a standardized format may occur as a result of new experiences, and that the ERFB was designed to provide an objective measure of ERT performance.

CHAPTER NINE
PHASE 3
EMERGENCY RESPONSE FOCUS BOARD DEVELOPMENT DISCUSSION

This Phase of the thesis involved a focus group discussion with Offshore Installation Managers. The purpose of the focused discussion was to gather information regarding the OIMs' perspective of the MEM/PICA evaluation process. In addition, I used this Phase to collect data concerning what information was considered critical to emergency response and where this information should be placed on a focus board. The potential user (i.e., future OIMs) input gathered during this Phase of the thesis is considered in regard to usability design methodology and represents a baseline in the development process of the emergency response focus board (Hall, 2001; Hennigar, 2001; Mayhew, 1999).

9.1 Phase 3 Methods

Research Questions:

1. What aspects of an emergency are considered important to OIMs and what information needs to be displayed on the focus board?
2. Where on the emergency response focus board should critical information be displayed?

The research questions selected for this Phase focus on the presentation of incoming emergency information. Given that the entire ERT uses the information located on a central focus board, it is important to ensure that the display is easy to understand and facilitates decision making. By developing an understanding of what and where information should be located, this Phase represents a baseline for the ERFB design process.

9.1.1 Participants

Three experienced Offshore Installation Managers (OIMs) were recruited during Phase 3 of the research. Recruitment was accomplished by providing my contact information to one of the SMEs who then provide my contact information (email and phone number) to OIMs. Interested OIMs contacted me for further details regarding the focus group discussion. Each participant had been or was currently employed as an OIM of an offshore oil and gas installation located on the east coast of Canada. Since these individuals hold extremely important offshore emergency response positions and have had many years of experience, their opinions related to the design and implementation of a new focus board could be of great value. The OIMs' ages ranged from 40 to 55 years.

Two of the OIMs worked on offshore installation located in Nova Scotia and the third OIM works on an installation in the North Sea. The focused discussion meeting was conducted in a similar manner to that of the subject matter expert interviews, in that similar semi-structured questions (list in Appendix D) were used. However, the questions were posed in a group setting as opposed to an individual setting. The purpose of the focused discussion was to elucidate responses (e.g., knowledge and opinions) in relation to emergency management assessment processes from those individuals who have previously been assessed while completing the MEM/PICA course.

9.1.2 OIM Discussion

The main purpose of the ERFB development discussion was to identify what aspects of the emergency response information needed to be included on the focus board, as well as to identify why particular information was deemed to be important in the development of situation awareness. A secondary purpose of the discussion was to address the OIMs' opinion regarding the current assessment process and if the six OPITO factors used during the MEM/PICA performance evaluation were deemed to be valid measures of how individuals would react during a real-world emergency.

During the meeting, I encouraged the OIMs to identify where on a focus board the critical information might be located. To capture this information I recorded the OIMs' response on an audio recorder and drew boxes on a whiteboard to represent specific information. As the OIMs indicated the type and position of the critical information, I used a large whiteboard to draw out a template of what an ideal focus board configuration might look like. Once the template was outlined, the group discussed additional focus board information in a brainstorming format until a final configuration was verbally agreed on. This information, the audio recordings, and the digital photographs of the template (Figure 22) were used to ensure that I could duplicate the critical information boxes in the exact locations on the electronic version of the Emergency Response Focus Board (ERFB).

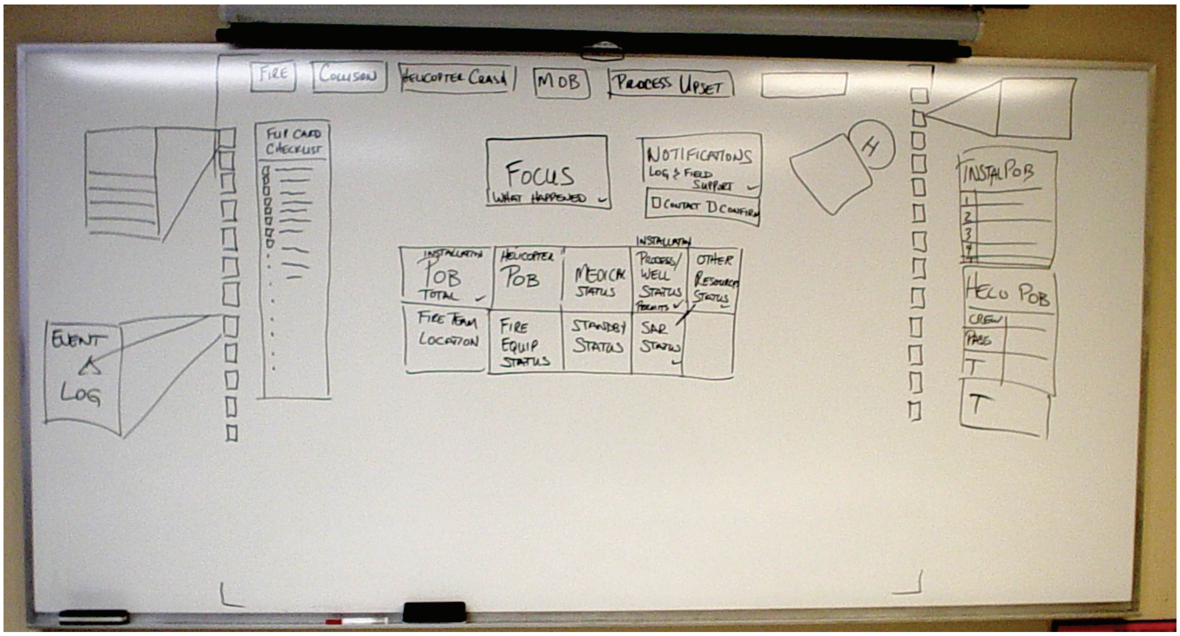

Figure 22. OIM focus discussion ERFB template.

9.1.3 Phase 3 Data Analysis

Data analysis of the focus group information was completed through a similar process to that used for the subject matter expert interviews, in that the electronic voice recordings were transcribed and coded in ATLAS.ti to identify themes relating to the assessment process. The analyses of both the expert interviews and offshore personnel focus discussion responses were then compiled to identify key aspects for assessment standardization, as well as the extent to which a situation awareness checklist could provide an objective measure of performance.

9.2 Phase 3 Results

During the ERFB focused discussion, OIMs identified the need for specific entry boxes that the entire emergency response team could quickly integrate into their understanding of the situations. Information related to the position of all installation personnel, status of any drilling operations, and focus of the emergency response were identified as being crucial to situation awareness. It was stressed, however, that the board should not be so cluttered with information that it would be difficult to understand. It was also pointed out that the ERT scribes should not have to search for information that has been buried under layers of drop-down boxes.

When discussing the possibility that external onshore emergency response teams could be given the opportunity to view, in real-time, the updated ERFB, OIMs suggested that this option should be kept to minimum. The OIMs indicated that if the external teams could view the updated board, it would be important to ensure that onshore ERT members did not constantly second-guess the actions of the installation ERT members. It was also mentioned that onshore ERT members should not be given the capability to remotely manipulate the ERFB.

During a discussion of simulation fidelity, OIMs indicated that the environmental cues of the simulation should be reflected on the EFRB. For example, it was suggested that if the simulation requires little information to be placed on the EFRB, the board should mirror this limited data by reducing the number of boxes necessary to input events. It was further suggested that a separate configurations could be used for each of the four basic emergency simulations. The OIMs also indicated that an electronic version of the emergency checklist would be of great benefit to team coordination and aid in the development of a cohesive mental map of the situation. However, when developing the electronic version of the ERFB, I found that the suggested board design became excessively complicated and believed that situation awareness would actually be reduced as a result of too much information being manipulated at any one time. This belief was grounded in the human factors design principles identified in Chapter 3 of this thesis. Figure 23 shows the ERFB as it was original designed (includes electronic checklists) with SMART Ideas® software (V 5.1.14.1). From the figure, it is clear that if too many dropdown boxes are opened at one time, they begin to obscure information located behind the opened box. Additionally, hand written text would have to be reduced in size every time it was inserted as the incoming information boxes had to be reduced to accommodate the checklist information in a sufficiently large format to be legible.

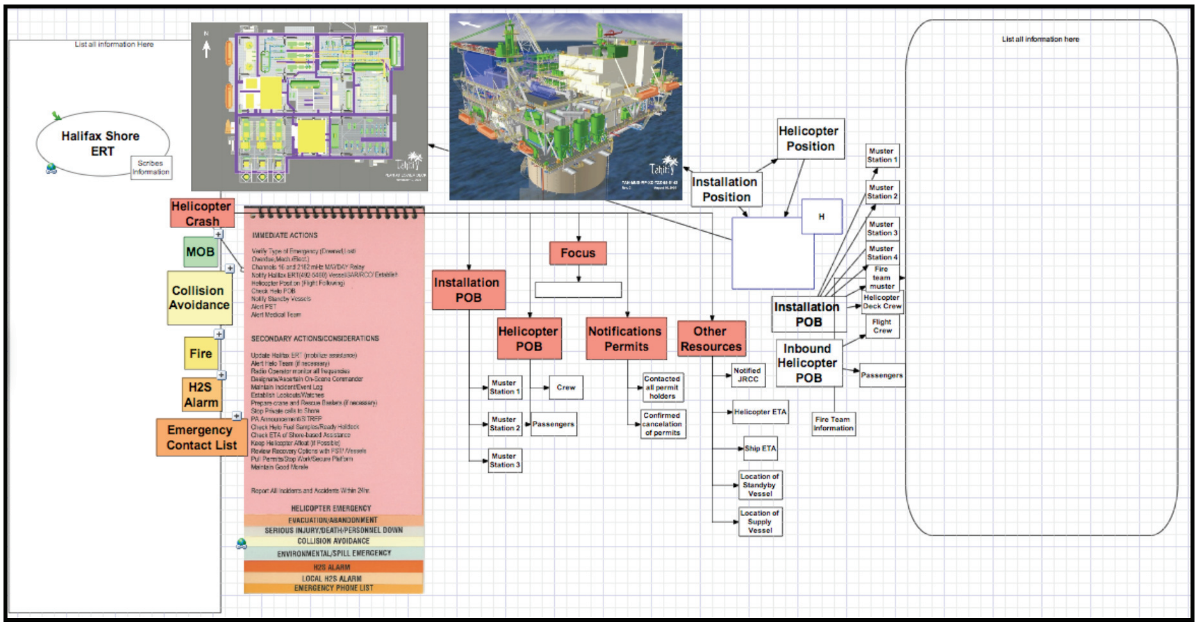

Figure 23. Original ERFB configuration containing checklist dropdowns.

9.3 Phase 3 Results Summary

As with the previous Phase, the following summary address the specific research question posed for this portion of the thesis.

1. What aspects of an emergency are considered important to OIMs and what information needs to be displayed on the focus board?

During the informal discussions with the OIMs, it was noted that the primary factor during any emergency offshore is the location and safety of all installation personnel. Every other aspect of the emergency event appeared to revolve around this single factor. It was further noted that once this information is obtained, the OIMs believe that they can manage nearly every other aspect of an emergency.

2. Where on the emergency response focus board should critical information be displayed?

Based on the initial discussion and development of the ERFB, information that was considered critical to the management of an emergency event needs to centrally located on the focus board. The information pertaining to the location of personnel, the particular type of emergency, and the scaled diagram of the installation appeared to be deemed most important, and this information was incorporated into the development of the second iteration of the ERFB.

9.4 Phase 3 Discussion

The opportunity to discuss the emergency response assessment process with end users helped establish ecological validity as well as identify the usability of the situation awareness checklist outlined in Phase 1 and 2. Furthermore, having users involved in the initial design process is one of the fundamental axioms of usability testing (Bowen & Reeves, 2009; Jasper, 2009; Tan, Liu, & Bishu, 2009). Without involving the potential users at this early stage, it is likely that I would have missed critical information and designed a focus board that was difficult to use, or made unrealistic expectations of the users, thus resulting a in product that would probably never be used as it was originally intended (Vincente, 2003).

Based on the comments made by the OIMs and two of the SMEs, the original design appeared to be too complex if time pressures existed during the emergency simulations. Furthermore, it was noted that information that is imbedded into dropdown screens was difficult to retrieve if additional information needed to be added. Based on the difficulties of the original design, I reviewed the comments made during the focus discussion and identified that it would be best to simplify the way in which scribes input information. I believed that if the focus board had representative icons for ships, helicopters, fast rescue crafts, and installation schematics, the scribe would not have to draw or write the information in a location that indicated the current understanding of the situation; they would simple move the icon when the information changed. I also assumed that if predetermined boxes were placed in a central location on the focus board, the scribes and the entire ERT would know where to look for updated changes.

However, despite the fact that I kept human factors design principles, usability, and end user requirements in mind, the original ERFB configuration design represented more of the users requests and proved difficult to use. Some of the specific difficulties with this first ERFB iteration included a requirement for the scribes to manipulate dropdown boxes in order to find information, modify all hand-written inputs into recognized text that needed to be reduced in size, and the need to scroll from side to side in order to see the entire data input surface. These shortfalls in the ERFB design arose as a result of trying to include the interactive components requested by the OIMs as well as limitations in the Smart Ideas™ software that I discovered during the development of the ERFB. Because this software was not intended to be used to create an emergency response focus board template, it is not surprising to encounter some difficulties. Therefore, after further discussion with the OIMs, it was decided that the original EFRB configuration was too complex and difficult to navigate. Based on these comments, two simpler forms of the ERFB (static and dynamic) were developed for testing in Phase 4. The two simpler versions were created using SMARTBoard Notebook software which limited the amount of input requirements for the scribes.

In addition, the original configuration condition was not used because of the need to incorporate appropriate usability standards on the amount of information presented to users and the excessive amount of time it might take individuals to locate information in a dropdown menu (International Organization for Standardization - ISO 9241-11). Clearly, information that is buried several levels in a display will be more difficult to locate than data that is visually present on the screen at all times. Furthermore, information that is not readily available may not be recalled during an emergency.

CHAPTER TEN
PHASE 4
EMERGENCY RESPONSE FOCUS BOARD NOVICE USER TESTING

The primary objective of this research Phase was to investigate the influence of different display models of the emergency response information and their effect on decision making and situation awareness. Preliminary findings from the previous Phases suggested that current ERT performance standards (both training and evaluation) lack consistency needed to predict future performance during a real-world offshore oil and gas emergency. One of the reasons for this deficiency appeared to be related to the lack of a standardized format for presenting incoming information on the focus board during emergency response simulations. It was continually noted during systematic reviews of technical documentation, subject matter expert interviews, and focused evaluation discussions with the OIMs that initial performance and subsequent assessments were inextricably linked to the performance of the ERT, which in turn was influenced by the information presented and recorded on a static display of incoming emergency information (focus board).

Therefore I propose that by standardizing the visual presentation format of the simulation data through the use of an electronic whiteboard as well as a standardized situation awareness checklist (developed in Phase 2 of this study), a reduction in subjective MEM/PICA assessment factors could be realized. I further hypothesize that differences in visual format of emergency response simulation information would influence response performance (e.g., reaction time and accuracy) and level of situation awareness (e.g., perception, comprehension, and prediction) that could be developed and maintained by the OIM and ERT members.

10.1 Phase 4 Methods

Research Questions:

1. To what extent does the visual display of emergency information affect situation awareness?

2. Does offshore experience affect the accuracy of responses made to SA cognitive probes?
3. Does the configuration of the focus board change the way in which participants answer self-rating SA questions?
4. When assessing situation awareness (using the Situation Awareness Global Assessment Technique), do individuals respond quicker when the focus board information is visually available to them than when it is blanked out?
5. Is vital response information retrieval faster on an existing focus board or a reconfigured (centralized information) emergency response focus board?
6. To what extent does the visual display affect the amount of time required to ensure the ERT has a shared understanding of the emergency?

The research questions for this Phase were used to identify aspects of SA as they relate to the two ERFB configurations. Specifically, the questions address a fundamental question of whether the presentation of the incoming emergency information affects critical performance aspects such as speed and accuracy. Moreover, the questions are designed to better understand whether individuals can gain a clear understanding of the emergency simulation without having offshore emergency response training.

10.1.1 Novice ERFB Participants

Based on the type of testing used in this Phase of the research, it was important that I recruited individuals with limited offshore emergency response training. Limited offshore experience was considered desirable as this ensures that the usability of the ERFB could be considered from the perspective of a new scribe or ERT member. I believed that if novice user can correctly answer SA questions when using the two ERFB configurations, it would reasonable to assume that experienced offshore emergency response personnel should also be able to answer similar questions. Therefore, I recruited 23 individuals attending their first Basic Survival Training (BST) course at SSTL as well as nine university students. Of the 23 BST volunteers, eight indicated that they had more than one year of offshore experience (ranged in time from 1 to 30 years), whereas the remaining 24

(15 from SSTL and 9 university students) individuals had no offshore training experience. However, as this portion of the research was used to test the newly configured electronic Emergency Response Focus Board (ERFB), there was no need for the participants to have emergency response management training and should be considered novice users. A total of 27 male and 5 female participants completed testing during this Phase and ranged in age between 19 and 54 years. Table 7 shows the demographic information for the test groups recruited for this Phase. University participants' ages ranged between 20 and 28 years, while the participants from SSTL ranged between 21 and 55 years.

Table 7. Demographic information for Phase 4 participants.

	Test Group		
Variable Mean – (SD)	Dalhousie University Students (n = 9)	SSTL Basic Survival Training Course Participants (1) (n = 15)	SSTL Basic Survival Training Course Participants (2) (n = 8)
Age	23 (3.91)	34.27 (9.43)	47.75 (6.71)
Offshore Experience (years)	0	0	7.88 (5.11)

10.1.2 Phase 4 Data Collection

Each participant was given a brief familiarization session in which the research protocol was explained in detail. The participants were encouraged to ask questions about the research design and how each of the measurements would be collected. After questions (if any) had been satisfactorily answered, participants were asked to read and sign an informed consent sheet as well as complete a demographic questionnaire (Appendix E). The familiarization training session took place in a classroom at SSTL for those individuals attending the BST course and in the general research laboratory in the Kinesiology suite at Dalhousie University for the undergraduate participants. An interactive whiteboard (SMARTBoard 680i, SMART Technologies) was positioned at the front of the room with a data entry person (scribe) positioned at the board to write down the information as it was transmitted through a pre-recorded audiotape (Figure 24). To facilitate participant understanding of the emergency response process, I instructed them on how to identify the most crucial information necessary to achieve a reasonable level of emergency response performance. The familiarization session required approximately 15 to 20 minutes to complete, depending on how quickly the individuals were able to comprehend the research instructions.

Figure 24. SMARTBoard™ 680i (77” screen) used for ERFB testing.

Given that offshore scribes do not usually receive training in how to organize the focus board information, I had intended on recruiting SSTL training staff members to perform the tasks of a scribe. However, availability of personnel was limited; therefore, I assumed the role of the scribe during the familiarization session and simulated emergency. By assuming the role of the scribe, I was able to ensure a level of consistency and that similar data was available to all participants during testing. During the training/familiarization session, participants were asked to identify (by pointing) where specific information was located on a generic version of the focus board (blank configuration of the status board used for Major Emergencies Management/Person In Charge Assessment training – MEM/PICA). In addition, they were asked to verbally respond to questions such as “how many people are currently in muster station 1" or "how many minutes until the search and rescue helicopter arrives at the installation".

In an effort to identify physiological factors associated with situation awareness, participants were asked to wear a heart rate monitor and wristwatch (Polar S810) for the duration of the testing session. The heart rate monitor was set to capture R-R (beat to beat) intervals that were used to calculate changes in heart rate variability, which is known to have an inverse relationship with increased stress and anxiety (Acharya, Joseph, Kannathal, Lim, & Suri, 2006; Gamelin, Berthoin, Bosquet, 2006; Sharpley, Kamen, Galatsis, Happel, Veivers, & Claus, 2000). A reduction in HRV has also been shown during "acute periods of mental effort" and is thought to represent autonomic modulation of heart rate (Wood, Maraj, Le, & Reyes, 2000, p. 131).

Based on the SA checklist developed in Phase 1 and the MEM/PICA subject matter experts and OIMs interviews, the critical information necessary for successful emergency response performance was determined to include the following information:

1. Number of personnel onboard an installation and their locations;
2. Relevant weather information – sea state, wind direction and intensity, and incoming weather patterns;
3. Location and status of fire team members;
4. Status and location of fire;
5. Relevant medical status of any casualties;
6. Status and location of secondary resources – supply ship, standby vessel, aircraft, and search and rescue assets;
7. Status of well or production systems;
8. Status of pertinent work permits that may influence the emergency situation;
9. Verification that external emergency response phone calls have been made;
10. Verification that incoming information is being logged; and,
11. Verification that installation personnel have received updated emergency response information.

In addition to the most relevant information, participants were also instructed to identify where this information was most likely to be entered on the emergency response focus board. For example, the left side of the board was used to record incoming information from ships and aircraft, weather and radar data, and outgoing contacts made by a radio operator. In contrast, the right side of the board was used to identify locations and status of installation personnel, such as muster station numbers, fire team complements, and medical information of any injured individuals.

After completing the familiarization session, participants were asked to complete a testing session requiring approximately 30 to 45 minutes. Each testing session consisted of a simulation of an offshore emergency (pre-recorded radio and phone inputs) in which participants were presented with incoming emergency information for a helicopter crash on deck. The participants were expected to pay attention to the incoming information in order to be able to identify key information that could be used to make appropriate decisions. The simulated emergency information was a pre-recorded audio file to ensure that all incoming information was standardized for each participant.

Figure 25 identifies the position of the scribe, researcher, and participant. The figure also identifies the location of the audio recorder, Polar watch (HRV data collection), speakers, and MacBook used to play the pre-recorded simulation. The participant was positioned 1.24 meters away from the SMARTboard to simulate the approximate position of an OIM during an emergency response simulation.

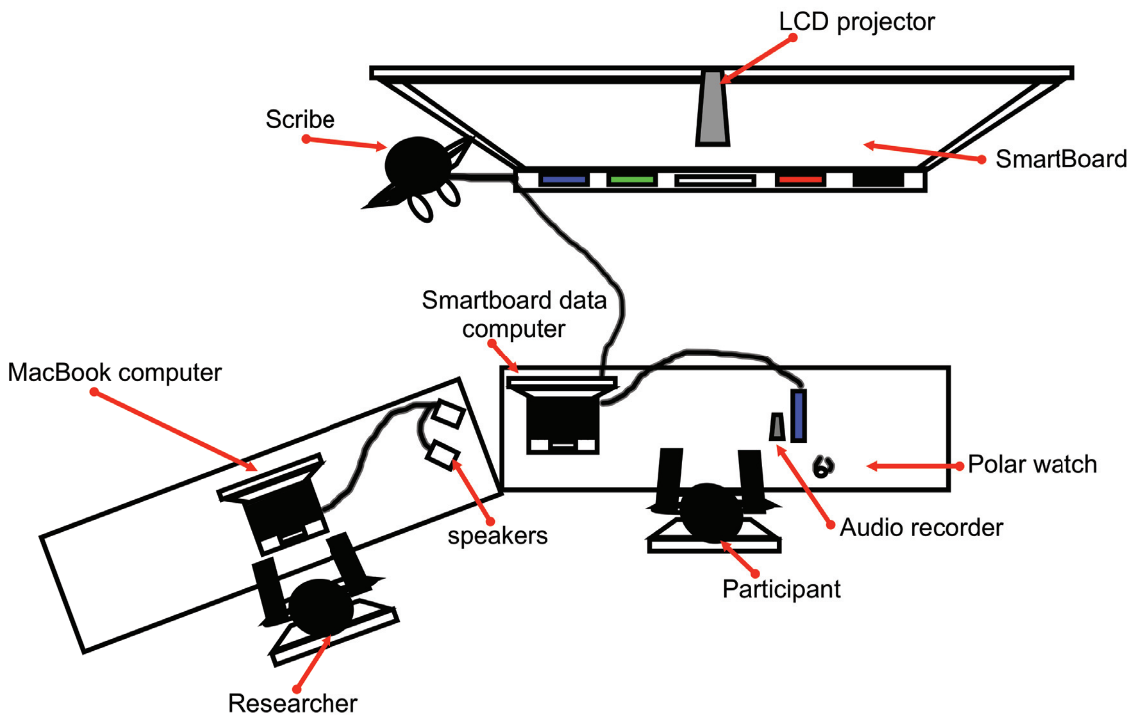

Figure 25. Experimental setup of ERFB novice testing at SSTL.

As in the familiarization session, I assumed the role of the scribe and transcribed information into the appropriate spaces as it was made available from the recording played as an audio file on the SMARTBoard 680i. The recording simulated radio calls and phone messages related to the crucial information listed above, as well as information necessary for development of a mental model of the situation. For example, when the helicopter crash on deck simulation was selected for data collection, I believe that it was important for the participants to hear the incoming radio transmission from the helicopter pilot and standby ship's captain, as well as relevant discussions from fire team members (i.e., team members are positioning themselves near the helideck), in order to develop a mental image of the preliminary events.

Furthermore, the helicopter crash on deck scenario was selected from the four possible simulations because it requires the OIM and ERT members to be aware of and use multiple external resources. External resources such as a standby vessel, supply vessel, or search and rescue ships and aircraft needed to be deployed to various positions around the offshore installation at different stages of the simulation in order to successfully complete the assessment criteria. Because this process includes an element of learning how and when to move these resources it was believed that in order to eliminate the influence of learning, each participant completed only one simulation testing session.

I informed the participants that although ERT members communicate with one another on a regular basis throughout normal MEM/PICA assessment procedures, this interaction (discussion of incoming information) would be minimal during the simulation procedures to ensure that I would not influence their SA responses. If excessive interaction did occur (participant asked several questions related to incoming information), it was noted on a data collection sheet. Throughout the simulation, participants were expected to watch the ERFB configuration as well as listen for and identify incoming radio and phone information to provide a basis to make decisions, such as whether a fire team should be sent to a particular area or whether it would be best to call for an abandonment of all personnel. As the participants were considered novices, decisions related to the helicopter crash on deck simulation were considered in the context of the incoming information; therefore, participants were given an opportunity to qualify their responses to the SA cognitive probes in a post-simulation debrief. All comments were recorded on a data collection sheet and for the purposes of this thesis; SA is defined by the accuracy of participant responses to cognitive probes.

Although novice offshore oil and gas personnel were not expected to detail their understanding of the situation to an emergency response team, time-out sessions (typically less than two minutes in length) were used to gather situation awareness data during the testing session. During each simulation freeze, I stopped the emergency audio recording to ensure that sufficient time was available to answer the SA questions posed to the novice participants. That is, when the OIM in the audio recording finished updating his understanding of the situation and all of the ERT members had added their relevant information to the discussion, I would pause the emergency audio recording and begin asking the participant to answer the query to the best of their ability. Therefore, during each of the testing sessions, participants were asked a series of relevant SA questions during simulation freezes. In some of the frozen simulation sessions (time-out), the ERFB screen blanked out the information on the screen, while in other time-outs, the screen remained visible throughout the SA question period. Simulation SA reaction time (time to initial response and total time to respond) and answers to at least five of the questions in Table 8 were collected. In addition, at least one of the questions from each level of SA was posed during the time-out period.

Table 8. Situation awareness questions and corresponding level.

Situation Awareness Checklist Question	SA Level
How many minutes will it be before the incoming transport helicopter arrives at the installation?	1
How many people are currently in muster station 1, 2, 3, etc…?	1
How many firefighters from team 1 or team 2 are assembled at the helideck?	1
How many people (crew and passengers) were on the incoming transport helicopter?	1
Is the missing person from the installation, the helicopter or the standby/supply vessel?	2
How many casualties are currently in sickbay?	1
Has JRCC (Joint Rescue Coordination Center) been notified?	1
Where is the standby vessel currently located?	1
Where (how close to your position) will the contact (incoming vessel) be in 10 minutes?	2
If you decide to evacuate personnel, what direction should the lifeboat travel toward?	2
What is the current muster total?	1
How long before the fire is under control?	3
Has the shore based operations team been notified?	1
What external resources have been deployed from shore?	1
What is the current status of the well?	2
How will the weather affect the situation in 1 hour?	3
Have the installation personnel being informed of the situation?	1
Has the general alarm been sounded?	1
What evacuation method would you use if you had 2 hours to move everyone? (e.g., jump into water, lifeboat, helicopter, ship)	3
Has the captain of the standby vessel been informed of the situation?	1
What is the position of the supply vessel?	1
Where is the fast rescue craft located right now?	1
Have all of the permits (permit-to-work) been closed?	1
When was the last update given to the muster stations?	1
How will the arrival of the medivac helicopter change the situation?	3
Where is the medic located right now?	1
How many people have been rescued from the helicopter?	1
Did anyone fall over the side of the rig?	1
What is the medical status of the rescued casualties?	1
Is any information missing from the focus board?	2

The SA questions contained in Table 8 were developed as a means of evaluating an individual's level of awareness during the time-out sessions. Responses were audio taped on a separate voice recorder to ensure that reaction times (RT) could be assessed. Participants were also asked to rate their own situation awareness (Appendix G) of relevant information at the end of the testing session as well as respond to usability questions (Appendix H) that were designed to identify possible deficiencies in effectiveness, efficiency, and satisfaction for each configuration.

10.1.3 ERFB Configuration Data

Based on the decision to use a less complicated ERFB design than the original one designed in Phase 3, participants were randomly assigned to one of two focus board configuration conditions that utilized aspects of the basic non-standardized focus board used during a typical MEM/PICA course. A control condition, which was termed "static" to reflect the fact that incoming emergency information was not easily moved from one position on the whiteboard to another, and an interactive condition, termed "dynamic" to reflect the capability to easily move icons from position to another. The control condition involved using the focus board in a configuration that resembles the current MEM/PICA whiteboard (Figure 26) and was configured as a blank whiteboard with several boxes outlined by black lines. The only difference between the whiteboard used during an MEM/PICA course and the control condition board was the use of the SMARTBoard system, which incorporate electronic markers. During both conditions, participants viewed the whiteboard in a similar manner to that of the Offshore Installation Managers currently working in the offshore environment. That is, participants were considered to be in the OIM position in that they only observe the input of data on the whiteboard and then answered questions related to available information. The control condition display (as with all other iterations) was developed with SMART Notebook software (V10.0.346.2) and displayed on the SMARTBoard 680i.

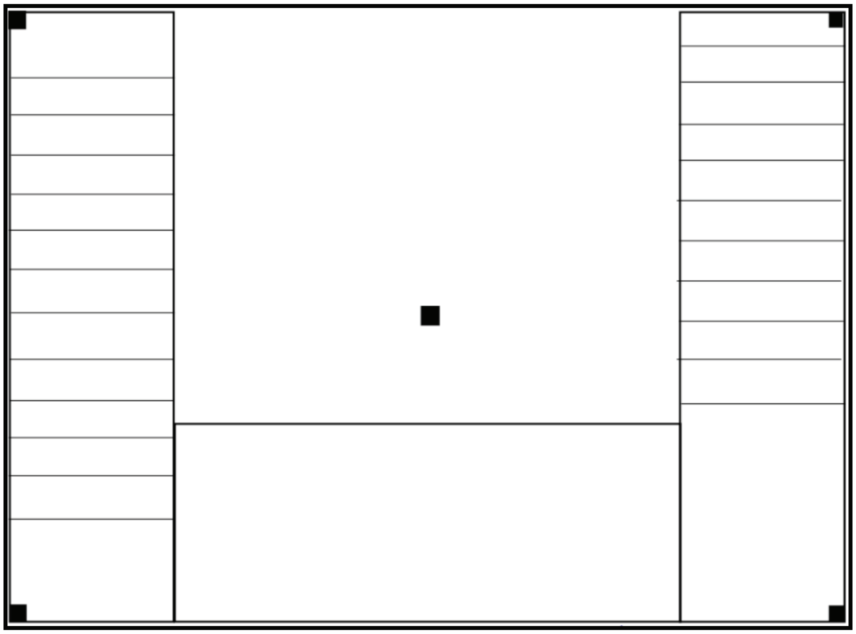

Figure 26. Static condition (SC) ERFB display configuration.

The dynamic condition (DC) was designed to utilize the electronic aspect of the SMARTBoard 680i (Figure 27) and included a combination of the original MEM/PICA configuration and central boxes containing key information related to external resources, weather and radar data, and internal muster station information. The term “dynamic” was used in order to identify the interactive nature of this configuration, which allowed users to interact with any object displayed on the screen whether it is written or typed text, a drawn shape or one that has been created in the software dropdown menus, or an inserted object from another file. The SMARTBoard Notebook software also allows individuals to increase, decrease, rotate, and/or change the colour and other properties of the selected object. Therefore, this second condition allows for change or movement of the hand-written and drawn information displayed on the ERFB by using the appropriate input selections. The dynamic condition was designed to examine the use of movable icons and text as it relates to information gathering and situation awareness in comparison to the standard hand-written format currently utilized during emergency response training, assessment of offshore teams.

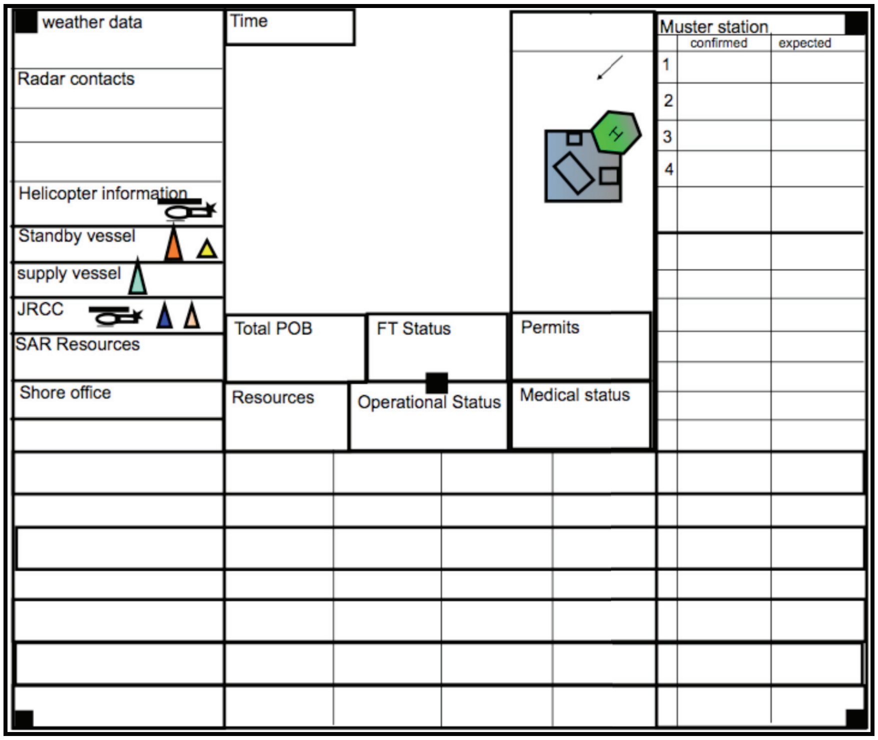

Figure 27. Dynamic condition (DC) ERFB display configuration.

The SMARTBoard system incorporates a save feature so that an event log can be stored on a local or area network. During the ERFB testing I saved each of the participants' board configurations to a 1 terabyte external hard drive at the end of the emergency simulation. I also saved a real-time video of each simulation, which was then used to identify the accuracy of the participant's SA questions. In order to ensure that both the audio recording and the board configuration video were recorded with a similar time stamp, I synchronized the computer connected to the SMARTBoard as well as the MacBook laptop computer.

10.1.4 SA Self-rating Data

In addition to the SA questions posed during the time-out periods, self-rating SA scores of confidence and true/false response were collected through the Qualitative Assessment of Situation Awareness (QUASA) questionnaire (Appendix G). The QUASA utilizes signal detection theory (SDT) techniques to assess actual versus perceived SA and to generate measures of sensitivity (d′) and response bias (β) (McGuinness, 2004, 2007). SDT is the relationship between a signal and the amount of noise in a particular environment (Tanner, & Swets, 1954) and for the purposes of this thesis is related to making a decision of whether specific information is present on the ERFB at a given time. Sensitivity (d′) can be defined as the difference or separation between the means of a signal and noise within a system. For example, if the ERFB system was designed in such a way that identifying the position of a lifeboat (signal) becomes increasingly difficult as more standby vessels (noise) are added to the visual display, sensitivity would decrease as each new vessel is added. A response bias (β) can be thought of as the tendency of an individual to respond in a certain way depending on the consequences of the response. If, for example, the consequence of missing a particular piece of information located on the ERFB resulted in an increased potential of injury or death to installation personnel, the OIM's tendency (bias) would be to focus a majority of his or her attention to that particular area of the ERFB. The true positive rate of hits (sensitivity – *d′*) and the true negative rate of correct rejections (specificity) were estimated by the following equations:

$$\text{Sensitivity } d' = (\text{Hits} + \text{False Alarms}) / \text{Hits}$$

$$\text{Specificity} = (\text{Miss} + \text{Correct Rejections}) / \text{Correct Rejections}$$

Both the true/false assessment of a statement, as well as the confidence (low/high) that the selection is correct were considered binary decisions. The following equations identify how a hit, false alarm, miss and correct rejection were calculated:

- **Hit** = correct response to SA self-rating question + correct level of confidence
- **False Alarm** = incorrect response + correct level of confidence
- **Miss** = correct response + incorrect level of confidence
- **Correct Rejection** = incorrect response + incorrect level of confidence

Figure 28 shows the SDT matrix that was used to identify the participants' response confidence judgments related to the true/false questions located on the SA self-rating questionnaire (Appendix G). Type 1 decisions are related to the state of the world and represent a signal (correct) and noise (incorrect) in the environment (Figure 28). Type 2 decisions are related to an individual's perceived understanding of the state of the world and their response to whether a signal exists.

		Type 2 decision about Type 1	
		"Correct"	"Incorrect"
State of Type 1 decision	Correct	HIT	MISS (error)
	Incorrect	FALSE ALARM (error)	CORRECT REJECTION

Figure 28. Possible outcomes for response confidence (metacognitive) judgments of true/false assessments (from McGuinness, 2004).

Figure 29 shows an overview of the data collection process. Each step in the process allowed time for participants to ask questions including the time-out sessions. If I believed that the questions would influence the individual's situation awareness, I indicated that I would answer it at the end of the next audio clip. This was done to allow time for the scenario to play out and build the situation rather than providing all of the answers at the beginning. The simulation audiotape was 30 minutes in length and Figure 29 clearly indicates the point at which the recording was started and stopped.

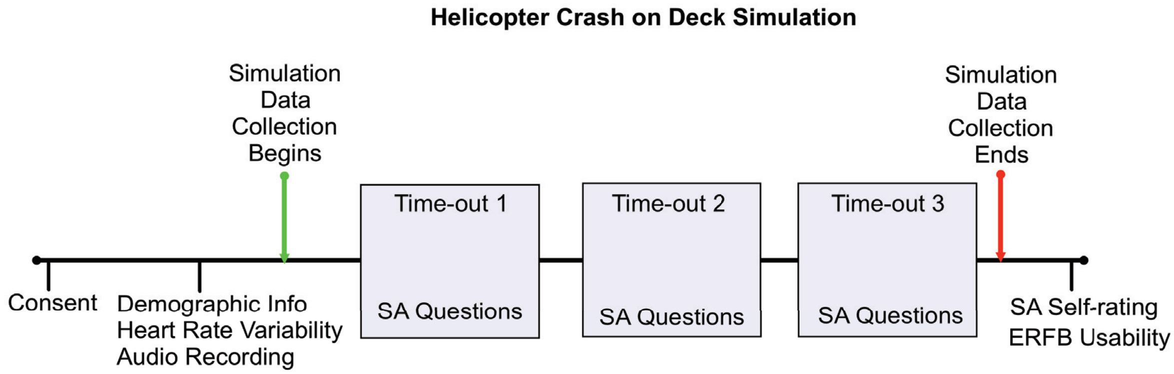

Figure 29. ERFB Phase 4 (novice) data collection process.

10.2 Phase 4 Results

Responses to the demographic information sheet were examined for differences in participant groups. As mentioned previously eight of the individuals attending a Basic Survival Training Course at SSTL indicated that they had some offshore experience. In order to explore this difference in past experiences, responses related specifically to emergency response were compared with Chi-square analyses. Results indicate that individuals who have some offshore experience are significantly more likely to have been in a leadership role during an emergency, which may have influenced the way in which they approach the emergency simulation (X^2 = 9.717, df = 1, p = .002) (Table 9). As this difference may be important in the overall design of the ERFB, experience is considered in each of the following sections. No other differences between the groups were found to be significant.

Table 9. Percentage of participants who have had leadership roles during an emergency based on offshore experience.

		Offshore Experience	
Demographic Information	Response	No Experience (< 1 year)	Some Experience (> 1 year)
Leadership role during an emergency (%)	No	18 (75)	1 (12.5)
	Yes	6 (25)	7 (87.5)
Total		24	8

During the simulated helicopter crash on deck emergency ERFB testing, participants were asked to respond to SA cognitive probe questions during three separate time-out sessions (Appendix F). A total of 788 probes were posed during the testing of the two different ERFB board configurations. In order to explore the different aspects of emergency response performance, the results for this Phase of the research have been separated into to three distinct components. The first component address usability of the ERFB configuration type with regard to the effectiveness, efficiency, satisfaction of the display. The second component explores the accuracy and reaction time associated with the two different configurations. This second component also reports the influence of the ERFB configuration as it relates to heart rate and heart rate variability. The third and final component of the results section details the response to the SA self-rating questionnaire as well as the sensitivity/specificity of the board design by examining the ROC (receiver operating characteristic) curve.

10.3 ERFB Usability

Usability testing of the ERFB configurations included aspects of effectiveness, efficiency, and satisfaction as well as observational and audio analysis. The control condition (static) ERFB replicated the blank whiteboard and Figure 30 shows a randomly selected static board after the emergency response simulation had been completed. The figure shows that the information identified as being crucial during the focused discussions (Phase 3 testing) was captured in the display. That is, the time of the incident onset, the type of emergency, muster station information, the focus of the ERT, weather data, operational status, medical status, and fire team status. The decision to use colour-coded information was based on initial pilot testing of the ERFB prototypes.

After completing the simulated emergency with the ERFB, participants were asked to complete a usability questionnaire that was used to identify effectiveness, efficiency, and satisfaction related to the display. Based on comments completed on the questionnaire (Appendix H), a total of 4 out of the 13 (30.8%) participants tested on static configuration indicated that the colour system helped when trying to create a mental model from the audio recording of the simulated helicopter crash in deck information. The usability questionnaire results indicated that 3 of the 13 (23.1%) participants recommended that larger spaces for information should be used to track external resources and movement of assets. Finally, from the usability questionnaire it was noted that 1 of the 13 (.7%) participants suggested that there should be labels to indicate each of the categories of information represented in the separate boxes.

Despite the minimal usability issues noted by participants, 11 of the 13 participants (84.6%) indicated that they could easily find the information they were looking for on the STATIC configuration. This result suggests that the static configuration was efficient for displaying the necessary emergency simulation information. As evidence of the configuration effectiveness, the participants' mean rating of the static display was 8.23 out of a possible 10 in regard to keeping them up to date during the simulation. In addition, the participants' mean rating of satisfaction of the static configuration was 7.77 out of 10.

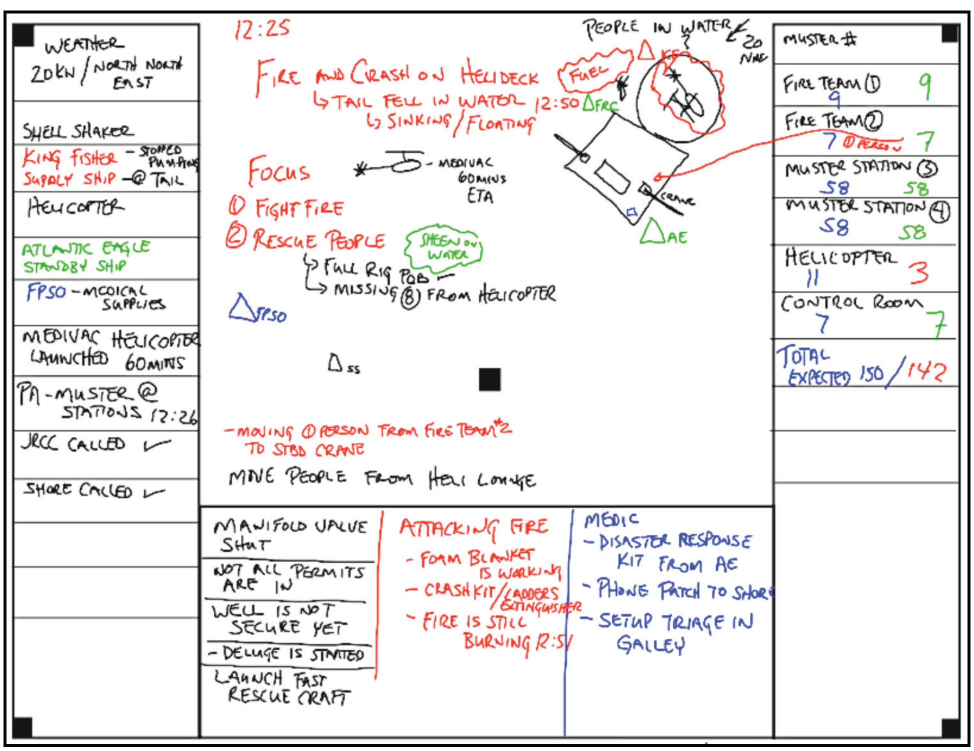

Figure 30. Static condition (SC) ERFB configuration after completion of simulated helicopter crash on deck (randomly selected display).

The other configuration (dynamic) used in Phase 4 testing included interactive (movable) icons that could be placed and moved anywhere on the installation diagram, based on incoming emergency information. Figure 31 shows a randomly selected dynamic configuration after the helicopter crash on deck simulation testing had been completed. Responses to the usability questionnaire (Appendix H) identified that a total of 2 of 19 (10.5%) participants indicated that they would like to see the list of external resources and fire team status to be better organized. A total 4 of 19 (21.1%) suggested that larger fields should be used to input incoming information. Five of the 19 (26.3%) believed that additional boxes are necessary for incoming information such as exterior temperatures, additional resources and well control. Additional comments suggested that the medivac helicopter should be shown in the direction that it is flying and that areas of key information (Total POB, FT Status, Permits, Operational Status, and Medical Status) located in the middle of the ERFB should be highlighted somehow to indicated importance.

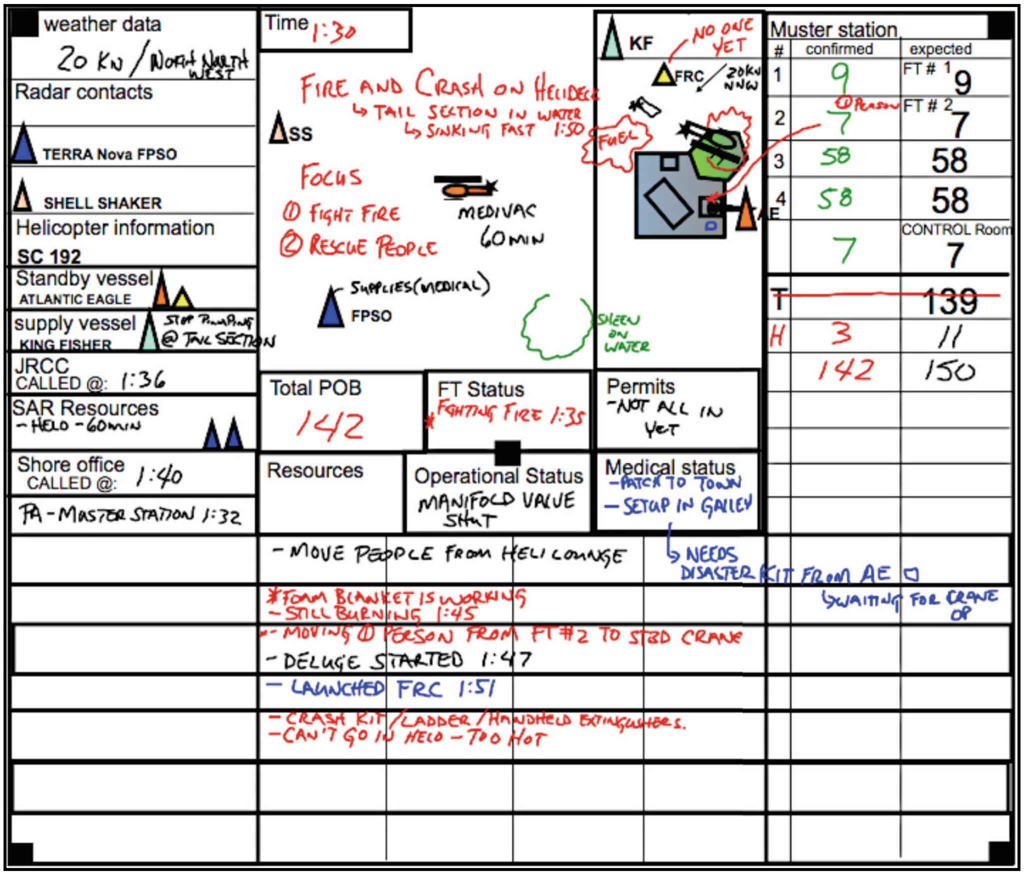

Figure 31. Dynamic condition (DC) ERFB condition after completion of simulated helicopter crash on deck (randomly selected display).

The 19 participants who were tested while using the dynamic ERFB indicated that the average overall effectiveness of keeping them up to date was rated as 8.32 out of a possible 10, which was similar to the limitations indicated by participants using the static ERFB. Satisfaction ratings for dynamic were also rated highly with an average of 8.29 out of a possible 10. Finally, all 19 (100%) participants indicated that they could easily find the information they were looking for on the dynamic ERFB configuration.

A comparison of Figure 30 and 31 reveals that the final displays for both configurations are similar in the amount of information and location of icons near the installation. However, Figure 31 shows that the icons and pre-identified information boxes reduced the amount of writing that needs to be entered. In addition, all of the icons used for dynamic configuration were duplicated in the external resource column (left side of ERFB) and can be used as a visual reference during time-out SA questioning.

10.4 Accuracy and Speed of Response Based on Configuration Type

This results section presents findings associated with accuracy and speed of response. Specifically, accuracy and speed of response were measured to determine the impact of: 1) the configuration type (e.g., static or dynamic); 2) the position (up or down) of the ERFB screen during SA questioning; 3) the level of SA question (e.g., perception, comprehension, and prediction); and, 4) when the time-out session occurred during the simulated emergency. These findings are also considered within the context of offshore experience.

10.4.1 Accuracy

In order to explore accuracy of response based on configuration type and SA question technique (i.e., was the ERFB information available or not), a 2 x 2 Analysis of Variance (ANOVA) was performed for configuration type and screen position. The ANOVA results indicate that there were significant main effects for both the configuration type and the ERFB screen position ($F(1, 745) = 7.396$, $p = .007$ and $F(1, 745) = 26.776$, $p < .001$ respectively). Figure 32 clearly shows that accuracy was greatest when using the dynamic ERFB configuration and when the display information was available.

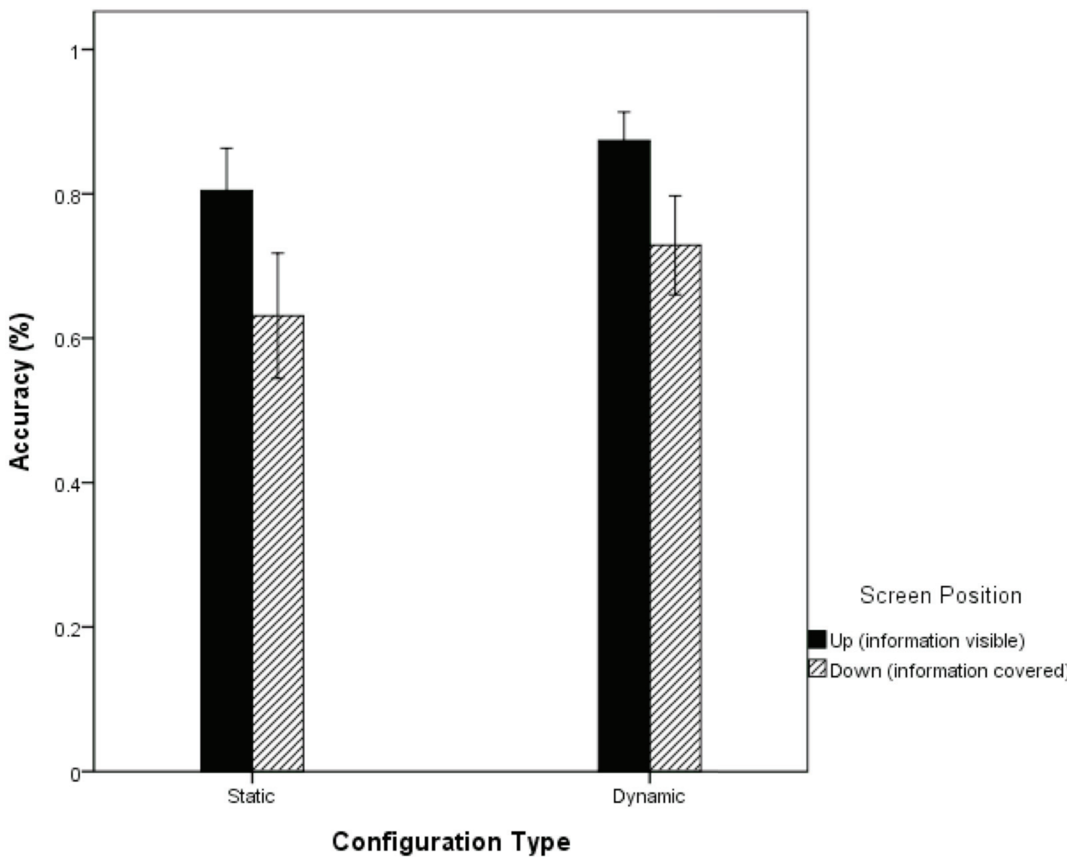

Figure 32. Accuracy of response based on ERFB configuration type and availability of information (position of screen). **Note:** error bars represent 95% confidence interval.

Accuracy was also examined in regard to configuration type and level of SA question. A 2 (SA probe level) x 2 (configuration type) ANOVA revealed that there is a significant interaction (F (2, 745) = 3.832, p = 022) between the type of SA question and which type of configuration is used to display incoming emergency response information. Figure 33 shows that accuracy was higher for all three levels of SA when using the dynamic display and that responses to *level 3* SA questions are significantly lower than for *level 1* or *2* SA.

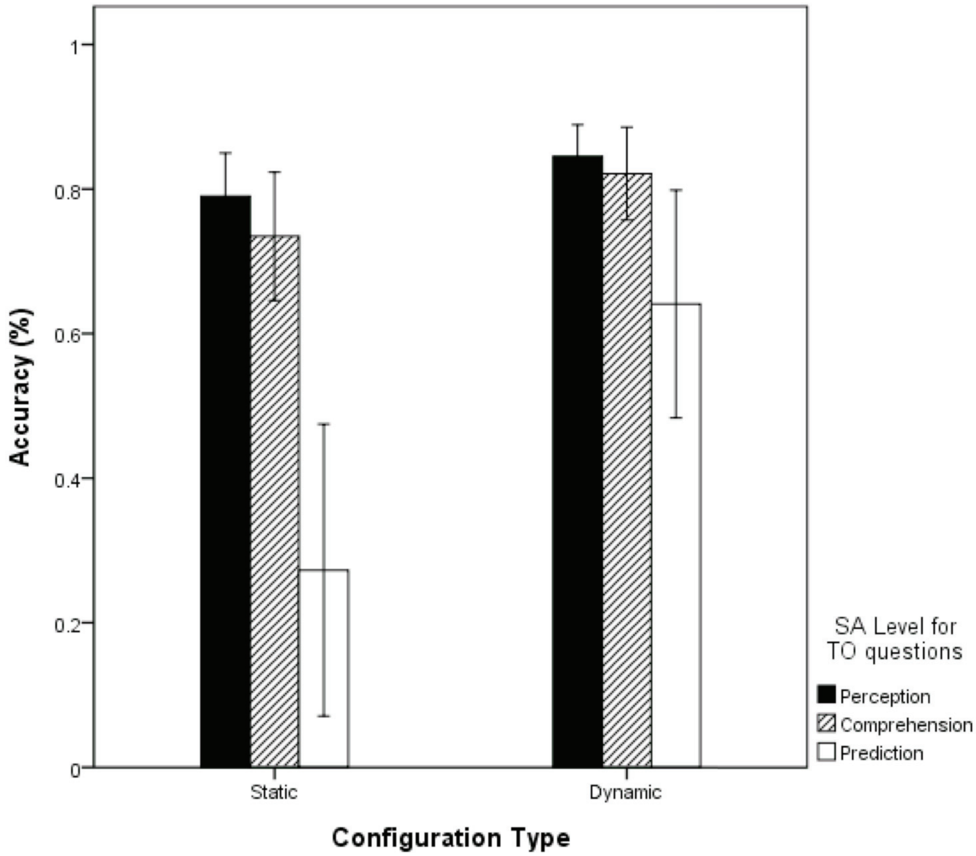

Figure 33. Influence of SA level and ERFB configuration type on accuracy. **Note:** error bars represent 95% confidence interval.

In order to examine the influence of ERFB configuration type and time that SA questions were posed (i.e., time-out session), a 2 x 2 ANOVA was conducted. The results indicate that significant main effect exist for both the configuration type (F (1, 744) = 7.779, p = .005) and the point in the simulation that the SA questions were posed (F (2, 744) = 8.377, p < .001). Figure 34 shows that accuracy is greatest during time-out 3 and that the dynamic display has greater overall accuracy than the static display.

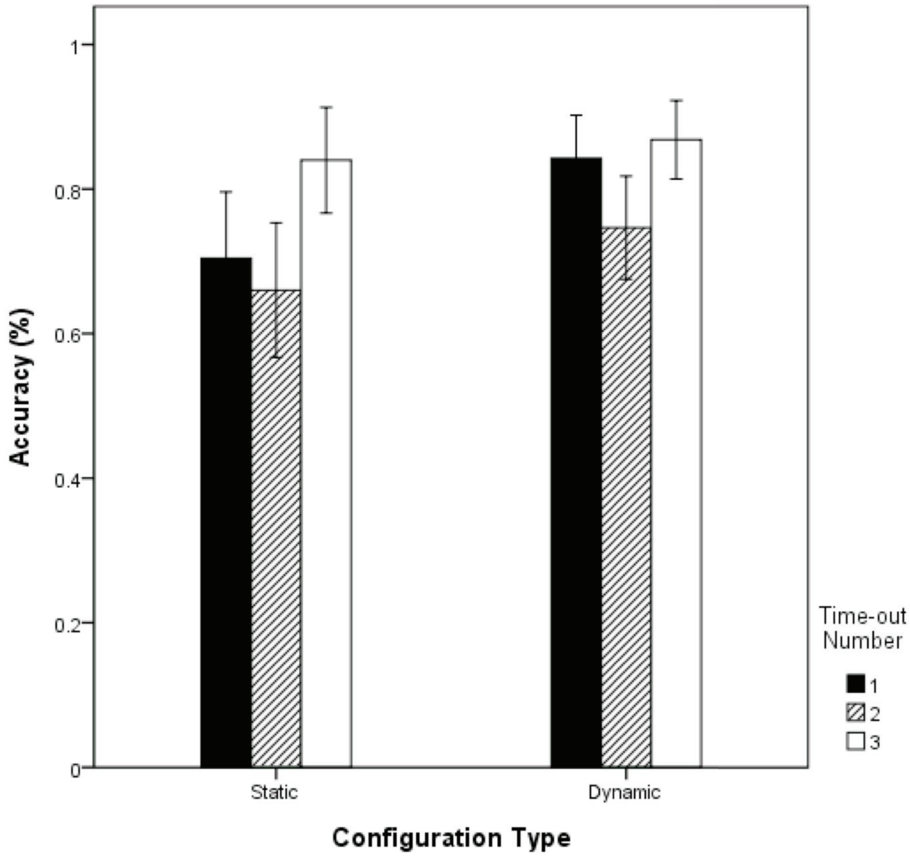

Figure 34. Influence of ERFB configuration type and time-out session on accuracy. **Note:** error bars represent 95% confidence interval.

Accuracy of response was further examined as it related to the time-out session in which the SA probe was posed as well as the level of SA question. A 2 (SA probe level) x 2 (screen position) ANOVA reveals that a significant interaction (F (4, 744) = 2.569, *p* = .037) occurred between the type of SA question and whether the display information was available during the questioning session. Figure 35 shows that accuracy values were higher for *level 1* and *level 2* SA questions when compared to *level 3* SA and that both comprehension and prediction SA increased during the last time-out session.

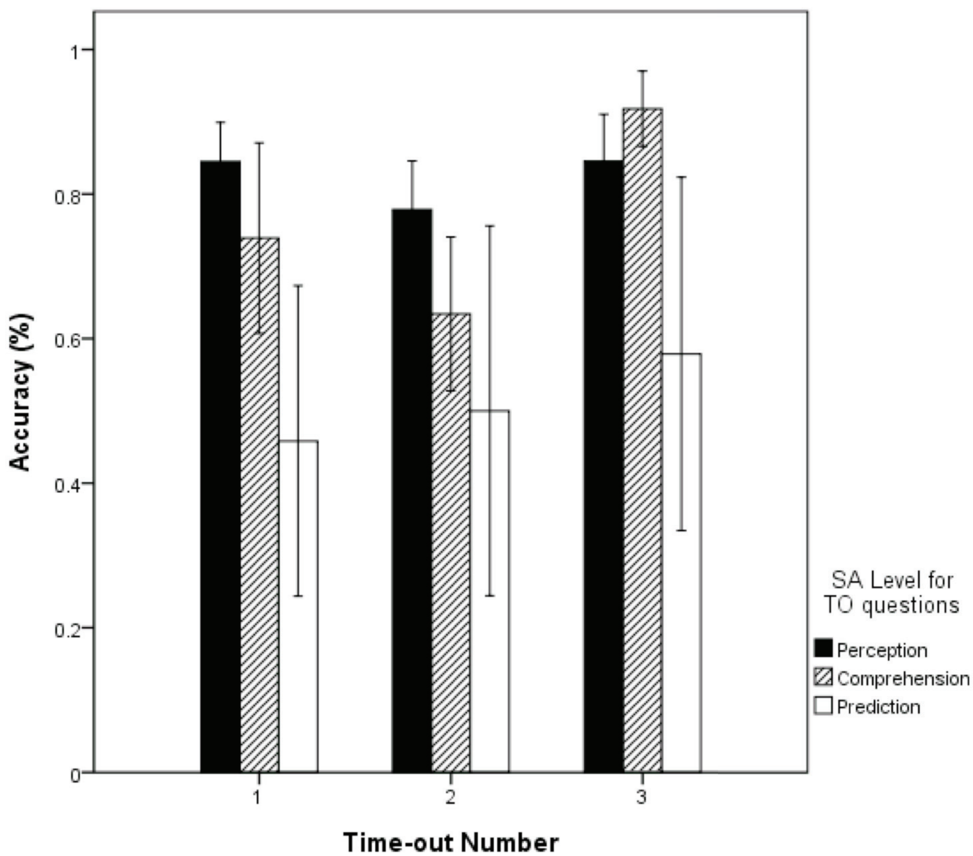

Figure 35. Influence of SA level and time-out number on accuracy. **Note:** error bars represent 95% confidence interval.

<u>*10.4.2 Speed of Response*</u>

Speed of response was examined for initial time to respond as well as the total time to respond. Initial time to respond represents the ability to begin an answer to a posed SA question and was measured from the moment that the question was completed until the point at which an answer was started. The total time to respond represents the amount of time individuals take to complete their answers and was measure from the moment that the response began until the end of the response.

Figure 36 shows the influence on time related to screen position and configuration type. The figure clearly shows that configuration type and screen position have some influence on the time it takes an individual to respond to situation awareness queries. As SAGAT uses a blanked out screen (screen down in this case), assessing SA based on reaction time it would appear that time was affected by screen position. A 2 (screen position) x 2 (configuration type) ANOVA revealed that configuration type differed significantly in the amount of time it took individuals to begin their response to the SA questions. The results show that if the participants were viewing a dynamic ERFB configuration (movable icons) with the screen in the up position, they were significantly faster to respond to the SA cognitive probes ($F(1, 788) = 4.337$, $p = .038$). Based on the similarity of response times when using the static display, it can be assumed that the information located on the display is not the most important factor when answering SA questions. However, the availability of information located on the dynamic configuration appears to have allowed for rapid confirmation of information believed to be correct.

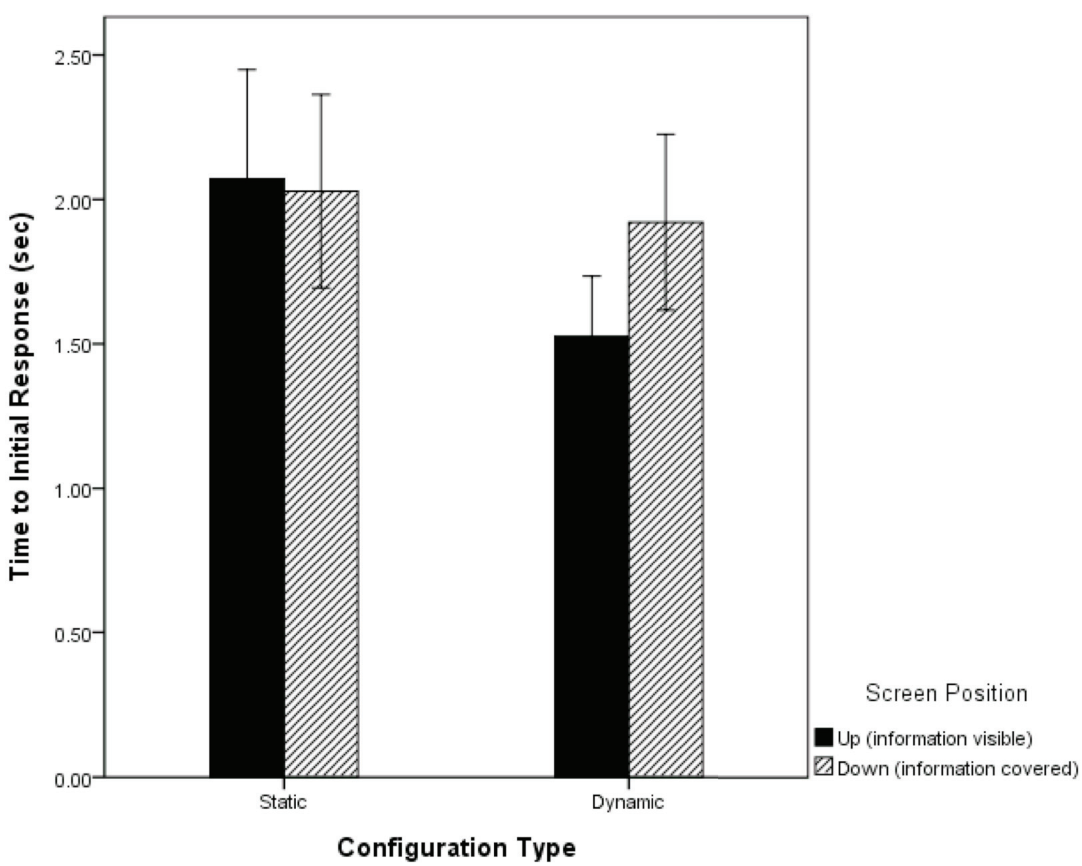

Figure 36. Mean time to initial response based on configuration type and availability of information on the ERFB (screen position). **Note:** error bars represent 95% confidence interval.

Figure 37 shows the initial time to response and configuration type based on time-out number. A 2 (configuration type) x 3 (time-out number) ANOVA indicated that a main effect for initial response time is affected by configuration type. The results show that participants were significantly faster to respond to SA cognitive probes when using the dynamic ERFB configuration (movable icons) (F (1, 787) = 6.023, p = .014). No main effects were found for time-out number based on initial response time. A similar 2 x 3 ANOVA was carried out for total time to respond. The results indicate, that based on configuration type, the time-out number did not significantly affect total response times.

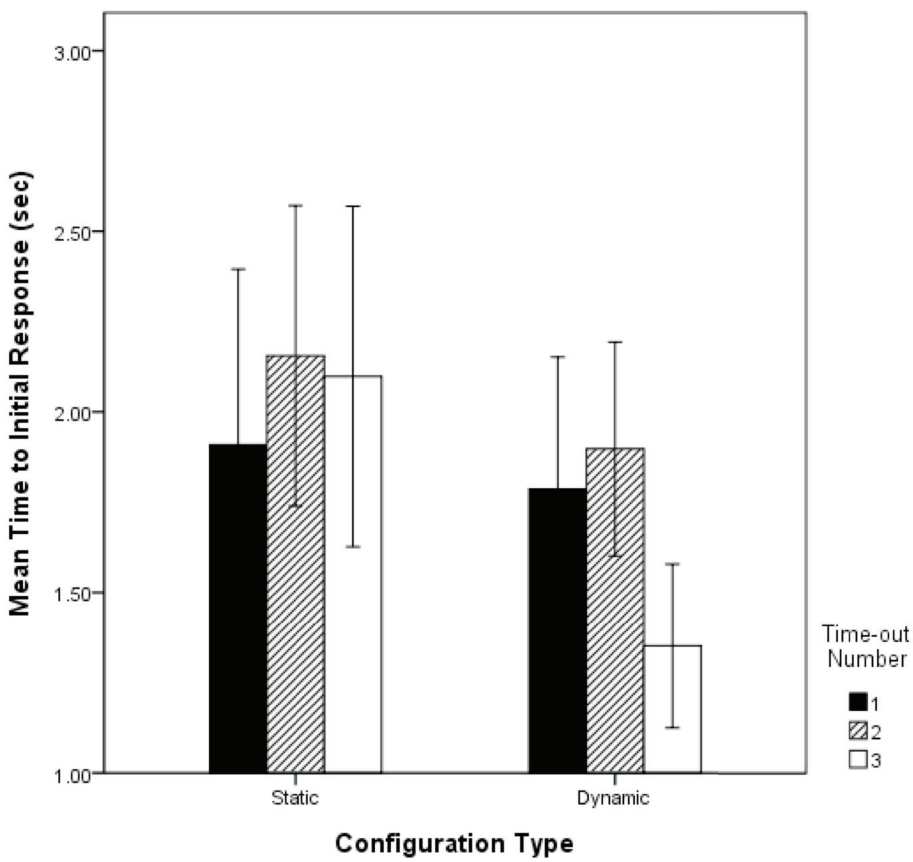

Figure 37. Time to initial response based on configuration type and time-out number. **Note:** error bars represent 95% confidence interval.

When comparing the overall response time in an effort to assess level of understanding (i.e. situation awareness), a 2 x 2 ANOVA revealed that main effect for configuration type significantly affects the total amount of time taken to answer the SA cognitive probes ($F(1, 788) = 3.921$, $p = .048$). The results clearly indicate that participants using a static ERFB configuration (blank screen) took significantly less time to complete their responses than those using the dynamic configuration. These results are supported by an analysis of the audio responses, in that participants using the dynamic configuration appeared to have greater contextually specific responses in regard to what was happening in the simulation. A two-way ANOVA also showed that the influence of the screen position clearly affected the overall response time taken to answer the probes ($F(1, 788) = 3.951$, $p = .047$). Figure 38 shows that minimal difference in total time occurs for the static ERFB condition (blank) regardless of whether the screen is up or down. Conversely, there appears to be a considerable difference in total time to respond based on screen position when testing was completed with the dynamic ERFB configuration (movable icons).

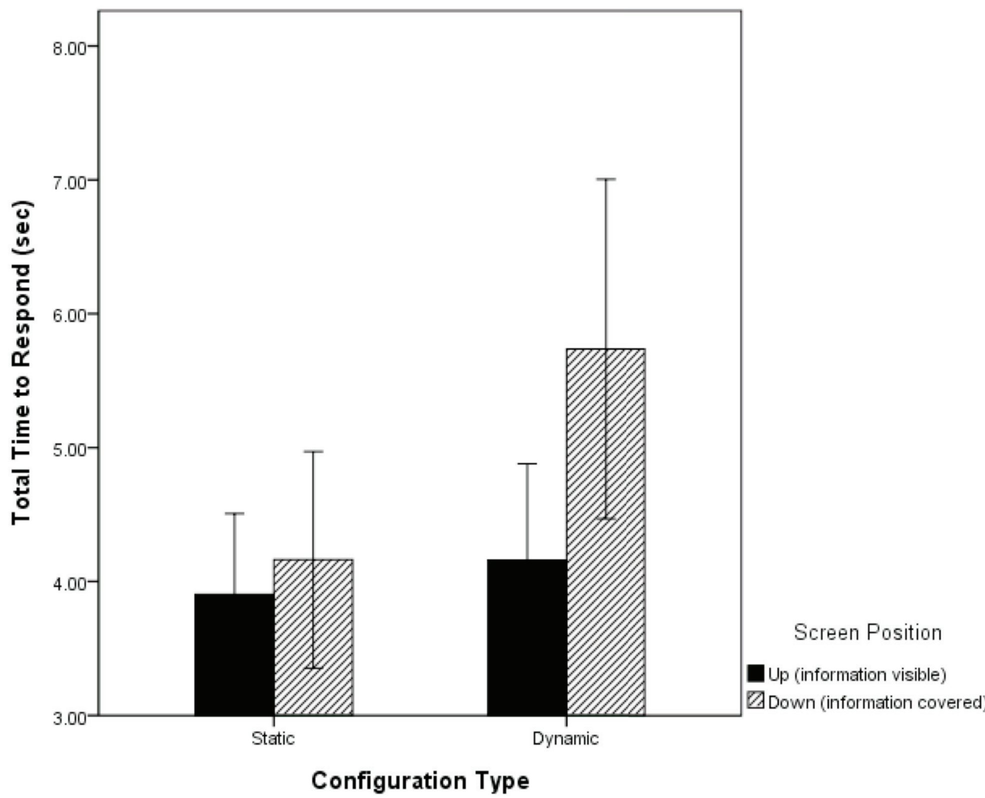

Figure 38. Total time to respond based on configuration type and availability of information (screen position). **Note:** error bars represent 95% confidence interval.

Total time to response based on the ERFB configuration and the level of SA question (i.e., perception, comprehension, and prediction) was examined with a 2 x 2 ANOVA. Significant main effects exist for SA question (F (2, 787) = 4.295, p = .014). The results indicate that individuals required more time to complete their responses when asked questions related to *level 2* SA (Figure 39).

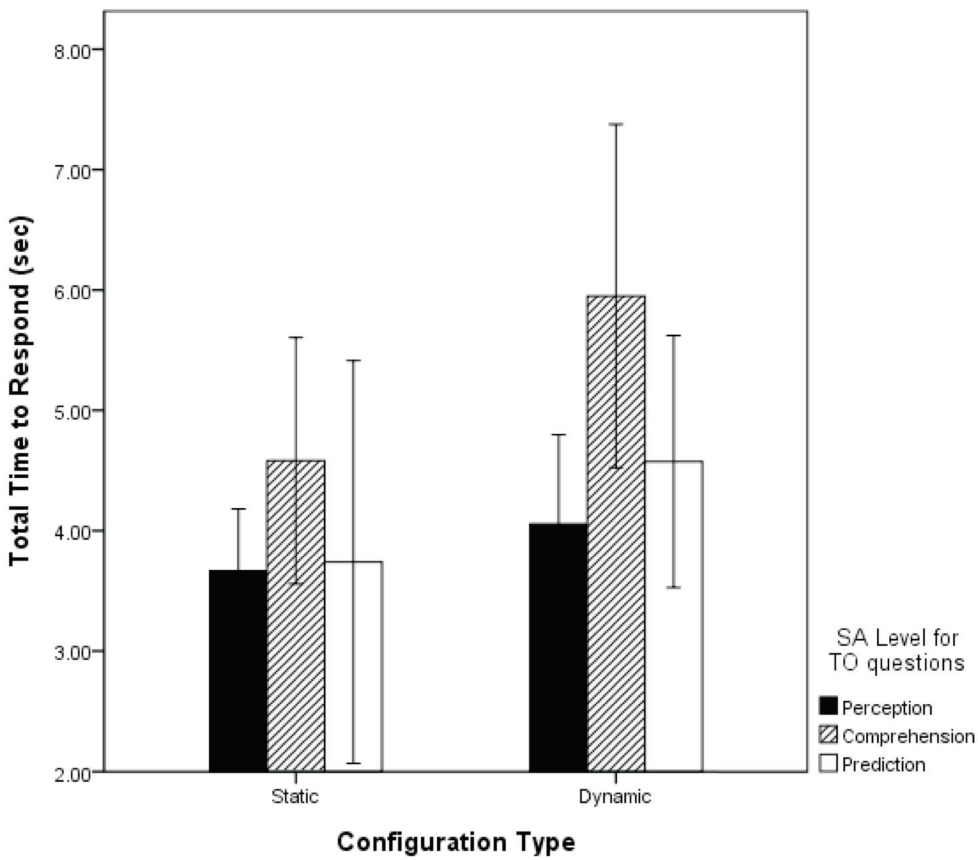

Figure 39. Total time to response based on configuration type and level of SA question. **Note:** error bars represent 95% confidence interval.

To further explore SA based on the time at which the cognitive probe is presented, a 2 (screen position) x 3 (time-out number) ANOVA was carried out for total time to respond. Results indicate that significant main effects exist for time-out number (F (2, 787) = 3.048, *p* = .048) and for screen position (F (1, 787) = 9.930, *p* = .002) based on total time to respond. This analysis of SA reveals that individuals take significantly longer to respond during the final time-out if the screen is down (covering the information) (Figure 40).

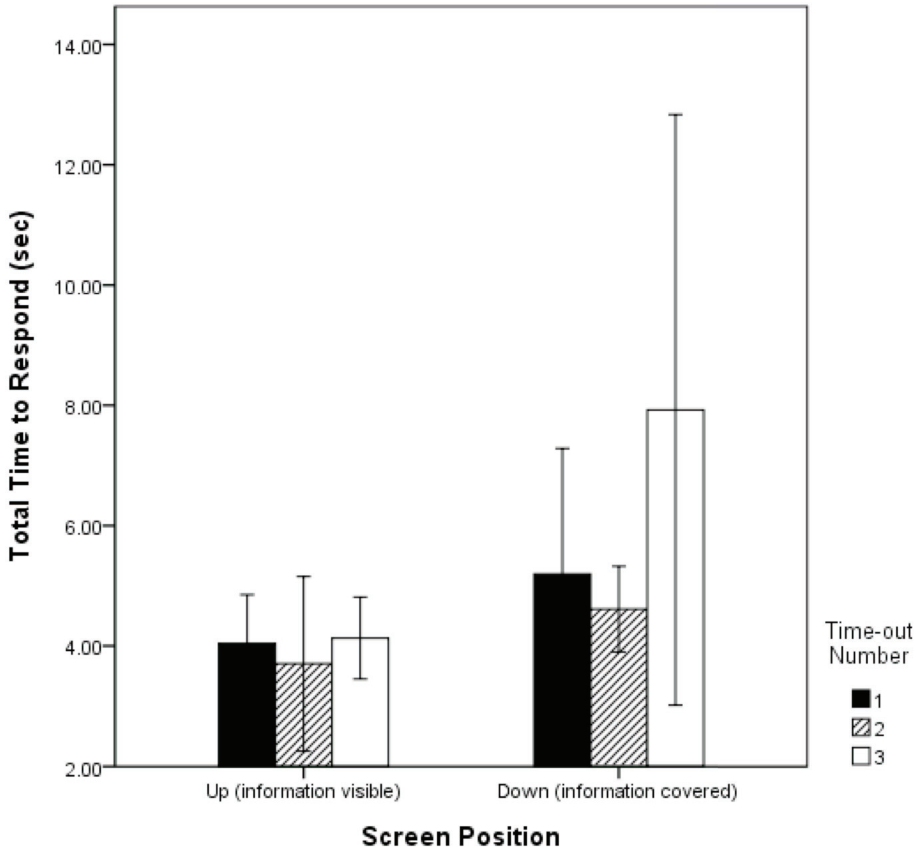

Figure 40. Influence of screen position and time-out number on total time to respond. **Note:** error bars represent 95% confidence interval.

10.4.3 Offshore Experience

As indicated in the description of participants recruited for this Phase, some of the individuals from SSTL had previous offshore experience. In order to explore the possibility that this experience influenced the accuracy of response or the speed of response, 2 x 2 ANOVAs were carried out. An ANOVA for accuracy of response based on offshore experience and configuration type revealed that there were no significant differences for experience; however, there were significant main effects based on configuration type ($F(1, 744) = 12.419$, $p < .001$). Figure 41 clearly shows that accuracy of response is positively affected by configuration type. The results further suggest that although accuracy increases with the dynamic ERFB configuration, it is not significantly greater if the participant had some offshore experience.

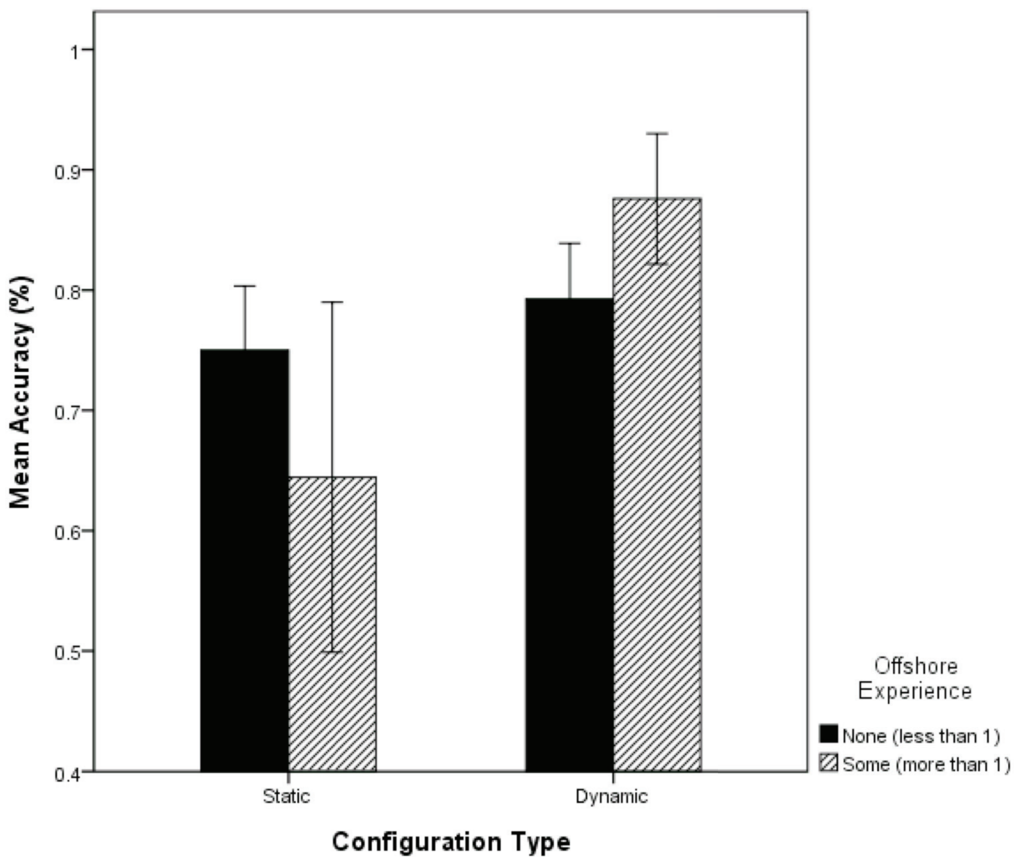

Figure 41. Interaction between accuracy of response, configuration type, and offshore experience. **Note:** error bars represent 95% confidence interval.

When exploring the influence of offshore experience as it relates to the amount of time required to initially respond to the time-out SA questions and when the question was posed, a 2 x 2 ANOVA reveals that there is a significant main effect ($F(1, 787) = 12.280$, $p < .001$). No significant differences were found for total time to response when considering offshore experience and time-out session. Figure 42 shows that those individuals with some offshore experience are significantly faster to respond to SA questions. However, there was no significant difference in speed of response based on time-out number.

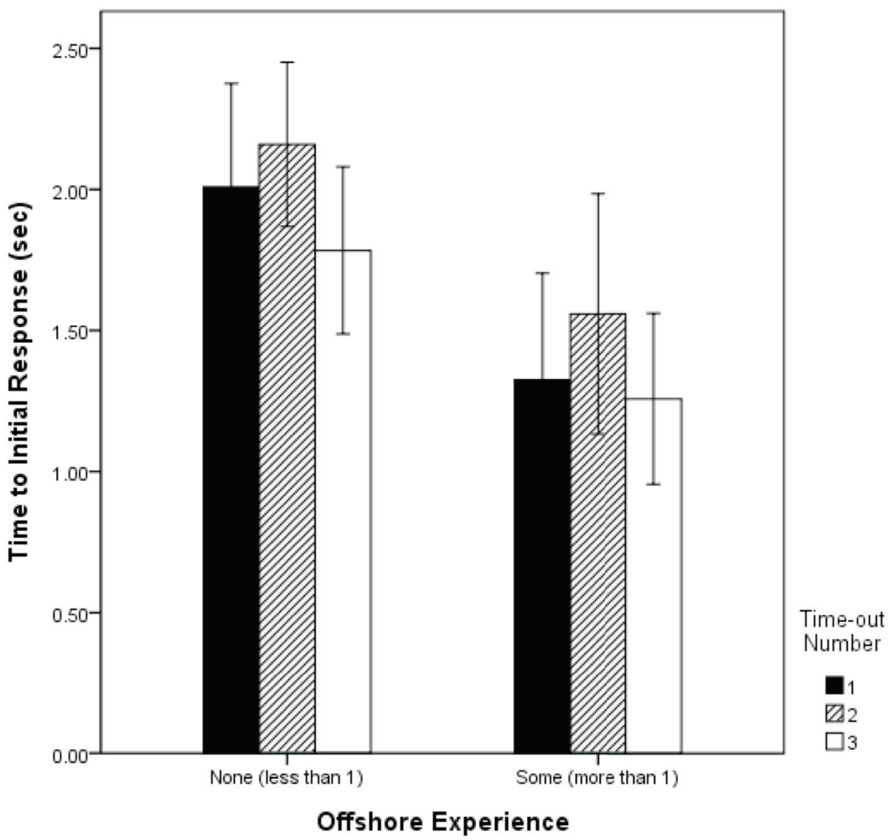

Figure 42. Influence of offshore experience and time-out number on speed of initial response.

10.4.4 Heart Rate/Heart Rate Variability based on ERFB Configuration Type

Because individuals were being tested on their ability to perceive, comprehend, and predict what will occur in the near future, heart rate and heart rate variability data were collected for each participant during the simulated exercise. However, of the 32 individuals completing this Phase of research only 20 files were complete. The remaining files were interrupted at some point throughout the simulation; therefore, were not used in the analysis. For the files that were analyzed, R-R heart rate variability (HRV – msec) interval means were analyzed by examining the standard deviation of the HRV R-R (SDRR) intervals based on configuration type, and time-out number. These two analyses were carried out in order to explore whether the ERFB configuration and/or the amount of information available influenced the participant's autonomic response (activation of sympathetic nervous system).

Kubios HRV (V 2.0) was used to examine the changes in variability for a five-minute baseline and 30 second averages for each time-out session. As HRV is an individual characteristic, each person was considered to be his or her own control. No statistically significant differences were found between the SDRR intervals for any of the times or based on ERFB configuration type.

10.5 ERFB SA-Self Rating Based on Configuration Type

Similar to the analyses conducted for accuracy and speed of response, this section of the results explores the influence of the ERFB configuration, and offshore experience. However, position of screen, level of SA question and time-out session parameters are not applicable as the SA self-rating questionnaire was completed after the simulation exercise was ended. As the SA self-rating questionnaire required individuals to select one of two responses (i.e., forced choice), the nominal data were examined with a Chi-square analysis.

Table 10 indicates the SA self-rating responses given by participants who were tested using both the static and dynamic ERFB configuration. The table outlines whether the individual responded true (T) or false (F) and their level of confidence (High or Low) to the SA self-rating questions. The first eight questions on the SA self-rating questionnaire were designed to measure whether the individual could remember key aspects of the simulation whereas the last two questions addressed whether individuals believed that they were aware of all the information that was on the ERFB and that all of the information was appropriately recorded on the board. The results from Table 9 indicate that question 5 "All personnel were mustered at their appropriate stations" was answered completely differently when using the static versus the dynamic ERFB. Twelve individuals from the static display group (92%) did not believe that all personnel were mustered at their appropriate stations, while 18 people of the dynamic ERFB group (95%) believed that everyone was where they were supposed to be. The correct answer in this case was that all installation personnel were accounted for and mustered in their appropriate stations.

Table 10. Comparison of SA self-rating responses and confidence ratings for the static and dynamic ERFB configurations.

SA Self-rating Question	Static Configuration							Dynamic Configuration						
	Response Numbers		Response Accuracy	Confidence		Confidence Accuracy	Response Numbers		Response Accuracy	Confidence		Confidence Accuracy
	T	F	%	High	Low	%	T	F	%	High	Low	%
1	1	12	92	11	2	85	0	19	100	19	0	100
2	6	7	54	9	4	31	3	16	84	16	3	84
3	0	13	100	12	1	92	0	19	100	18	1	95
4	2	11	85	10	3	77	1	18	95	17	2	90
5	1	12	8	11	2	15	18	1	95	17	2	90
6	1	12	92	10	3	77	0	19	100	18	1	95
7	10	3	77	6	7	46	18	1	95	15	4	79
8	10	3	77	8	5	62	12	7	63	14	5	74
Average			**73.13**			**60.63**			**91.5**			**88.38**
9	6	7	54	10	3	77	8	11	58	14	5	74
10	10	3	77	7	6	54	11	8	63	10	9	53

The SA self-rating confidence responses as they relate to ERFB configuration results indicate that individuals were significantly more confident that their answers to the self-rating answers were correct when using the dynamic ERFB configuration (X^2 = 5.878, *df* = 1, *p* = .015). Table 11 shows the SA self-rating responses as well as the percentage of the totals for each category.

Table 11. SA self-rating of confidence based on ERFB configuration type.

		ERFB Configuration	
SA Self-rating	Response	Static	Dynamic
Confidence (%)	High	91 (70.5)	156 (82.1)
	Low	38 (29.5)	34 (17.9)
Total		129	190

In order to examine differences in SA self-rating confidence levels, a Chi-square analysis was conducted to identify whether offshore experience influenced responses (Table 12). The results indicate that ratings of confidence were significantly higher for individuals who had some offshore experience (X^2 = 4.754, *df* = 1, *p* = .029).

Table 12. SA self-rating of confidence based on offshore experience.

		Offshore Experience	
SA Self-rating	Response	No Experience (< 1 year)	Some Experience (> 1 year)
Confidence (%)	High	178 (75.5)	69 (86.3)
	Low	61 (24.5)	11 (13.7)
Total		239	80

10.5.1 Sensitivity and Specificity of Configuration Type as it Relates to Signal Detection Theory

Based on research conducted by McGuinness (2004), correct SA self-rating level and confidence in one's response was examined through the use of signal detection theory. As noted, previous offshore experience influenced confidence as well as accuracy of self-rating questions. The following definitions were used to test the participant's response to the self-rating SA questionnaire and represent confidence ratings as a subjective estimate of the probability that the answer to the SA question was correct.

Sensitivity $d' = (\text{Hits} + \text{False Alarms}) / \text{Hits}$

Sensitivity $d' = (131 + 22) / 131$

Sensitivity $d' = 1.17$

Specificity = (Miss + Correct Rejections) / Correct Rejections

Specificity = (27 + 21) / 21

Specificity = 2.29

Table 13 identifies the total number of hits, false alarms, misses, and correct rejections made by novice participants (no offshore experience). Actual SA state is defined by the binary choices available to participants (i.e., correct or incorrect). From the equation identified in Section 10.2, the overall sensitivity (d') to the self-rating questionnaire was 1.17 whereas the true negative rate of correct rejections (specificity) was 2.29.

Table 13. Phase 4 ERFB participants without offshore experience **(n = 24)**

		Decision (Confidence) About SA Query Accuracy	
		Correct	Incorrect
Actual SA State	Correct	Hit 131	Miss 27
	Incorrect	False Alarm 22	Correct Rejection 21

Figure 43 shows the difference between sensitivity when considering the influence of configuration type. The ROC (receiver operating characteristic) curve plots indicate that novice participant's sensitivity (*d′*) for testing on the static ERFB configuration was .36. However novices tested with the dynamic ERFB configuration showed sensitivity (*d′*) of 1.79 (Figure 44, panel B).

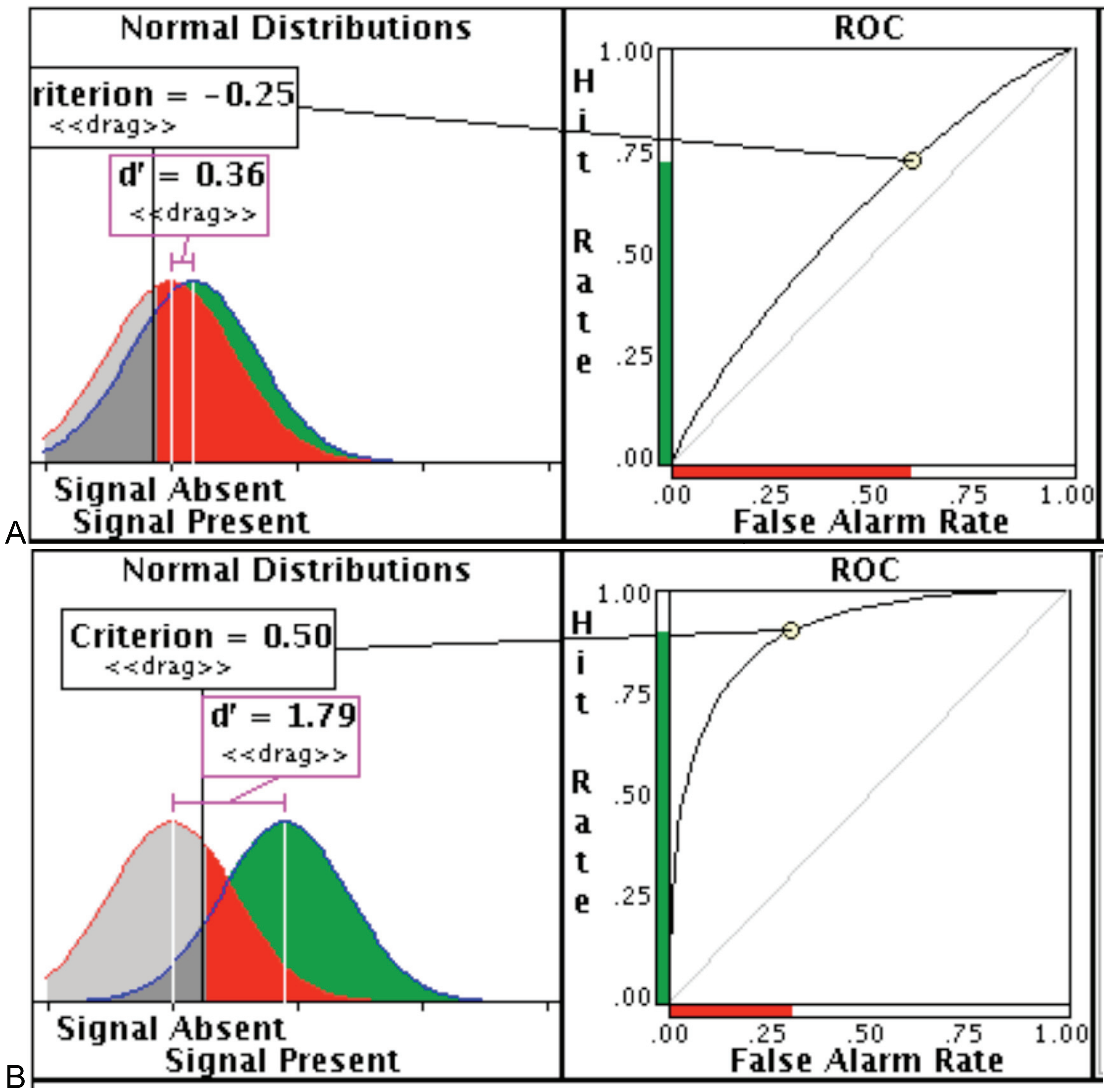

Figure 43. ROC curves for participants without offshore experience. Panel A represents sensitivity (*d′)* for static ERFB configuration. Panel B represents sensitivity (*d′)* for dynamic ERFB configuration. **Note:** figures create with WISE Signal Detection Applet (http://wise.cgu.edu/sdtmod/signal_applet.asp)

From Figure 43 it is clear that the hit rate was higher and the false alarm rate lower for those individuals who had no offshore experience using the dynamic ERFB configuration. When testing sensitivity (*d′*) for the eight participants that had some offshore experience Table 14 shows that 95 % of the responses are made up by hits and correct rejections. Overall sensitivity (*d′*) for the novice users that had some offshore experience was 1.06 while the true negative rate of correct rejections (specificity) was 1.57.

Sensitivity *d′* = (Hits + False Alarms) / Hits

Sensitivity *d′* = (50 + 3) / 50

Sensitivity *d′* = 1.06

Specificity = (Miss + Correct Rejections) / Correct Rejections

Specificity = (4 + 7) / 7

Specificity = 1.57

Table 14. Phase 4 ERFB participants with offshore experienced **(n = 8)**

		Decision (Confidence) About SA Query Accuracy	
		Correct	Incorrect
Actual SA State	Correct	Hit 50	Miss 4
	Incorrect	False Alarm 3	Correct Rejection 7

Figure 44 shows the ROC curves for participants with offshore experience based on configuration type. Panel A (static ERFB) shows that the area under the ROC curve is 0.714 while the area under the curve for Panel B (dynamic ERFB) is 0.844. The ROC curve plots indicate that offshore experienced participant's sensitivity (*d′*) for testing on the static ERFB configuration was 3.09. However when these same participants completed testing with the dynamic ERFB configuration they showed a sensitivity (*d′*) of 2.27 (Figure 44, panel B). From Figure 44 it can be seen that although the hit rate is higher for the static ERFB configuration, the false alarm rate is also higher.

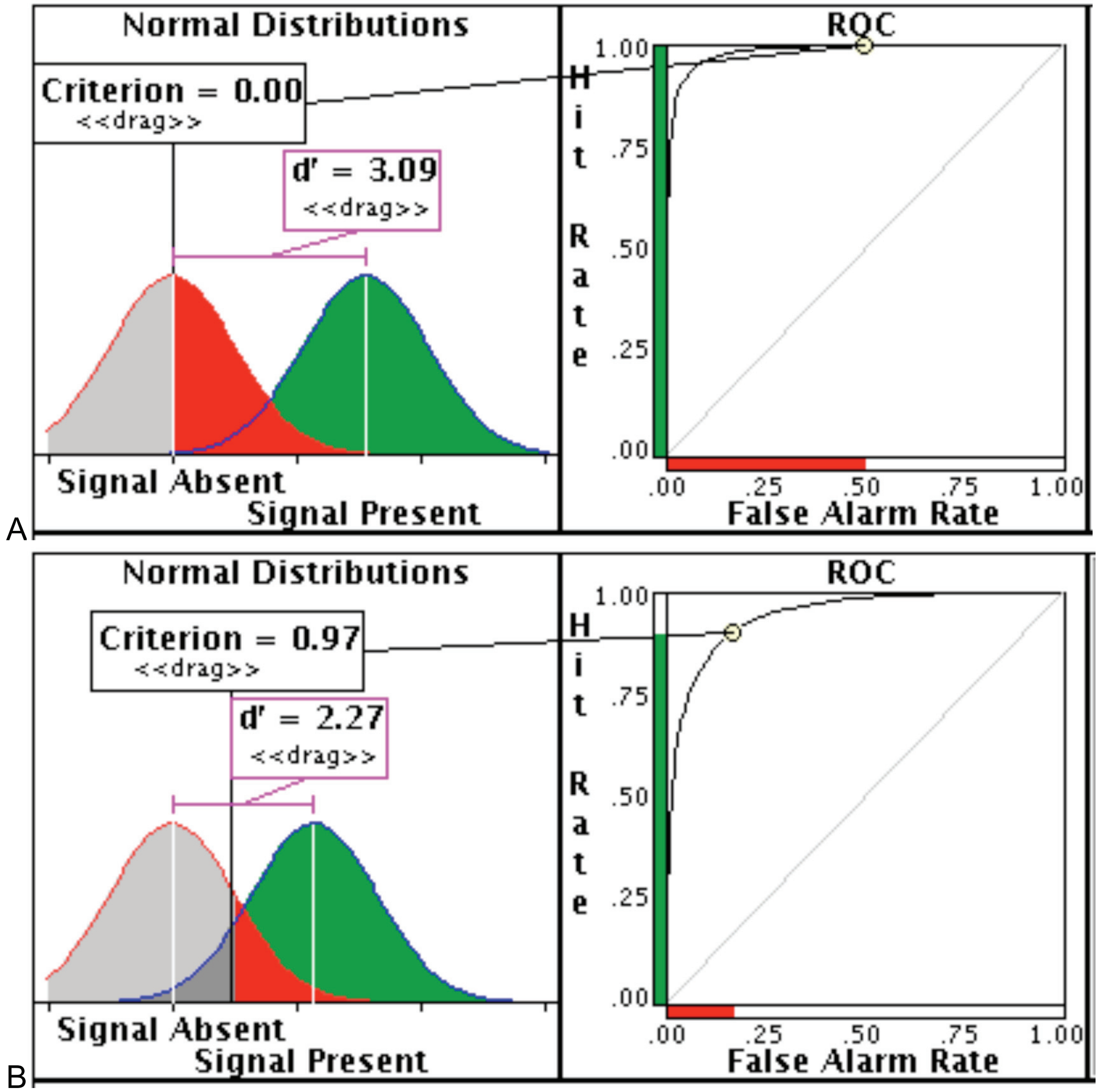

Figure 44. ROC curves for offshore experienced participants. Panel A represents sensitivity (*d'*) for static ERFB configuration. Panel B represents sensitivity (*d'*) for dynamic ERFB configuration. **Note:** figures create with WISE Signal Detection Applet (http://wise.cgu.edu/sdtmod/signal_applet.asp)

10.6 Phase 4 Results Summary

The following summary is designed to consolidate the results from this Phase of research and directly addresses the questions posed.

1. To what extent does the visual display of emergency information affect situation awareness?

Based on accuracy, initial and total response times, and confidence results, it appears the manner in which emergency response information is displayed has a direct link to the development and maintenance of SA. The results clearly show that accuracy and reaction time are significantly better when using the dynamic ERFB configuration compared to the static display. Given these results, it can be concluded that SA is high for the dynamic ERFB configuration.

2. Does offshore experience affect the accuracy of responses made to SA cognitive probes?

From a quantitative HSI perspective the results clearly show that there are significant influences based on experience (personnel selection) and configuration type (human factors engineering). It was also noted that accuracy of response, initial response time, and overall response time were significantly affected by the display type which related directly to both safety and survivability aspects of HSI. These findings suggest that human factors design principles incorporated into the ERFB design were beneficial for both the novices and experienced participants. However, given that experienced participants were significantly more accurate when using the dynamic ERFB, the benefits associated with the interactive component should be considered during future development of emergency response focus boards. Additionally, from a qualitative HSI perspective, the results identified that experienced individuals take longer (increased richness) to complete their responses to situation awareness questions associated with comprehension of incoming information. It was also noted that individuals appeared to have a better understanding of the emergency response information during the last time-out while testing on the modified ERFB. Quality of responses as well as accuracy was also affected by experience and availability of information.

3. Does the configuration of the focus board change the way in which participants answer self-rating SA questions?

There was no significant difference in how the participants answered the SA self-rating questionnaire. In fact, only one question (related to the location of installation personal in their correct muster station) was answered differently by participants in the two configurations.

4. When assessing situation awareness (using the Situation Awareness Global Assessment Technique), do individuals respond quicker when the focus board information is visually available to them than when it is blanked out?

This question has two distinct answers. One is related to initial response time for static versus dynamic and the other is related to SAGAT versus cognitive probes posed when information is visible. Initial response time is significantly faster for the dynamic configuration; however, during screen down positions (SAGAT), initial time to respond is slower than when the displayed information is visible.

5. Is vital response information retrieval faster on an existing focus board or a reconfigured (centralized information) emergency response focus board?

The overall initial response time for the static configuration (similar to the existing dry-erase whiteboard used by offshore personnel) was 2.05 seconds, whereas the mean time for the dynamic display was 1.68 seconds. Although the difference (0.37 seconds) may not appear to be substantial, the results indicate that the dynamic display significantly decreased reaction time and even the slightest increase in performance may make the difference between a positive outcome and disaster during an emergency.

6. To what extent does the visual display affect the amount of time required to ensure the ERT has a shared understanding of the emergency?

Results indicate that experienced participants were significantly more likely to take longer to complete their responses. This was due in part to them being able to elaborate and identify factors that were important to the SA cognitive probe response. Results also indicated that accuracy of response was significantly influenced as the simulation unfolded. Interestingly, participants appeared to have difficulty with the SA probes during time-out session 2. This was probably due to the amount of new information added to the simulation between the initial time-out and the second time-out.

10.7 Phase 4 Discussion

As one of the components of HSI, human factors engineering is important to emergency response on several levels, such as equipment design, ergonomic layout of the control room, and usability. It was however, the usability/functionality of the ERFB that was of the greatest interest to developing a standardized format of visual display for MEM/PICA evaluations and ultimately real-world applications. Given that the existing focus board format (blank dry-erase whiteboard) currently used in offshore settings did not appear to be effectively standardized in regard to information location or generic icons that represent particular resources, it became apparent during the analysis of archival training videos in Phase 1 of this thesis that it was important to address these issues. By taking in to consideration the human factors principles associated with display design suggested by Wickens et al. (2004) and Yeh and Wickens (2001), I ensured that the dynamic ERFB designs was legible, avoided absolute judgment of similar information, incorporate redundancy, and grouped element information together. Additionally, I used aspects of pictorial realism (e.g., offshore installation schematic, SAR helicopter, and ships) to ensure that a clear depiction of the situation could be used to augment the limitations of working memory.

Based on the results of this Phase, the dynamic ERFB configuration (movable icons) was significantly “better” than the static ERFB configuration when considering initial response time, total response time, experience, and accuracy of answer. Specifically, all participants were faster to respond when using the dynamic configuration and significantly faster when the visual display could be seen. This particular result is important when considering situations that require rapid responses from an individual in charge; it seems to be critical that pertinent information is easily located. The fact that participants responded over 500 milliseconds faster when using the dynamic configuration could under certain circumstances be the difference between life and death during an emergency. The results further indicate that the participants took significantly longer to complete their responses when using the dynamic configuration. As longer responses do not necessarily equate to better understanding, I examined the audio recordings of the response to ensure that participant answers were considered from a contextually correct basis. As noted previously, the increase in length of the responses was due to considerably more elaboration occurring when the participants responded to the SA cognitive probes. The 1.5-second difference is important, in that giving a more complete answer to ERT members may aid in clarification of a response.

In order to discuss specific aspects of the findings from this Phase of the thesis, the discussion section has been divided into the same three components used in the results section above: 1) usability; 2) accuracy and speed of response; and, 3) SA self-rating. The discussion of each component reflects the overarching goal of including the human, technology, and the environment (i.e., the HSI framework) in the development of the ERFB design.

10.8 Phase 4 Usability Related Configuration Type

Jasper (2009) suggests that using just one type of usability assessment limits the ability to identify shortfalls in a user interface design. By utilizing a self-report questionnaire, expert evaluation and observational analysis, this Phase of research was able to look at several different components of usability for the two ERFB configurations. Results indicate that although the ERFB designs are effective, efficient, and satisfactory, some changes to the overall design should include a colour-coded system of identifying key information, larger field for incoming information, and a list of external resources. Results further indicate that usability ratings for the dynamic (movable icons) configuration were similar to that of the static (blank control condition) configuration; however, layout satisfaction was rating considerably higher for the dynamic display. This increase in satisfaction and functionality identifies that the usability of the dynamic configuration was superior to the older design and based on the post-testing comments from participants, the dynamic configuration aided them to better understand the situation. Furthermore, as indicated by the speed of the initial response, ease of finding information was better when using the dynamic versus the static configuration.

Theoretically, these usability results suggest that a dynamic ERFB should be incorporated into all future MEM/PICA testing sessions to ensure that OIMs and ERT members are able to created a more effective shared mental model of the emergency event. However, the functionality and practical use of the dynamic ERFB must be further examined to ensure that the results from the novice participants from a simulation can be expected to yield similar benefits when used by an individual tasked with responding to a real-world emergency. Based on user-centered design research outcomes, Jokela (2004) suggests that the process of testing a new user interface is invariably affected by the goals set out by the end users and that these goals may not be the same as those set by the designers. Therefore, the future iteration of the dynamic ERFB templates need to reflect the needs of the end user and not just the typical usability aspects of effectiveness, efficiency, and satisfaction.

10.9 Phase 4 Accuracy

Saner, Bolstad, Gonzalez, and Cuevas (2009) argue that the accuracy of individual team members understanding of a situation directly influences the overall shared SA and that errors at low levels of SA influence higher levels of decision making. Given that team SA was not directly assessed, accuracy of response in this thesis is linked specifically to the primary concern of ensuring that individuals can gather relevant information from the ERFB in an effort to respond to situation awareness questions. This focus is based on the occurrence of relatively predictable sequences of events within different emergency events and that a display that aids in creating an accurate understanding of the relevant information is extremely valuable.

10.9.1 Time-out Number Influences Accuracy

In order to explore a change in understanding associated with SA, accuracy was explored by considering the point at which a query was presented to the participants (time-out number). Prior to analysis, it would make sense to assume that as the simulation evolves, and more information begins to emerge, individuals should gain a better appreciation for what is going to take place in the immediate future. For example, during the first time-out session most of the muster list numbers had not been phoned or radioed into the control room; therefore, the OIM, the research participant in this case, would have no idea whether all installation personnel are accounted for. Knowing where all of the personnel are located is a primary component of managing an emergency and the absence of this information during the first time-out could influence the manner in which an OIM envisions the simulation. The results appear to confirm that participants were significantly more likely to respond correctly during the final time-out than during the previous two sessions. However, it was noted that during time-out 2, participants showed the lowest percentage of correct answers (73% versus 80% for TO1 and 86% for TO3). Results also indicate that the participants were significantly more likely to answer SA questions related to perception, comprehension, and prediction more correctly during the last time-out. Only prediction increased during each of the timeout sessions, while both perception and comprehension decreased during time-out session 2. These results were not surprising, given that the majority of time-out 2 sessions were completed with the screen covered, thus the participants needed to recall the information instead of visual locating it on the ERFB. Based on these findings and when considering situation awareness as it is assessed through an SAGAT model, it is suggested that the results would have shown a lower level of accuracy in the other two time-sessions if the screen was covered (blanked out).

10.10 Phase 4 Speed, Accuracy, and SA Level of Response

The results indicate that the level of SA questions (perception, comprehension, or prediction) does not significantly change the amount of time participants take to initiate a response. SA level does however, influence the amount of time it takes individuals to complete their responses. Specifically, offshore experienced participants took a full 2.7 seconds longer to complete an SA response based on comprehension when compared to perception and a full 2.6 seconds longer when compared to prediction. Inexperienced participants showed similar (albeit less pronounced) results. The results further indicate that the level of SA query significantly influenced the accuracy of responses. As mentioned in the previous section, accuracy of response was influenced by time-out session; however, the results further indicate that *level 3* SA (prediction) is most affected by configuration type.

Results from these analyses suggest that the ability to predict what will happen in the near future is significantly more accurate when using the dynamic configuration. Not surprising though, this level of SA remains lower than level 1 or level 2 regardless of configuration type. Experienced individuals answer more correctly when using the dynamic configuration; however, prediction remained approximately 60% even when using this advanced form of emergency management display.

10.10.1 Offshore Experience and Response Time

As noted in the results section, individuals who had some offshore experience were significantly faster to answer the SA cognitive probes as well as being significantly more confident when self-rating their situation awareness. The results further indicated that experience influenced the amount of time it took individuals to complete their responses. When reviewing the audio recordings it was clear that this longer time to complete the response was due to the experienced participants not only answer the questions posed to them; they would elaborate on their initial response to the point that it was sometimes difficult to think of subsequent SA questions. These findings are similar to those pointed out by

Durso et al. (1998) in which faster reaction times were correlated with a higher rating of SA. The results also revealed that experienced participants were significantly more likely to respond correctly to the SA cognitive probes; however, this only occurred when they were using the dynamic ERFB configuration. It appears that when using the older (static - blank) configuration there was no difference between experienced and novice participants. These results support the idea that expertise is not necessarily beneficial when placed in situations that do not require the use of specialized procedural and declarative knowledge (Beilock, Wierenga, & Carr, 2002). The results also appear to indicate that when presented with a display that aids in developing a vivid mental image of a plausible offshore emergency situation, experienced individuals were able to utilize their long-term working memory to develop a likely outcome and thus be able to answer SA probes correctly even when the ERFB could not be seen (Ericsson & Kintsch, 1995).

Not surprisingly, experienced participants answered the SA cognitive probes more accurately than did the novice individuals. However, it was noted that even without experience, participants answered these questions at an 80% accuracy rate when using the dynamic ERFB configuration. This result was surprising in that the novice participants had no previous offshore experience, nor had they experienced what it might be like to consider requirements associated with managing an emergency. Although not formally analyzed, comments from the novices showed that they clearly understood what was happening in the scenario. Some of the novices were even able to identify that the weather would impact the future situation because wind was blowing smoke and flames across the helideck, which would cause problems for the rescue of personnel still trapped inside the helicopter. The results from both the novices and the experienced participants support the initial assumption that if the novice users could correctly answer the SA questions, experienced users should also be able to correctly answer emergency response queries.

10.11 Phase 4 SA Self-rating

From the results of the SA self-rating questionnaire, it was noted that individuals were significantly more confident in their responses when using the dynamic ERFB display. This suggests that when a strong mental image of the situation is developed, subsequent questions related to SA are compared to what is thought to be true. Conversely, a mental image that is not entirely complete leaves room for doubt and subsequent questions related to SA may be based on a best estimate/guess of what has occurred. In addition, it was interesting to find that confidence is also influenced by the amount of previous offshore experience a person has obtained. This result suggests that experience fosters a belief that the mental image created during the simulation is correct and therefore confidence in its accuracy should be high (Chen, & Risen, 2010; Festinger, 1954). Sensitivity (correct response and correct confidence) was significantly greater when using the dynamic configuration and the area under the curve ranged from a low of .629 for novice participants using the static ERFB configuration to a high of .844 for those participants who had offshore experience using the dynamic configuration. Given that the ROC curves show a trend toward the upper left corner of the plot, it can be assumed that the dynamic configuration is more useful than the static display in detecting signals.

CHAPTER ELEVEN

PHASE 5

EMERGENCY RESPONSE FOCUS BOARD END USER TESTING

As mentioned in the introduction of this thesis, the previous research results have shown a possible link (negative correlation) between the complexity and automation of a production system and an operator's understanding of that system's state (Endsley, 2000; Wickens, 2008). Endsley (1995a,b) further indicates that rapid access to more relevant information undoubtedly leads to better performance and is often indicated by a higher level of situation awareness (SA). However, based on the large body of research pertaining to information processing, it is reasonable to conclude that more information is *not* always beneficial when trying to make decisions in dynamic environments and that it may be the type of presentation and visual interpretation of the critical information that will aid in performance outcomes.

Therefore, the final Phase of this thesis research was focused on identifying whether ERT members could: a) effectively utilize the ERFB in the same manner as using a plain whiteboard; b) establish a satisfactory level of SA (*level 2*); and, c) perform their emergency response duties to a level that would be expected during an actual MEM/PICA assessment. In addition, this Phase was used to better understand how HSI and, more specifically, how SA assessments could be utilized in a training environment. During Phases 1 and 2, I developed an SA checklist that was based on the situation awareness of individuals who have to imagine what it might be like to be involved in an emergency such as a capsizing or an onboard fire. And it should be mentioned that the actual testing environment lacks many of the physical attributes of a real offshore environment.

Although this may be seen as a serious limitation to appreciating an individual's level of SA during an emergency, these training environment constraints represent similar conditions for the majority of training programs used to certify hundreds (possibly thousands) of emergency response personnel yearly. Therefore, the primary objective of this research Phase was to investigate the influence of visually presented emergency response information and its effect on decision making and the development/maintenance of situation awareness of experienced offshore ERT members. Preliminary findings from the previous Phases (particularly 1 and 2) suggest that the presentation of interactive visual information during emergency response simulations may be beneficial to developing and maintaining team SA.

11.1 Phase 5 Methods

Research Questions:

1. Will a change in the information delivery system (ERFB configuration) affect the amount of text (e.g., incoming emergency information) that a scribe writes on the focus board?
2. To what extent does the final ERFB template aid the ERT in developing and maintaining situation awareness?

The research questions for this last Phase of data collection explore the influence of the display type on the requirement placed on the scribe. Additionally, the questions highlight the differences associated with text-based versus visual-based display systems. By answering the research questions, it may be possible to identify specific design criteria for future ERFB display configurations.

11.1.1 Offshore ERFB End Users Participants

Research participants for this Phase were recruited from individuals completing the Major Emergency Management/Person In Charge Assessment (MEM/PICA) certification at the Survival Systems Training Limited facility located in Dartmouth, Nova Scotia. The final group of participants were currently employed as emergency response team members working in an offshore environment. Five individuals volunteered and were considered to be “end users,” as they would be the offshore personnel who would have the most direct contact with the final ERFB configuration developed during this research. Furthermore, these individuals also have intimate knowledge of how offshore emergency response management processes are conducted and had completed at least one BST course in the past three years. The age of these participants ranged between 24 and 52 years (mean = 38, SD = 12.39).

11.1.2 Final ERFB Iteration Testing Data

The final iteration of the ERFB (Figure 45) utilized the results from the dynamic configuration (Chapter 10 above) testing and the various elements that the MEM/PICA participants believed were necessary to accomplish the tasks involved in each emergency scenario. Additionally, all of the human factors design principles were considered while making modifications to this final ERFB iteration. Unlike the novice testing (Phase 4), this ERFB configuration was used for all four possible emergency scenarios including situations in which all installation personnel needed to be evacuated into lifeboats. By working with the MEM/PICA participants to jointly create this final iteration, there was potentially greater user support than if I simply presented the users with what I believed to be the best possible design. However, even with the MEM/PICA participant input, many of the key components from the dynamic configuration (above) were preserved in this final display (Figure 45).

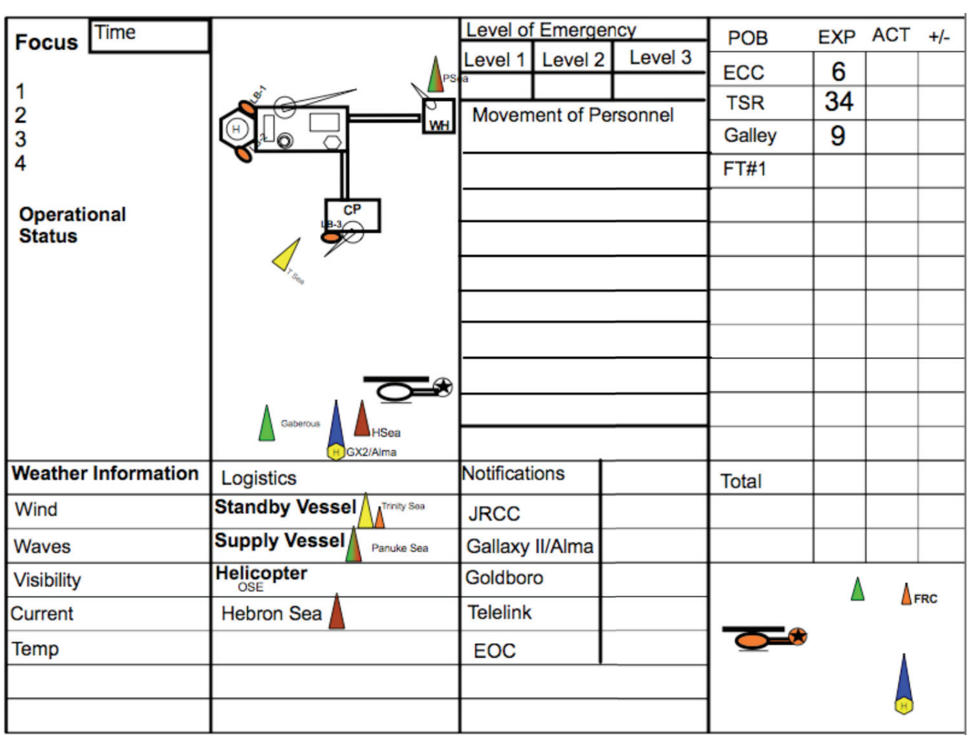

Figure 45. Final ERFB configuration for MEM/PICA.

A comparison between dynamic and MEM/PICA configuration clearly shows that components related to operational status, notifications, muster lists, external resources, and weather information are included in both configurations. However, the final ERFB configuration added both the movement of personnel and the level of emergency. Level of emergency was also considered important to the OIM and ERT members, in that the response procedures used by onshore and offshore personnel differ depending on the level of emergency.

11.2 Phase 5 Data Collection

As the participants for this final Phase of data collection were considered to be experienced offshore operators, Phase 5 differed from that used in Phase 4. One of the major differences in data collection stemmed from the fact that I needed to collect data from the participants while they were not being assessed for their MEM/PICA certification evaluations. That is, I collected data from participants only when the SME assessor was not also evaluating them and that none of the information was used for course assessment purposes. This restriction was clearly outlined and discussed prior to requesting volunteers. Therefore, after obtaining informed written consent from the OIMs and ERT members, and based on findings identified during the SME interviews, this Phase examines the transcription and integration of incoming radio transmissions, phone calls and verbal information input on the final iteration of the ERFB within the simulated command and control room setting. Of particular interest to the standardizing of information used for the development of SA, I examined the usability of the ERFB through the user's performance and capability to manipulate the focus board items. Audio recordings and the OIM's heart rate variability were collected to empirically document the effect of the interface display format. Participants were observed (observational task analysis – Bell & Lyon, 2000; Ericsson & Kintsch, 1995; Patrick, James, Ahmed, & Halliday 2006) as they interacted with the electronic emergency response focus board and all aspects of the time performance were manually recorded during the simulated emergency events. I also collected the number and length of time-out sessions, number and length of public addresses, telephone calls, and radio transmissions to examine any differences that might exist between the archival videos and the final ERFB configuration testing sessions.

To minimize the potential of influencing the MEM/PICA participant's evaluation process, SA questions could not be asked during this ERFB testing process, so I manually recorded (transcribed) verbal responses to ERT members' questions and time-out briefings as well as the accuracy of the OIM's assessment of the simulation. I recorded the number of flip chart sheets used during each scenario, as an indication of information that was clearly used to maintain SA. The information contained on the flip chart paper was any data that could not be placed on the ERFB due to spatial constraints of the display size.

After completion of each emergency scenario I discussed the use of the ERFB with the OIM from whom I had been collecting HRV data and asked for their subjective opinion of how the board configuration helped or hindered the process of team understanding. I also asked the participants if there were any changes or improvements that they would make to the board. I then had each of the OIMs complete the same self-rating SA and usability questionnaire used for the Phase 4 testing participants. On the last day of MEM/PICA assessment testing, I asked all of the course participants to comment on their general impressions of the ERFB and specifically the configuration used during the training. This was done to gather feedback from the entire ERT group as opposed to just an individual perspective, which might be skewed by the fact that the OIM never actual touches the ERFB and only passively interacts (i.e., only views the information input by scribes) with the display.

11.2.1 Recorded Data

Participants' verbal responses were recorded by the SMARTBoard 680i software program and an audio recorder (Sanyo, ICR-S700RM). This recorded data was transferred to a password protected laptop computer (Apple, MacBook). As previously mentioned, the MEM/PICA candidates currently have their performance video and audio taped for future analysis by a subject matter expert. This evaluation process was not altered during the MEM/PICA testing; therefore, those individuals who did not wish to be involved in the data collection process were given this opportunity to opt out of the video and audio analysis. Although given the opportunity, all MEM/PICA course members volunteered to participate in the ERFB evaluation process. Participants from both groups (novice and MEM/PICA) were assigned an alphanumeric code to ensure confidentiality; however, individuals were informed that due to the limited number of potential volunteers, confidentiality could not be absolutely guaranteed. However, no mention of specific dates or employers of the individuals were made during documentation of this research. As with Phase 2, 3 and 4, all participants received a copy of the informed consent sheet prior to agreeing to take part in the study. All video recordings of the MEM/PICA remain the property of SSTL and are stored at their facility in a similar manner to previous MEM/PICA course data. SSTL stores the data in a locked room for a period of seven years. Permission to view this data was obtained through the Training and Operations Manager at SSTL.

11.3 Phase 5 Results

Based on the novice testing in Phase 4 of this project, the final EFRB configuration incorporated both movable icons and specific text boxes that could be utilized by the ERT scribes. Figure 46 (below) also shows that the additional weather and level of emergency boxes were added to this final iteration. However, one of the greatest changes was the addition of the "movement of personnel" boxes. Information concerning personnel tracking was considered to be extremely important in understanding the exact location of individuals during the most difficult periods of the scenario. The MEM/PICA candidates made this particular change as they noted that the previous focus board (blank whiteboard) made it difficult to track where people were being moved during the emergency simulation. During a debrief with the SME assessor facilitating the course, it was indicated that he had "never seen a team organize the movement of personnel and POB tracking as well as this group." It was also noted that the external event logging sheets that are normally stored on a flip chart was considerably reduced when the team was using the new EFRB configuration. For example, during the first day of emergency response testing, the MEM/PICA members used 3 to 4 flip chart pages per simulation to record events that could not be placed on the EFRB due to spatial constraints and organization. However, when the team used the final MEM/PICA configuration, approximately ¼ of a page was needed to record extra information. Although this quantitative measure is not normally recorded, it can be assumed that once a flip chart page has been flipped over, it is difficult to recall the information that is no longer visible.

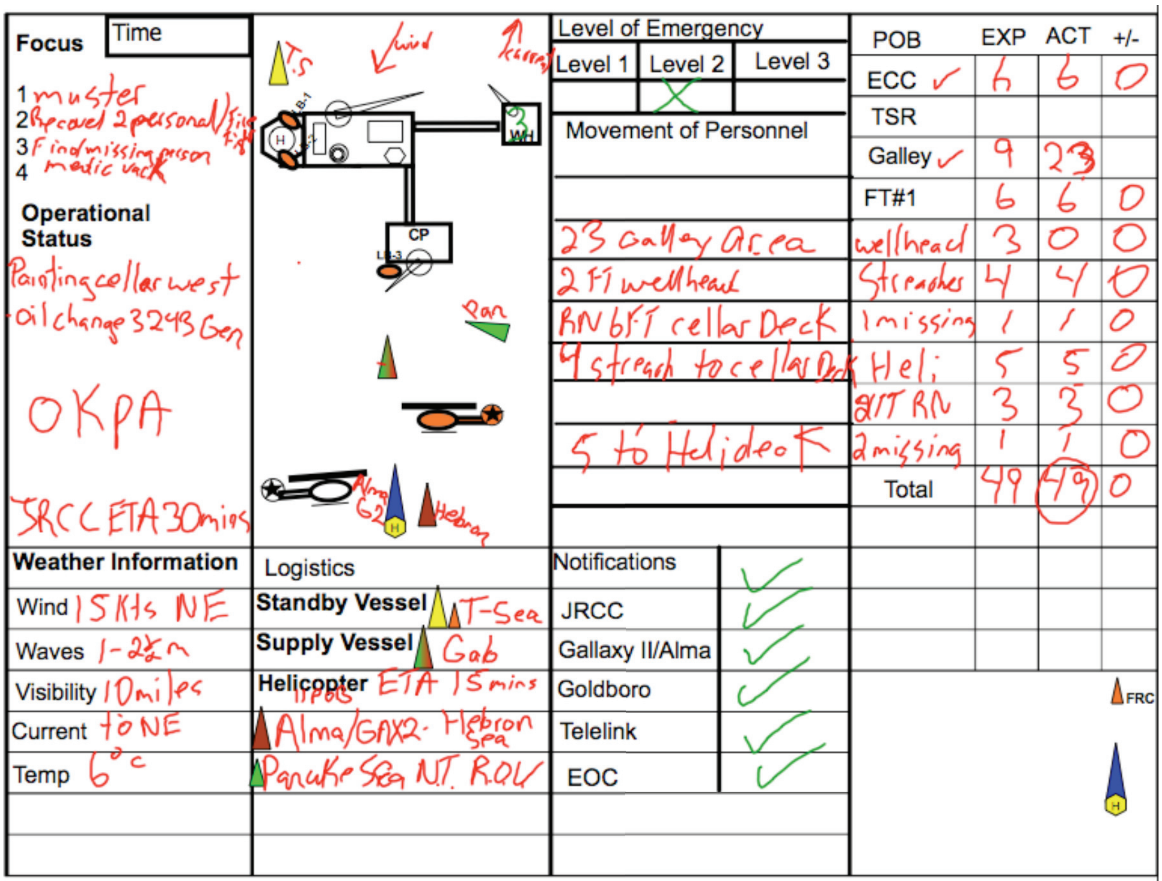

Figure 46. Final EFRB configuration after MEM/PICA testing in Phase 5.

11.3.1 Usability

The five participants from this last Phase of testing rated the new configuration's mean effectiveness at 8.2 out of a possible 10. The overall satisfaction of the configuration layout and functionality was rated at 8.1 out of a possible 10 and all MEM/PICA personnel (100%) indicated that they could easily find the information they were looking for throughout the emergency simulation. Table 15 shows that OIMs using the old configuration (blank whiteboard) spent more time updating their team during time-out sessions than those utilizing the final EFRB configuration. Mean combined time spent on time-outs (TOs), public announcements (PAs), phone and radio for the old whiteboard configuration (archival videos) was 11.09 minutes, while the OIMs using the final ERFB configuration required a mean time of 7.48 minutes to complete similar tasks under similar simulation conditions. This represents a difference of 3.61 minutes; however, as these mean values were collected from two separate conditions (i.e., final ERFB iteration and original dry-erase whiteboard) during two separate Phases, it was not appropriate to conduct statistical analyses.

Table 15. OIM time spent on time-outs (TO), public announcements (PA), phone calls, and radio transmissions.

		Time spent on Task (seconds)				
OIM Number (Old/New)	Simulation Type	Total time of Exercise	Total Time for Time-outs	Total Time on PA	Total Time on Phone/Radio	% Time Spent on Task
1 (O)	Helicopter Crash on Deck	3090 (sec) (51.5 min)	618 (10.3 min)	34	N/A	21.1%
2 (O)	Helicopter Crash on Deck	2718 (45.3 min)	658 (11 min)	156 (2.6 min)	334 (5.7 min)	42.2%
2 (O)	Collision Avoidance	2948 (49 min)	584 (9.7 min)	89 (1.5 min)	543 (9 min)	41.3%
6 (O)	Collision Avoidance	2040 (34 min)	229.7 (3.8 min)	61.1 (1.0 min)	89.2 (1.49 min)	18.6%
7 (O)	MOB	2573 (43 min)	358 (6 min)	N/A	N/A	13.9%
7 (O)	Fire in Engine Room	2164 (36 min)	246.5 (4.1 min)	N/A	N/A	11.4%
8 (O)	Fire	2130 (35.5 min)	381 (6.4 min)	71.7 (1.2 min)	N/A	21.3%
9 (O)	MOB	3115 (51.9 min)	661.2 (11 min)	207.6 (3.5 min)	N/A	27.9%
Average times for old configuration		2638 (43.9 min)	467 (7.8 min)	77.4 (1.3 min)	17.3	24.8%
3 (N)	Collision Avoidance	900 (15 min)	273 (4.6 min)	65 (1.1 min)	N/A	37.6%
3 (N)	Helicopter Crash on Deck	3540 (59 min)	444 (7.4 min)	49	N/A	13.9%
3 (N)	Wireline Failure	2880 (48 min)	262 (4.4 min)	89 (1.5 min)	96 (1.6 min)	15.5%
3 (N)	Fire on Wellhead/MOB	3420 (57 min)	470 (7.8 min)	114 (1.9 min)	N/A	17.1%
4 (N)	Fire on Wellhead/ MOB	3120 (52 min)	412 (6.9 min)	80 (1.2 min)	N/A	15.8%
4 (N)	Fire - Explosion	3240 (54 min)	313 (5.2 min)	150 (2.5 min)	N/A	14.3%
5 (N)	MOB	2100 (35 min)	370 (6.2 min)	76 (1.3 min)	N/A	21.2%
5 (N)	Fire on Cellar Deck	1560 (26 min)	170 (2.8 min)	75 (1.3 min)	42	18.4%
Average times for new configuration		2595 (43.3 min)	339.3 (5.7 min)	87.3 (1.5 min)	17.25	19.2%

Figure 47 indicates the differences in the mean total of OIM's time spend in time-out sessions, PAs, radio. As, Figure 47 appears to shows differences in variability of mean time on task based on the old configuration type, a *t*-test was performed to explore the standard deviation of this variability. Although there is a difference in the mean variability of 4.28 (mins.) between the two configuration types, the results do not indicate a significant difference in the variability between configurations.

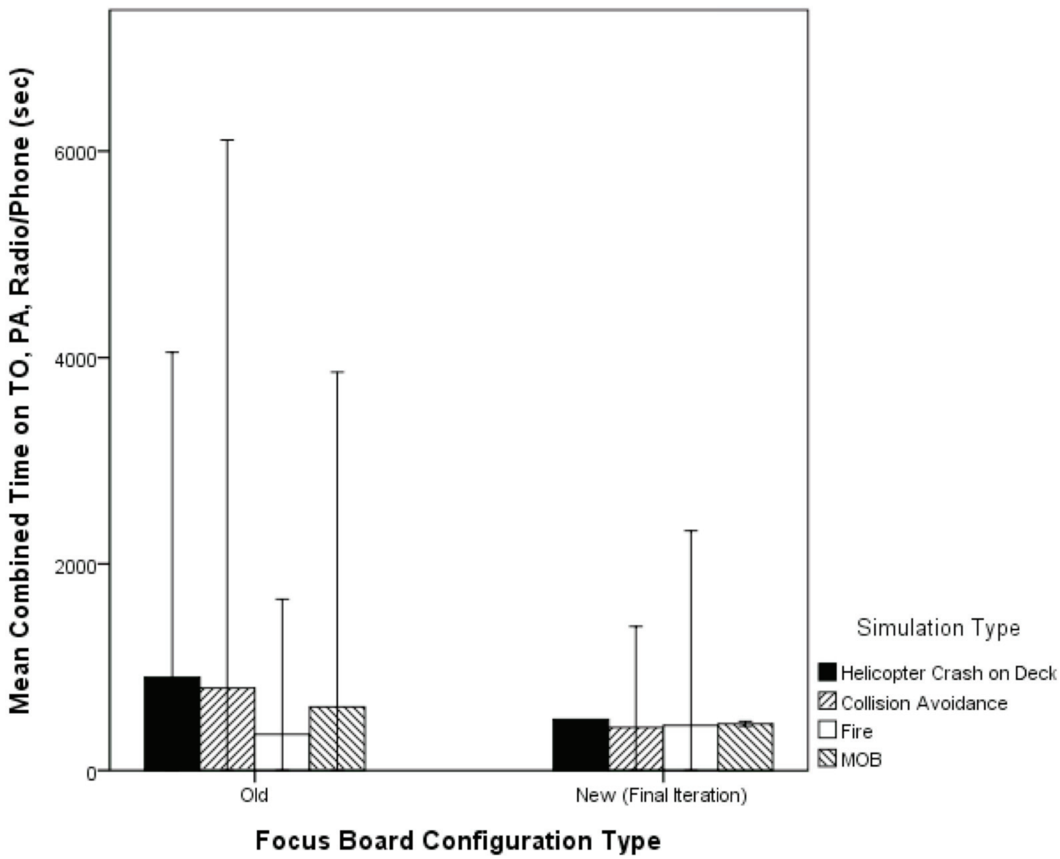

Figure 47. Mean time of total OIM time spent on tasks based on configuration and simulation type.

Table 16 details the number of time-out sessions, PAs to rig personnel, phone and radio communications to show that although there is a considerable difference in the time spent updating and briefing the ERT members, there is virtually no difference in the average number of time-outs or PAs. ANOVAs were used to explore the difference in configuration types based on the number of time-outs, PAs, and phone/radio calls made during the emergency simulation. No significant differences were found.

Table 16. Comparison of time-out, PA, and phone/radio numbers between old and new focus board configurations.

Old Focus Board Configuration Simulation Number	Number of Time-out Sessions	Number of PAs to Rig Personnel	Number of Phone/Radio Communications
1	4	3	0
2	5	3	11
3	6	0	0
4	6	3	0
5	4	0	0
6	6	9	0
7	6	1	0
8	5	5	5
Average (OLD)	5.25	3	2
New Focus Board Configuration Simulation Number	**Number of Time-out Sessions**	**Number of PAs to Rig Personnel**	**Number of Phone/Radio Communications**
1	7	3	0
2	3	3	0
3	6	4	0
4	8	6	0
5	6	3	0
6	2	3	1
7	5	3	2
8	7	5	0
Average (NEW)	5.5	3.75	.38

11.3.2 SA Self-rating Results

A similar QUASA analysis conducted for Phase 4 conditions revealed that MEM/PICA participants show the greatest level of sensitivity for this final ERFB configuration. Table 17 indicates that these individuals had a combined hit + correct rejection rate of 97.5%. Figure 48 shows sensitivity (*d'*) for the ROC curve for this group as 4.06. Clearly, this ROC shows that the new MEM/PICA board has the combined effect of a high hit rate while maintaining a low false alarm rate.

Table 17. Signal detection matrix for MEM/PICA participants using final ERFB configuration.

		Decision (Confidence) About SA Query Accuracy	
		Correct	Incorrect
Actual SA State	Correct	Hit 34	Miss 1
	Incorrect	False Alarm 0	Correct Rejection 5

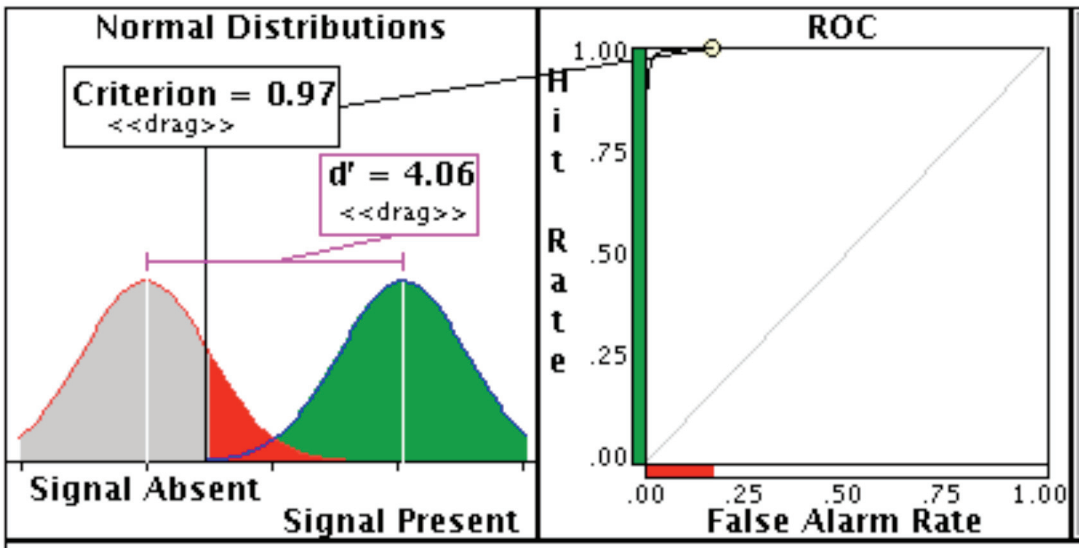

Figure 48. ROC curves representing sensitivity (*d'*) for MEM/PICA participants using the final ERFB configuration.

11.4 Phase 5 Results Summary

This final Phase results summary also addresses the research questions posed at the beginning of this chapter.

1. Will a change in the information delivery system (ERFB configuration) affect the amount of text (e.g., incoming emergency information) that a scribe writes on the focus board?

From the observational analysis and examining the flip chart sheets used during the pervious MEM/PICA emergency simulations, there was considerably less text required to maintain the understanding of the situation. This reduction in the requirement to constantly change the information on the ERFB allowed scribes to assist in other tasks such as contact shore based resources or pass along vital information to installation personnel.

2. To what extent does the final ERFB template aid the ERT in developing and maintaining situation awareness?

Based on the response from the MEM/PICA candidates and the SME, it can be concluded that the newly designed ERFB aided in specific aspects of SA development and maintenance. Specifically, comments related to personnel tracking the organization of external resources were promising. However, it was noted that during one of the simulated emergency events involving an inbound vessel on a direct collision course with the installation, the ERFB design does not appear to have changed the decision making strategy of the OIM. In this instance, the OIM abandoned all personnel into lifeboats well before the vessel could have made navigational changes to avoid the installation and before ever asking what type of vessel it was. These decisions were made based on past MEM/PICA training experiences in which the OIM had seen similar cues that lead to the eventual evacuation of the installation. On hearing these cues, the OIM automatically assumed (confirmation bias) the vessel was on a direct collision course with the installation and large enough to warrant evacuation. He ignored visual cues placed on the ERFB that indicated that considerably more time was available before there was a need to abandon.

11.5 Phase 5 Discussion

Flin and Slaven (1994, 1995) suggest that in order to assess an OIM's performance, it is important to provide situations (i.e., simulations) that would be experienced in the offshore environment. Although this seems a reasonable starting point for an assessment of performance, it becomes clear that it is difficult to simulate all the possible situation parameters, particularly if one is examining responses related to an emergency. For example, the conditions experienced in the Piper Alpha incident go far beyond what current simulations can replicate. Therefore it is important to identify which aspects of the situation are most important for the assessment of performance. If it is determined by MEM/PICA subject matter experts that paper exercises conducted at the ERT's place of work are sufficient to extract the required performance information such as the ability to communicate an emergency response plan effectively. Then it is also necessary to identify which exercises are most effective at meeting the needs in this assessment process. If however, it is determined that more fidelity, such as sounds or visual cues that would be expected during a real-world emergency are necessary, it is again important to identify what and how much detail in the simulation is required to predict performance in emergencies. It is imperative then; to ensure that baseline measures of performance are gathered before any changes are implemented to a simulation. Collection of baseline measures ensures that any changes in performance (both positive and negative) can be attributed to the modified training.

The OPITO standards as well as Flin and Slaven (1994), indicate that an OIM should be assessed in a high fidelity simulation at least once before being appointed to a position of command during an emergency. It is further suggested that the individual is evaluated at least once a year after the initial assessment and that an independent assessor should conduct this annual process. Although the standards suggest that the assessments should take place, there is little description of what is considered high fidelity. If the situation-specific portion of the proposed combination of factors is considered, the simulation needs to be designed to ensure that similar aspects of error related to human/interface interaction can occur during the assessment as would be expected in a real emergency. For example, the simulation should only include information or devices that are available in the environment in which the individual would normally operate. Otherwise, the individual may be successful at achieving a high level of situation awareness in the simulation without being able to achieve similar results in the real world. An opposite effect is also possible if the simulation does not include information or equipment that would be expected in the normal operating environment. It could be argued that the lower the fidelity of the simulation, the greater the cognitive workload that will be needed to create a mental image of the situation or how to use a piece of equipment that would be available only in the real context.

Further to the discussion of simulation fidelity, Gonzalez (2004) points out than when testing individuals in dynamic situations, the time constraints placed on decision making during performance represent a clear indication of performance. Therefore, it should be required that assessment processes include an element of time constraint during particular simulations. However, arbitrarily adding time constraints to all scenarios should be avoided if they would not be expected in the real-world situation. Conducting a task analysis of the requirements and an ergonomic assessment of the physical space (beyond the scope of this thesis) in which emergency command will take place should help alleviate discrepancies between the simulation and real-world environment.

11.5.1 Phase 5 Usability

As indicated in the methods section, I discussed overall effectiveness and satisfaction with the MEM/PICA participants at the end of their training course. The OIMs and other ERT members attending MEM/PICA course indicated that the modified focus board was helpful to understanding what was happening in the simulation. MEM/PICA member comments indicate that the ERFB is an effective tool and there was general agreement that it would be an effective tool for both training and operational use. Based on the rating of effectiveness, satisfaction, and ease of locating information, it appears that the final MEM/PICA ERFB configuration achieved the goal of keeping personnel continuously informed of the status of the scenario. In response to the comments made by the MEM/PICA participants, the SME indicated that he would be using the modified ERFB for future courses. While developing the MEM/PICA configuration, I examined technical schematics of the installation in order to develop a visual aid that resembled the basic shape and size of the environment in which the ERT members work. The decision to add a realistic looking visual aid was based on the belief that a generic model is more difficult to incorporate into a mental model of the situation.

Furthermore, the decision to add the realistic model was designed to aid the scribes during the input of incoming information. The results from this Phase appear to support these decisions. In fact, I found that even without experience using the touch screen surface of the new ERFB, individuals designated to be scribes were able to easily manipulate the SMARTBoard. During several of the MEM/PICA evaluations I noted points during the simulation at which the OIM and one of the scribes would move a ship or helicopter icons to a new location in an attempt to better understand the actual physical location of the external resources as it existed in the real-world. By physically manipulating the icons, it appeared that the ERT members were updating their mental model of the situation occurring outside of the control room. When using the old version of the focus board, this active movement and updating could only be done if the scribe erased the existing information and redrew or wrote the information in the new location. In support of this observation, it was noted by all SMEs and many of the OIMs that the scribe was one of the most important members of the emergency response team. Interestingly though, the scribes receive no formal training on what information should be transcribed to the focus board, where it should go, or how much information to record. In order to identify where gains in performance can be realized in further design and testing of the ERFB the following sections discuss the results as they related to an HSI approach.

11.5.2 Differences Between MEM/PICA Performances

Although not found to be statistically significant, I believe it is important to point out some of the observational findings concerning the performance of OIMs using the old and new MEM/PICA configurations. Of particular interest, the time spent during time-out sessions was considered an important aspect of the development and maintenance of SA. Time-out sessions do not always benefit or update personnel outside of the control room, and external resource coordinators such as fire team members or standby vessel captains outside of the installation control room are expected to manage the emergency on their own while the ERT members focus on their primary goals. If time-out sessions are to be used, it is important that this valuable time be spent ensuring that ERT members are aware of what the OIM believes to be true at the moment as well as update their own understanding. ERT members should be instructed to update the external resource coordinators and installation personnel waiting in muster stations so that all parties can evaluate a clear outline of the circumstances. The Piper Alpha disaster stands as a stark reminder of a real-world example of what can happen when individuals are not kept informed about the current situation.

The results appear to indicate that the total time spent on tasks was somewhat higher when using the old configuration versus the final MEM/PICA ERFB configuration. The time on task is important to overall SA, in that performance of secondary and sometime less important tasks may divert attention. Recent research has shown that when individuals divert their attention away from a primary task (maintaining a high level of situation awareness) to a secondary task (making a phone call to the shore office), they are less likely to return their full attention back to the primary task (Wickens & McCarley, 2008). This may include missing a change in the visual display (ERFB) that occurred while attention was directed to a secondary task.

CHAPTER TWELVE
GENERAL DISCUSSION

12.1 Discussion

Based on the fundamental need to better understand human performance in emergency situations and given the importance of the current offshore emergency response training process, I proposed that the MEM/PICA assessment processes would benefit from a focused Human System Integration investigation. Furthermore, I indicated that the overarching objective of this thesis was to reduce health, safety and environmental (HSE) risk by enabling Offshore Installation Managers (OIMs) and Emergency Response Team (ERT) members to effectively respond to system disruptions and emergency conditions. The following discussion outlines what I believe to be a positive first step to accomplishing this objective. By examining the findings from each of the five Phases, within the context of HSI, I suggest future steps that can be taking during the development of the ERFB as well as possible training and assessment improvements. I also outline some specific limitations to this research and suggest that further testing of the ERFB should be undertaken before it is fully implemented into the offshore emergency response systems. This chapter ends with recommendations for future emergency response testing and offers my understanding of how components from HSI and SA can be integrated into one overarching framework for future ERFB testing.

Booher (2003) warns, “the hazards of not fully comprehending the people-technology interface all too often results in tragic and costly unintended consequences” (p. xv). Emergency events such as the Piper Alpha disaster, Exxon Valdez, Ocean Ranger (U.S. Coast Guard, 1983), and most recently the ditching of Cougar helicopter 491 in March of 2009 (TSB, 2009) represent a clear need to identify – even at the most basic level – integrative links between operating systems (e.g., technology, humans, and the environment in which they work). This thesis represents my investigation of the current offshore emergency management assessment process and the implementation of a reconfigured focus board design used to examine its effect on the development and maintenance of situation awareness in emergency scenarios.

It is worth noting at this point that the desire to undertake this research stems from personal involvement in emergency situations and revolves around a fundamental question of “why do some individuals perform better than others during an emergency?” Is it training that makes the difference and if so why? Is it personality, the environment in which the emergency occurs, the available resources, or is it a complex interaction of factors that makes the difference between whether someone make the right decisions that eventually saves their life? My personal involvement in emergency situations has always been from the standpoint of training. As a survival instructor for more than ten years, I was in close contact with thousands of individuals working at the most dangerous end of an operation or system and on more than one occasion, some of those individuals did not survive an emergency situation that was considered survivable by subject matter experts. Therefore, this thesis is an attempt to better understand and identify key aspects related to the role of training in emergency response setting with the ultimate goal of improving human performance. Phase 1 of this thesis, for example, was carried out to directly address underlying aspects of standardization related to past emergency response management training. It was hoped that by examining previous training techniques, insight into why some emergency events end in tragedy while others are viewed as a minor annoyance that should be avoided in the future.

Furthermore, it is my position that far too often individuals develop what might be considered a reactive approach to what is usually called an “accident.” For example, within the marine and passenger transport industry Prince (1920) writes, “the sinking of the Titanic has greatly reduced the hazards of the sea” (p. 23). I would suggest that although changes to navigational displays, ship hull designs, and crew preparedness occurred during the years immediately following the sinking of the Titanic, little was done prior to the tragedy to examine the possible consequences associated with limited lifeboats and minimal safety training for the passengers (Battles, 2001). Do we need to wait for an emergency event to occur before we address the underlying components that will surely be involved in its management? I believed that an examination of the current training and evaluation practices in the offshore emergency management environment would aid in identifying possible interventions that could be used to enhance the efficacy and standardization of the program. Specifically, Phase 2 of this thesis was directed at exploring the global assessment factors used by MEM/PICA assessors as it became apparent that OIMs did not complete the emergency simulation in a similar manner, yet received similar scores in their assessment scenarios. That is, all of the archival videos were of OIMs who had successfully received certification to hold a position of command in the offshore community. I postulated that if OIMs use different techniques to complete the training, there must be some mechanism in place that evaluates these differences against a set standard. Flin and Slaven (1994, 1995) outlined the desirable traits of OIMs and OPITO documentation outlining the basic guidelines for assessors, but the paucity of documentation associated with how to actually conduct an assessment was somewhat surprising.

My first intent for this thesis was to develop a situation awareness checklist that could be used during OIM and ERT member assessment. However, after interviewing the SMEs, it became apparent that the MEM/PICA evaluation process is not currently standardized to a level that discourages individuals from making subtle changes that are based on personal preferences and past experience. As an example, each of the SMEs indicated that, although there is a set list of criteria associated with OIM performance evaluation, they all have an internal checklist that needs to be satisfied before they are willing to grant certification. The SMEs did, however, indicate that if an evaluation is challenged by an MEM/PICA candidate, there is always a second assessor available to review the physical evidence (video and audio tapes of performance) before a final decision is made. Furthermore, it was noted that if the two assessors disagree with the overall evaluation, a third person would be required to resolve the impasse. This does not however, negate the fact that each assessor has his or her own checklist that is never audited by a governing body. Interestingly, it was pointed out by the SMEs that although they know other assessors use an internal set of criteria to evaluate performance, none of the experts know exactly what the other is using as their primary evaluation criterion. This lack of shared knowledge concerning the internal checklist may stem from the SMEs rarely discussing the performance of a MEM/PICA candidate if the candidate accepts the assessment. That is, one primary assessor is responsible for the evaluation, documentation, and certification of the OIM. The second assessor is typically focused on ensuring that the emergency simulation occurs according to the prearranged script. Therefore, the establishment of an agreed upon SA checklist appeared to be only one of the steps needed to ensure that SMEs can address differences in their evaluation procedures. A second and more important step appeared to be related to the presentation and standardization of the incoming emergency response information (e.g., the use of an ERFB) and represents what I believe is the first step in the development of a baseline objective measure of performance.

Phase 1 and 2 testing was specifically directed at understanding the MEM/PICA evaluation process; however, after reviewing the archival performance videos and interviewing the SME, I realized that I needed to direct my attention toward the visual display of incoming emergency response information rather than attempting to standardize the overall assessment checklist. This focus on the visual display was the result of identifying that every one of the archival videos showed a different focus board layout. Each of the focus boards shown in the videos appeared to be different in the amount of information recorded, position of critical information, and whether a visual representation of the installation was used. It also appeared that incoming information would change location based on the scribe's preference. By altering the way in which the emergency response information is consolidated and recorded by the ERT members, I believe that the simulation environment should become more standardized. I believe that this standardization may in turn reduce the subjective evaluation of performance by allowing the SMEs to compare test ERFB displays to what might be considered a "gold standard" for a particular emergency event. The "gold standard" could be developed by SMEs so that MEM/PICA candidates have the opportunity to see what a final ERFB display should include (e.g., personnel tracking, external resource location, fire team status information).

Based on the indication that the majority of the offshore incidents examined by Sneddon, Mearns, and Flin (2006) and Jones and Endsley (1996) were the result of errors made at the perception level of SA, I believe that only by addressing incoming information would it be possible to ensure that all ERT members (including the OIM) are able to develop and maintain a shared mental model that is actively created by the entire team. I hypothesize that by standardizing the visual presentation format of the simulation data through the use of an electronic whiteboard, a reduction in subjective assessment factors could be realized. Based on the results of this thesis, I further hypothesize that differences in visual format of emergency response simulation information would influence response performance and level of situation awareness that can be developed and maintained. In addition, I hypothesize that novices would take longer than experienced offshore personnel to respond to event specific questions related to a simulated emergency situation. I further predicted that experienced ERT members would focus on qualitatively different aspects of an emergency than novice team members. Additionally, I believe that if a system failure is novel, that experienced team members may have more difficulty resisting well-established internal coping strategies (in spite of it being clear that these techniques are inappropriate for a given situation). Finally, I hypothesize that if a display of critical information related to the emergency event is available to all ERT members, team situation awareness as well as OIM awareness should be enhanced.

Support for these hypotheses can be seen in human factors research related to the optimization of dynamic visual display systems (Campbell, Mete, Furness, Weghorst, & Zabinsky, 2008, Donavon, & Triggs, 2006; Yeh, & Wickens 2001), attention and cognition (Staal, 2004), emergency management training (Kontogiannis, 1999), simulation based team training (Cooke, et al., 2000; Cooke, et al., 2001; Shapiro, et al, 2007), and situation awareness (Endsley, 2004, Wickens, 2002). However, it is the integration of aspects from different theoretical frameworks that is needed to fully understand how the performance observed in training influences real-world performance. Given that an HSI assessment approach is designed to evaluate the influence of the human, the environment, and the available technology, the following sections address the underlying subcomponents related to these main overarching factors. In order to address specific aspects of the results, each Phase is explored in isolation. After discussing the specific findings, an integrative approach is implemented to address recommendations related to human performance and human/computer interaction associated with emergency survivability.

Based on the examination of previous research and technical training documents, I had initially planned to develop an SA checklist for the subject matter experts, which could be used in future MEM/PICA evaluations. However, after examining the archival training videos, it become clear that a greater contribution to the standardization of emergency response training would be accomplished by minimizing the variability in the organization and display of incoming emergency response information. By developing a standardized display of the incoming information, I believed that ERT members would be able to identify where relevant cues could be found on the focus board.

It is also important to note that when examining the archival videos of MEM/PICA training and relevant technical documentation, I found it interesting that OIM performance is evaluated without considering the influence of team interactions. That is, by using the OIMs' performance as an indication of team performance, the SME evaluations did not appear to take into account that the of the scribe or the radio operator might influence the amount of time the OIM spends updating the team during a time-out session. Additionally, recent research indicates that a shared mental model may not exist in such a way that all individual of a team understand what is happening in a particular situation (Cooke, et al., 2003; Gorman, et al., 2006). Based on this assertion, future OIM assessments, should consider the influence of other ERT member performance.

During Phase 2 interviews with SME assessors confirmed that a standardized approach to assessments that began with a general understanding of the OPITO evaluative techniques becomes individualized over time. Of particular interest, interview results identify that not *all* of the assessors conducting MEM/PICA evaluations believe there is a need for time-out sessions, nor do they agree on a set number or duration of these sessions. These differences in evaluative approaches appear to be based solely on the SME's personal experience and a desire to improve and update the existing evaluation process. Unfortunately, this is precisely the incremental shift away from a standardized process that human factors researchers warn against (Reason, 1990; Vincente, 2003; Wickens, 2008).

However, one point that was made very clear, was that SME's put a considerable amount of time and effort into the development and implementation of the emergency response scenarios. Based on interview responses from the SMEs, I believe that this effort is in part due to the desire to increase the level of fidelity into the simulations so as to create an environment in which the OIMs and ERT members forget that they actually are in a simulation. The SMEs appear to believe that if the ERT members and the OIMs recognize that they are in, a close to reality situation, the evidence gathered during the training may provide a better prediction of how the individual will perform during a real-world emergency. This notion of the effect of high fidelity during training is consistent with suggestions by both Meichenbaum (1985) and Gonzalez (2000). Thus, SMEs and OIMs appear to believe that the MEM/PICA training program establishes an excellent baseline of emergency performance (comments made during Phase 2 interviews and Phase 3 focused discussion). In addition, Shapiro, Morey, Small, Langford, Kaylor, Jagminas, Suner, Salisbury, Simon, and Jay (2004) appear to support these observations despite statistical evidence from their findings.

Interestingly, though, both SMEs and OIMs agree that ERT scribes should have more training than is currently available. As one of the main sub-components of an HSI assessment, personnel selection procedures, identify the need to recruit individuals who are capable of performing the skills that may be required under both normal operating conditions and those during an emergency. Selection, however, is only part of the larger requirement. Training the individuals to be competent in their capacity to perform the skills requires an understanding of what tasks will be required during the emergency. The training of scribes to correctly identify what information should be placed on the ERFB needs to consider cross-modal integration to ensure that auditory information is transcribed into a relevant visual display that will benefit the development and maintenance of the ERT's situation awareness. For example, if a vessel is on a direct collision course with the offshore installation, it is not sufficient to simply write this information in a small box on the left side of the focus board. The scribe should track the incoming information by creating a timeline that makes sense to everyone on the ERT. If it is known that evacuation of the installation requires a minimum of 20 minutes to complete, the time line should clearly indicate this with a warning. Figure 49 is offered as an example of this type of timeline for collision situations. In the figure, "Closest Point of Approach (CPA)" is used by ERT members to identify when and where the incoming vessel will collide with the installation.

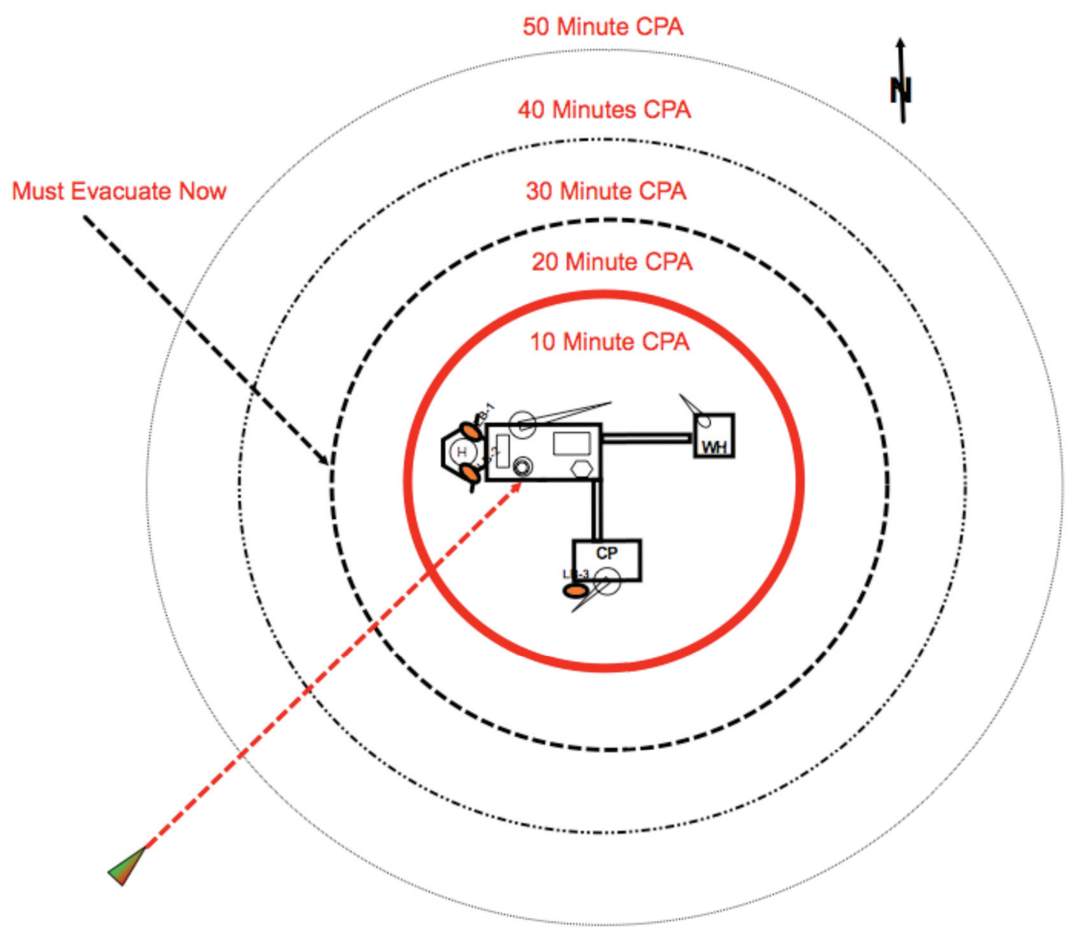

Figure 49. Example collision avoidance timeline for the ERFB.

Figure 49 also identifies the direction that the lifeboats should take to avoid the incoming vessel. As the ERFB is an interactive touch surface, the scribe only needs to move the icon of the vessel along its known track to indicate proximity to the installation. As the icon moves closer and closer to the installation, the entire ERT can visual identify how close the incoming vessel is as well as how much time they have left until they absolutely have to evacuate. In order to identify that a CPA timeline needs to be developed for collision avoidance, a lists of tasks associated with the duties of the scribe needs to be developed. I would also encourage offshore organizations to create a similar set of task lists for all ERT jobs. These lists could then be considered during personnel selection to ensure that the appropriate testing such as cognitive and physical abilities or procedural skill performance related to the specific task requirements could be evaluated.

By following these suggestions and considering the findings from each of the Phases, the risk of errors made during emergency management decision making can be reduced by sharing an understanding of the situation on the ERFB. Specifically, this shared visual display limits the probability that the OIM has a completely different idea of what is occurring. Therefore, I believe that risk exposure can be reduced in each of the three main components of HSI (i.e., human, technology, and environment).

12.2 Future Research Ideas for Testing HSI and SA in Offshore Emergency Response

As most of the emergency response training for OIMs is currently completed through a combination of low and high fidelity simulation (although the terms are not clearly defined in the assessment literature), it would be beneficial to examine simulation performance enhancements based on the following objective measures:

- Initial reaction time to answer clearly defined SA questions
- Overall amount of time required to answer queries,
- Total number of time-out sessions,
- Durations of time spent away from simulation (phone calls to shore)

- Self-rating of SA questions
- Accuracy of answers based on recorded information
- Record of HR/HRV as a measure of cognitive load

Based on the improvements in accuracy of response realized in this change to the MEM/PICA assessment process, I would recommend that any time a substantial change is made to a simulation, a full examination of the effect should be carried out. For instance, if audio cues such as explosion sounds or visual signals such as flashing lights are added to an existing simulation, objective measures should be taken to ensure that there is an actual benefit gained by adding this level of realism. In order to accomplish this recommendation, the results from this thesis are offered as a baseline by which future improvements can be compared. However, it is advisable for emergency response training facilities such as SSTL to further examine the existing archival evidence to ensure that changes to programs can be managed effectively.

Given the results from the dynamic and the final EC2 ERFB testing, I would also recommend that:

1. If the electronic surface is not used in future MEM/PICA training and evaluation, the existing whiteboard should be modified to include critical information related to the position of personnel and level of emergency.
2. This information should be centrally located to ensure that a scribe standing near the side of the focus board does not block the updated status.
3. In addition, an installation schematic large enough so that ERT members can indicate physical locations of personnel and emergency resources on the display should be developed for the existing whiteboard.
4. The installation schematic should be specific to the MEM/PICA candidates being tested to ensure that the mental image related to the simulation does not compete with one that has been established through previous experience.

5. Additionally, if a whiteboard is to be used during training and testing, crucial information related to survival (i.e., abandonment), muster stations (i.e., head counts), position of other vessels in the immediate area, incoming helicopters, and capabilities of resources should have designated box locations.
6. Pertinent information related to these boxes should be entered prior to testing so that the scribe's workload is reduced. The same would be true for information related to weather and the availability or status of lifesaving appliances such as lifeboats and liferafts.
7. This reduction in the scribe's workload should be considered as a fundamental shift in the current training procedure; however, this change is essential if the evaluative process is to reduce the impact of confounding variables, such as a lack of understand which information should be placed on the focus board, influencing the OIM's performance.
8. If the goal of the MEM/PICA training is to evaluate the emergency response capability on the Installation Manager, then the testing should not be skewed by variables that are beyond the control of the individual being assessed.

12.2.1 Enhancement of SA Testing for Offshore Emergency Response

When exploring SA with regard to the MEM/PICA performance, SAGAT measurements do not appear to be appropriate for future testing. Blanking the screen information clearly showed a reduction in accuracy of response and an increase in response times regardless of experience or configuration type. The ERFB information would never intentionally be blocked out during an actual emergency; therefore, it is unlikely that an estimate of an OIM's or ERT member's simulation performance, in which the screen has been covered, would represent actual performance in a real-world situation. Given the results of Phase 4 testing, I would suggest that SA be measured; however, I believe that cognitive probes posed while the screen is visible would represent a more realistic approach to gathering physical evidence for emergency response performance. I would further recommend that SA self-rating questions be developed for each of the four main simulations. OIM responses to these questions could then be used to establish a performance database that could be used to gauge the effectiveness of future MEM/PICA simulation changes.

In order to examine future SA enhancement of focus board configuration, testing should include visual search information to ensure that an understanding of how the placement of incoming information placement affects awareness. The baseline data presented here can be used as a guide to establish what information is being used to develop and maintain SA under different scenarios; however, more data are needed to ensure that the ERFB design accounts for slight variations in different scenarios. Additional ERFB templates should also be developed to explore cognitive loading related to SA in different scenarios. These manipulations of box location and pre-entered data under various conditions could then be used to establish which information is crucial during a particular emergency and which information may increase the cognitive demands of the operator.

12.2.2 Future ERFB Enhancements

To further enhance the capabilities of the ERFB I believe a spreadsheet-like function should be embedded into the POB (Person On Board) boxes. This spreadsheet type program could tally all of the columns related to POB so that the scribe does not have to constantly add the numbers to arrive at a total. While completing Phase 5 data collection with the MEM/PICA members, I witnessed several points during the eight simulations in which 2 scribes, the operations lead, and the OIM were engaged in tallying the POB lists to ensure they all knew exactly how many people are accounted for on the installation. These tallied numbers should then be reflected into a central box so that the entire ERT can quickly reference the POB status. Furthermore, when the POB number matches a target value, the box could change colour (from red when below expected value to green when numbers are met) and/or fade slightly. Ideally, this change in colour would draw the OIM's attention long enough to update his or her situation awareness, thus reduce the cognitive resources necessary to achieve a high level of SA. If this feature is included in only the centrally located boxes, the change in color or fading should allows the OIM or ship's captain to maintain a clear understanding of what is happen without having to search the entire status board.

One further recommended modification to future ERFBs would be to integrate external viewing of the focus board information. This information should be made available to all personnel assisting in the emergency response as well as those waiting in muster stations. Given the existing software available for SMARTboards, personal data appliances (PDAs) could be made available at all muster stations or satellite command posts. It might also be beneficial if muster checkers located at each of the gathering points had the ability to electronically input the total number of individuals currently in their respective stations directly to the ERFB. This updated information would reduce the need for multiple radio and telephone calls, thus decreasing the amount of radio chatter and the need for an individual to update the board every time a new number comes in. This electronic inputting system could also allow muster station personnel the ability to check current numbers from other stations so that they could update individuals waiting to be told what is happening. It can be assumed that if there were a noticeable reduction in cognitive and physical workload, there would be surplus resources that could be allocated to other tasks such as increasing the level of situation awareness (Endsley, 2000).

Onshore personnel located at remote command posts or within the search and rescue community should also be given access to view the ERFB as it is populated in real-time. It is standard practice within the offshore emergency management system to organize key personnel onshore to offer any assistance and expertise available to the emergency site. Typically, the onshore group must rely on faxed information from the offshore installation or telephone calls to the control room. This information is then placed on a whiteboard similar to that located in the control room. However, if, the ERFB system is used, onshore personnel can view the exact information located on the focus board in the control room. Additionally, if search and rescue personnel located at a rescue coordination center had access to the ERFB information, they could develop a better understanding of the emergency resource needs.

12.3 Limitations

The primary research challenges for this project are inherently related to identifying and quantifying mental processes associated with emergency response. Whether conducting SA, information processing, decision making, or job analysis assessments, it is, under certain circumstances (natural settings), difficult to identify precisely which attributes of human performance are related to slower reaction times or final selections made during decision making tasks. Furthermore, the limitations associated with acquiring data in the dynamic environment of an offshore emergency response training simulation highlight the need to address real-world constraints that are likely to be experienced in an installation control room.

Limitations also existed in the amount of available SMEs interviewed in Phase 2 of this research. Ideally, I would have been able to interview OPITO certified assessors from different training organizations in order to develop a better understanding of the six global assessment factors. Similar limitations existed during the focused discussion of the ERFB development. If additional OIMs had been available, the first iteration of the focus board may not have had as many of the difficulties related to the drop down boxes. When testing the static and dynamic ERFB configurations, it would have been beneficial to increase the number of individuals with some offshore experience so that a more even distribution of results could have been used to develop the final ERFB iteration. Furthermore, by assuming the role of the scribe, I was not blinded to which configuration was being used; therefore, this may have influenced the results. However, all recordings of the two configurations were analyzed to compare the amount of available information, and no differences were founds. Therefore, although limitations existed in regard to the scribe position; in this instance, not having different personnel (i.e., SSTL instructional staff) perform the tasks should be seen as a benefit.

Any conclusion related to HRV must be tempered by the fact that several of the participant's recordings from the polar monitor were incomplete. This lowered the number of recordings and limits the real-world applications associated with the link between HRV and cognitive load. Finally, the limited number of available OIMs attending the MEM/PICA may have influenced the discussion of usability. It would be preferable to have at least 10 OIMs complete testing on the final ERFB iteration, however, this test would require more than 12 months to complete as there is rarely more than 2 OIMs on any one MEM/PICA course.

Based on these limitations, a cautionary approach is recommended when considering the full implementation of an ERFB into the offshore emergency management system. Consideration of the environmental conditions that may exist in an offshore setting should be taken into account before integrating and ERFB as both illumination and power supply may affect the user interface. Additionally, a modification to the existing system may result in changes to ERT interactions that were not recorded in this thesis. Therefore, a larger sample size may be necessary to identify further changes in performance.

These limitations highlight difficulties in assessing human performance, particularly in emergency situations, and present one further reason for the use of HSI assessments, in that both qualitative and quantitative measures could be used within a proposed mixed-research method. This approach to identifying human interaction as it relates to personnel selection, safety and performance within the offshore environment further represents a considerable step forward in the offshore emergency response management system.

12.4 Recommendations

Although much of the results and discussion were considered in isolation, the following recommendations are based on all Phases of this research and reflect a holistic Human System Integration approach. Furthermore the following recommendations echo those made by Jones and Endsley (2004); but, extend them to the offshore oil and gas environment. The primary focus of this thesis was based on the concern that current MEM/PICA assessments lack standardization that is based on empirical evidence to support what is considered one of the best offshore emergency management training systems in the world (personnel communication with OIMs and MEM/PICA candidates). Therefore Each Phase is considered with regard to possible improvements.

12.4.1 Phase 1 Recommendations

Based on the observational and illustrative methods used during this initial Phase of research, I would recommend that archival videos be examined in more detail in order to identify baseline parameters that can be used if future changes to the MEM/PICA course are considered. The establishment of a baseline is important to ensure that a SME shift in course presentation follows a manageable change process.

12.4.2 Phase 2 Recommendations

The results from the SME interview conducted in the second Phase of research revealed that differences exist in the way MEM/PICA evaluation criteria are utilized. Therefore, I recommend that SMEs conduct annual workshops to discuss recent developments in MEM/PICA assessment procedures. I further recommend that a third party assessor audit MEM/PICA course evaluations based solely on physical evidence gathered during a randomly selected course. This audit could take place in conjunction with the workshop and could be used to assess inter-rater reliability of evaluation processes.

12.4.3 Phase 3 Recommendations

Phase 3 was extremely valuable in developing the ERFB configurations. In regard to the human factors engineering sub-component of HSI, it was important to involve end users and expert emergency response assessors in the early Phases of the ERFB system design. Through this process it was possible to identify and reduce interface difficulties that could have potentially contributed to the development of SA errors. This fundamental aspect of user-centered design ensures that the end product has “buy in” from the primary stakeholders as well as ensuring ecological validity (Endsley, Bolte, & Jones, 2003). Additionally, by considering the three main components of HSI (human, environment, and technology) when testing the EC2 ERFB configuration, it was possible to identify user interface changes that could be considered for future design changes. Therefore, I recommend that any further development of the ERFB should involve usability testing with end users.

12.4.4 Phase 4 Recommendations

Based on the findings from Phase 4 testing, I would recommend that an ERFB similar to the dynamic configuration be used in all future MEM/PICA courses. I would further recommend that offshore installations are equipped with interactive focus boards to enhance the development and maintenance of the ERT's situation awareness. The benefits identified from using this type of configuration were particularly important when considering that most of the participants from this Phase of testing had no offshore experience, yet were able to answer emergency response questions at a level that would be expected during any MEM/PICA course.

12.4.5 Phase 5 Recommendations

Comments made by the MEM/PICA candidates and the SME conducting the emergency management performance evaluations clearly indicate that a dynamic ERFB is of considerable benefit when tracking personnel movements and external resource allocation. As these two components are fundamentally important during a real-world emergency report, I further recommend that a similar system be implemented on offshore installations.

12.5 Final Comments

Why do some individuals know what is going on around them while others appear to lack even a basic understanding of the situation? Endsley and Bolstad (1994) have suggested “some individuals are better at SA than others” (p. 260). Unfortunately, no definitive answer has been provided to explain why these individual differences exist. One possible reason for the lack of clear consensus lies in the diversity of the measurements as well as the differences in human capabilities. Differences in capabilities associated with decision making, information processing, and performance have been well documented and suggest that it is best to consider a combination of abilities that are enhanced through experience and training (Cooke, et al. 2007). However, when considering the level of SA attainment, all measurements ultimately reduce to the performance of the individual or group. And although SA is not considered decision making (Andre, 1998; Endsley, 1995a, b), performance is inextricably linked to the decisions made and the actions taken. The decision to act or ignore the system/environmental cues is further based on the individual's assessment of the situation, level of arousal, attentional resource capacity, and experience.

From an individual point of view, Gugerty and Tirre (2000) note that when testing navigational skills, general cognitive abilities and working memory limitations are predictive indicators of situation awareness. Durso and Dattel (2004) suggest that when considering air traffic controllers, it is short-term memory that influences the level of situation awareness that can be attained. Further still, Sohn and Doane (2003) showed that SA level could be predicted for novice pilots if working memory capacity was considered. The Enhancing Safety Through Situation Awareness Integration (ESSAI) (2000) taxonomic structure used in a review of SA proposes a dichotomous relationship between internal and external factors that affect the development and maintenance of SA in a direct or indirect manner. This dichotomy is used to represent "those factors that are related to the cognition of the individual, and those that are related to the task environment" (p. 43). If however, these two factors are considered in more detail, it is difficult to reconcile the point at which one factor no longer influences the other and becomes an independent component that excludes all aspects of the first. For example, at what point does the perception of the elements in the environment stop being influenced by experience, goal-driven behaviour, and ability and start being influenced by stress and workload, design, automation, rules, and procedures? It could be argued that the components represent a multidimensional rather than dichotomous influence on the development and maintenance of SA.

Given the results and discussion of this thesis, Figure 50 depicts my understanding of the relationship between the current research testing of the ERFB and the underlying HSI approach. In the figure it can be seen that although the main components of technology, human, and environment are directly linked to HSI, it is the sub-component links that help identify how situation awareness and objective performance measures can be used to understand why some individuals out perform others during an emergency. Only by detailed examination of these links between each of the factors will it be possible to identify specific interventions (technological or environmental) that may aid in survival.

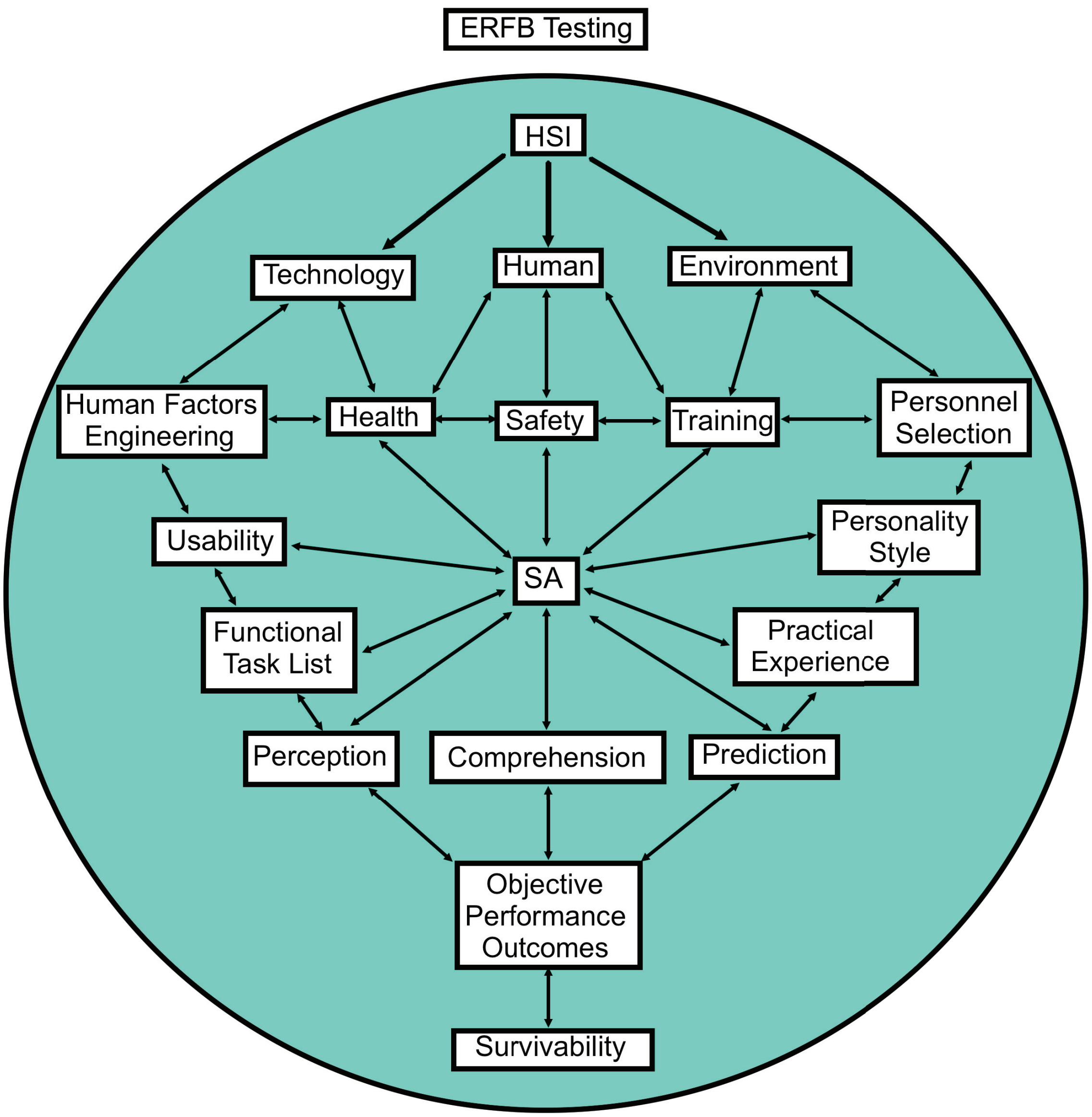

Figure 50. Link between ERFB testing and HSI investigation.

Based on the links identified in Figure 50, it is the multidimensional aspect that lies at the heart of HSI and only by considering the influence exerted by various factors will it be possible to make a prediction of performance based on training or personnel selection or the usability of a particular technology (Henningar, 2001). It should be kept in mind however, that each component shown in the figure contains a multitude of sub-components that may influence the way in which an individual will perceive, comprehend and predict the response that will best achieve the desired goal. For example, documenting the tasks that will be carried out by the ERT members and identifying bonifide occupational requirements should be used to inform future personnel selection processes. Human factors engineering should be informed by the necessary equipment requirements to perform the ERT job tasks while considering the environment in which the skills will be completed. Training outcomes such as those outlined for MEM/PICA courses need to be based on the occupational requirements while utilizing the equipment that has been tested through a HFE process. Safety goals and risk reduction can only be reached if the appropriate HFE assessments have been completed, the occupational requirements established and the "right" people have been selected for the specific job.

From the findings outlined in this thesis, approaching emergency response with the intent to add more rigorous investigation to the assessment process can reveal significant benefits. This thesis represents an important first step in extending human systems integration and situation awareness research into an industry that is continuously increasing the complexity and automation of operating systems in more remote locations. Meeting the goals of integration between the human, technology and the environment will ultimately affect survivability, which, in the end, is the primary goal of conducting this research.

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Appendix A – OIM (DEP OIM) ASSESSMENT PROFILE (SSTL, 2008)

OPITO APPROVED STANDARD | GROUP TITLE: MANAGING OFFSHORE INSTALLATIONS | UNIT: CONTROLLING EMERGENCIES (CORE UNIT)

CANDIDATE		TITLE		PLATFORM		COMPANY		SHEET #	
SCENARIO #		OF		ENDORSEMENT		TYPE OF INCIDENT			

ELEMENT & PERFORMANCE CRITERIA	Above Std.	ACCEPTABLE	Below Std.	OBSERVATIONS/COMMENTS
1. ASSESS SITUATION:				
1.1 Obtain, evaluate, & confirm information				
1.2 Interpret evidence validly				
1.3 Make valid decisions				
1.4 Identify contingencies				
1.5 Review potential outcomes				
2. TAKE EFFECTIVE ACTION:				
2.5 Develop plan				
2.5 Review plan				
2.5 Update plan				
2.2 Use appropriate resources				
2.6 Put resources in place quickly				
2.7 Coordinate and direct E.R. Teams				
3. MAINTAIN COMMUNICATIONS				
3.1 Inform essential personnel of emergency & progression				
3.2 Inform relevant personnel of action plan				
3.3 Promote common understanding amongst EMT				
3.4 Report status of situation to installation staff				
3.5 Maintain key events & communication record				
3.6 Identify & utilize alternative means of communication				
4. DELEGATE AUTHORITY TO ACT				
4.1 Decide which activities should be delegated				
4.2 Delegate activities				
4.3 Check understanding of those delegated to act				
5. MANAGE SELF & TEAM PERFORMANCE				
5.1 Request assistance & action from others				
5.2 Inspire confidence within team				
5.3 Recognize strengths & weaknesses within team				
5.4 Maintain appropriate degree of detachment				
5.5 Use safe working practices				
6. DEAL WITH STRESS				
6.1 Recognize symptoms of stress in team				
6.2 Take effective action to maintain activities				
6.3 Take effective action to reduce stress levels				

Appendix B
Helicopter Crash Simulation Video Transcripts

ERT Member Colour Code	
Radio Operator (RO)	
Offshore Installation Manager (OIM)	
Scribe	
Fire Team Lead (FTL)	

Event	Time (min)
Atlantic Eagle (standby vessel calls the RO for a radio check)	0:07
Transport helicopter call rig to confirm helicopter landing officer (HLO) is in position	1:18
Helicopter pilot check in (on final)	1:22
HLO calls pilot to confirm final	1:30
Pilot confirms deck status and notes that one of the landing lights are out on the deck	1:34
HLO indicates that one of the heli-deck crew members will check on the light	1:45
Pilot calls HLO to confirm wind direction	1:51
Shell Shaker (ship) calls RO about a possible sheen on the surface of the water	2:12
Ongoing vessel operations are interrupted due to a possible spill which has created a sheen on the water's surface	2:26
Radio operator calls the King Fisher (fueling ship) to get a visual inspection to confirm the spill	2:45
Radio operator calls for the OIM to discuss the possible spill	2:53
OIM arrives in control room	3:00
Discussion about pumping operations commences	3:05
The fueling vessel TERRA NOVA (FPSO) (King Fisher – KF) is told to halt pumping	3:16
Helicopter pilot calls HLO	3:20
Radio operator calls the King Fisher vessel	3:36
King Fisher responses and asks what the problem is	3:40
Radio operator informs King Fisher of the possible sheen on the water	3:50
Pumping is Halted	4:12
Standby vessel (Atlantic Eagle – AE) calls helicopter pilot to indicate that the ship crew can see a fire in aircraft's port engine	4:17
Pilot confirms the fire and tells the rig that he is coming in hard	4:28
Pilot calls mayday – mayday – mayday – mayday	4:35
Helicopter crashes on deck	4:58
Immediately after the crash a fire on the helideck is reported to the radio room (RR)	5:00
General Alarm is sounded and all personnel are requested to make their way to the appropriate muster station and to bring survival suits	5:05
Emergency response personnel arrive in the control room	5:06
An explosion is reported to the RR (not sure who or where the call is coming from)	5:22
Scribe starts to input information on the focus board	5:25
KF calls RO to indicate that the helicopter's tail section is about to fall into the water and that they plan to break away before it falls on top of them	5:30
KF confirms a pull away and that the lines have broken	5:46
Radio operator calls KF and asks if they could stay within 500 feet so that they can assist if necessary	5:51
Atlantic Eagle (standby vessel) calls control room about launching their fast rescue craft (FRC)	6:11
Radio operator confirms that the OIM would like their FRC in the water	6:20
Atlantic Eagle confirms that their FRC is being readied for launch	6:32
KF reports that they have ruptured one of their lines (spilling oil on the water) during the pull away	6:53
OIM requests that the manifold valves on the rig be closed to prevent further oil leakage	7:00

On scene fire commander (part of the emergency response team) begins a situation update	7:14
OIM calls for a time out	7:47
Radios and telephones continue to be answered (fire team 2 calls in to confirm their position and status of fire and personnel on board – P.O.B. information comes in)	7:50
OIM calls for a time away again Time out is started (1) Time out includes a quick recap of events ✪ Crash ✪ Number of personnel onboard the helicopter (9 P.O.B. + 2 pilots = 11) ✪ Fire on helideck ✪ KF difficulties ✪ Confirmation that the rigs fuel manifold has been shut ✪ P.O.B. of rig JRCC has been notified (RO)	8:24
Phone rings	8:45
OIM asks if there are any further suggestions or comments ✪ Confirmation that the drill floor personnel have completed their shut down is requested ✪ Movement of personnel from the heli lounge to the muster stations is suggested	8:52
Phone rings (AE calls in)	9:13
Time out is ended	10:13
Drill floor personnel call control room to confirm that the well is secure	10:22
Focus board is updated	10:24
Joint Rescue Coordination Center (JRCC) calls to confirm that a rescue helicopter is on its way to the site	10:49
Medic calls to confirm the number of causalities	11:05
Medic requests information concerning triage in the galley	11:12
RO confirms the situation is been assessed	11:13
OIM asks the radio operator to contact AE so that they can get in touch with JRCC to verify status of the rescue team	11:19
Medical first responder team is formed and equipment is moved to the helideck	11:20
OIM requests situation update from on scene fire commander	11:24
On scene fire commander begins situation update – fire team numbers are confirmed (FT 1 = 9 and FT 2 = 7)	11:26
AE calls in for update and indicates that they are now positioned 500 feet away from the rig	11:39
Radio operator responses to AE call and asks if the emergency response equipment can be placed on the starboard side of the rig deck	11:42
AE calls to check on starboard crane operator	11:50
Rig crane operator confirms that he is ready to move the emergency response equipment to the starboard side of the rig	12:20
Aviation fuel is reported in the water by AE operator	12:34
Status of TERRA NOVA (FPSO) is requested by OIM	12:38
A call is made to the AE from the TERRA NOVA (FPSO) “don’t call the boat, we need it” (is referring to the FRC that is already in the water)	12:41
TERRA NOVA (FPSO) operator confirms that they have received the instructions and will comply	12:50
Radio Operator calls JRCC	13:10
Muster station numbers start to come in and are recorded on focus board (not sure if they have all of their numbers) – OIM checks status board	13:20
Rig radio operator calls starboard crane operator	13:37
Crane operator responses and confirms that the emergency response equipment is to be placed on the starboard side	13:42

Fire team 2 calls fire team lead with updated status of fire	13:50
OIM requests that the spare crane operator be moved to help fire team 2 with the helideck	14:12
AE calls radio operator to request that fire team 2 moves to another radio frequency	14:37
OIM calls a time out in 30 seconds	15:00
Request for JRCC response time is made by radio operator (OIM request)	15:17
OIM asks radio operator to confirm that the AE is in position (close standby)	15:19
Time out is called by OIM (2) Recap information is as follows: ✪ Full P.O.B ✪ Fire team is making good progress ✪ Location of the crash is confirmed to be on the port side of the helideck ✪ Deluge system is not going to be used ✪ "is anyone missing" ✪ "did anyone get out" ✪ the only thing that AE has said is that there is fuel in the water	15:20
Radio call from rig deck to control room	16:45
OIM requests that the AE FRC be launch to look around	16:50
Time out is ended (instigated by call from KF)	17:04
KF calls in to check status and confirm that the tail section has fallen into the water on the port side	17:04
Radio operator confirms that they have received the message concerning the tail section	17:16
KF calls control room to indicate that the tail section is on the port side and is "sinking fast"	17:37
FRC from the AE is launched to see if they can recover any survivors	17:56
AE's FRC contacts radio operator to confirm that they are now in the water next to the tail section	18:00
Radio operator asks AE's FRC if they can see any survivors in the water or still in the tail section	18:05
AE's FRC does not see any personnel in the water at this point	18:08
Radio operator calls AE to see if the tail section is drifting (away or under rig)	18:41
Radio operator asks AE to pull in closer to have a better look at the tail section	18:56
Emergency response team waits for confirmation that the AE is closer to the tail section of the helicopter which is still at the surface but mostly submerged	19:30
On scene fire commander calls control room with situation update ✪ Both fire teams are in position and the progress is moving alone ✪ Fuel is still burning around the helicopter ✪ Helicopter will be too hot for anyone to go inside	20:11
Fire team 2 calls FTC to confirm that the fire is still burning "but its not getting any worse"	20:54
AE is positioned next to rig and is awaiting the crane operators instructions (emergency response equipment)	21:07
AE's FRC calls control room to confirm that they alongside the tail section and no one appears to be in the water	21:28
JRCC calls radio operator with an 1 hour ETA	22:17
King Fisher calls control room	22:21
Crane operator call radio operator to suggest that someone from the helicopter might have fallen into the water	22:54
Radio operator calls crane operator to indicate that they have people looking in the water	23:01
AE calls the control room	23:22
OIM calls time out in 30 sec	23:52
Starboard crane operator calls to indicate that the emergency response kit from the AE has been moved onto the deck	24:01
Radio and phone calls continue to be answered	24:10
Time out is called by OIM (3) Recap information is as follows: ✪ P.O.B. numbers are confirmed (139 on rig + 5 from helicopter, 2 pilots and 4	24:27

passengers missing) ✪ Rescue helicopter is 1 hour back ✪ AE and KF are standing by ✪ AE's FRC in the water ✪ Fire needs to be put out and the recover of 6 individuals ✪ Drift is discussed with regard to survivors	
Deck crew call radio operator	25:36
Time out continues Further discussion concerning drift of both survivors and tail section	25:40
Rescue helicopter (Rescue 911) calls in and ends the time out	26:00
Rescue 911 confirms that they can take 4 personnel back to shore	26:10
AE's FRC confirms that they have rescues 2 survivors in the water (swimming)	26:57
Rescue 911 contacts rig control room to indicate that they are now 50 mins away and inquire about casualties	27:33
Starboard crane operator contacts the control room to indicate that the emergency response kit has been placed on the starboard forward deck and is secure	28:03
OIM checks focus board updates	28:20
OIM uses general personnel address (PA) to brief rig crew about the status of the situation	28:37
OIM requests an update from JRCC	29:47
AE calls rig RO to indicate that the 2 casualties are now onboard and the FRC has been launched again	29:53
On scene fire commander calls control room with a situation update ✪ Fuel is still leaking from the helicopter and it is not safe for any of the team members to go inside	30:13
Medic calls in to update casualty status	
AE calls control room to indicate that their medic is assessing the 2 casualties and will report back as soon as they know more	31:03
OIM gets drawn into a conversation with the radio operator about how to best move the casualties and where to put them	31:05
AE indicates that they can take 2 casualties	31:10
JRCC can take 4	31:20
KF is considered for possible casualty transport	31:22
OIM calls time out in 30 seconds	31:25
Time out is called by OIM (4) Recap information is as follows: ✪ Fire is out on the helideck ✪ 3 casualties from helicopter have been accounted for ✪ AE has 2 casualties to go to KF ✪ 2 helicopters are on their way (1 from JRCC and one from Cougar Helicopters)	31:53
AE calls rig control room	32:01
Time out continues ✪ P.O.B. stands at 139 on the rig + 5 from the helicopter ✪ 6 personnel still missing (2 pilots + 4 passengers) ✪ JRCC helicopter is 50 minutes away ✪ TERRA NOVA (FPSO) is on standby for SAR techs	32:03
AE calls rig control room	33:55
Rescue 911 calls and ends time out	33:58
Rescue 911 indicates that they are actual 55 minutes away	34:15
Rescue 911 calls rig control room to confirm that they will be able to take a total 4 casualties onboard their helicopter for med-evac	34:43
AE calls rig control room to update casualties status	35:00
AE medic confirms that one of the casualties has a broken leg	35:34
Radio operator tells AE medic that the med-evac helicopter in on its way	35:57
Medic indicates that he is busy in the galley and needs some help	36:05

OIM decides to send three roughnecks from the drill floor to help the medic	36:16
OIM checks status board and time (presumable to consider time out)	36:28
AE calls control room to confirm that their FRC has reported that the tail section has sunk below the surface	37:04
Radio operator asks the AE to keep its FRC in the water (port side) to continue searching	37:15
On scene fire commander calls control room to indicate that the aircrew are still inside the helicopter	37:29
AE calls control room to ask what they are going to do with the casualties	37:50
Radio operator asks AE to standby until he can discuss the matter with the OIM	37:58
Radio operator briefs OIM about the AE and indicates that they could take one more casualty and then transport all three over to the TERRA NOVA (FPSO)	38:01
OIM asks if there is anyone on the AE that can deal with the other casualty (i.e. advanced first aid)	38:29
A discussion between the OIM, radio operator, and scribe begins concerning the transfer of casualties from the AE to the TERRA NOVA (FPSO). ✪ It is decided that the two casualties on the AE should be transfer to the TERRA NOVA (FPSO) ✪ OIM reaffirms that the Rescue Services (JRCC) helicopter can only take four critically injured casualties ✪ Radio operator indicates that the KF is still out at 300 meter and asks if he should call them into the close standby position when the AE has begun to move to the TERRA NOVA (FPSO)	38:44
Radio operator calls AE	39:09
OIM calls a time out in 30 seconds (5)	39:19
Radio operator passes the transfer plan information to the AE (transport their 2 casualties to the FPSO)	39:27
AE confirms the transfer plan and starts to move away from the rig	39:31
Radio operator calls the KF	39:35
Medic in the galley confirms that the three roughnecks have arrived	39:39
Radio operator requests that the KF move into close standby position as soon as the AE has move off position	39:44
OIM calls time out	39:54
AE calls control room	39:59
Time out continues Fire is out on the heli-deck	
AE calls control room again	40:11
Time out continues AE has moved to transfer their 2 casualties 2 med-evac helicopter are in their way (1 JRCC and 1 from Cougar) Rescue Services helicopter will take 4 critically injured casualties from the FPSO Discussion about casualties movement occurs	
OIM ends time out	41:17
Radio operator calls AE	41:18
AE confirms that the 2 casualties have been transferred to the FPSO	41:32
OIM makes general announcement ✪ fire is under control ✪ all helicopter personnel have been accounted for ✪ movement of casualties ✪ remain at muster station until further notice	41:33
Radio operator informs the scribe that the KF is now in close standby position	42:07
Focus board is updated	42:10
AE calls control room to indicate that their FRC is still in the water and requests that KF launches their FRC to relieve the AE crew	42:14
Radio operator indicates that the AE FRC should stay in the water and continue searching	42:26
On scene fire commander calls radio operator with a situation update	42:40

✪ 3 personnel are still onboard the helicopter (2 pilots and 1 passenger) ✪ they will need lots of medical help	
Location of all P.O.B. is discussed (update of focus board)	43:00
Rig radio operator calls KF to ask FRC crew to suit up	43:04
Radio operator asks AE FRC to wait until KF is waterborne before recovering the boat	43:19
AE FRC confirms that as soon as the KF FRC is waterborne they will make their way back to their own ship for recover	43:37
OIM discusses location of all P.O.B. (focus board update)	43:41
OIM asks “what’s the problem with the numbers on the status board”	43:51
Scribe says “personnel are not all accounted for”	43:57
OIM clarifies that there are two personnel (pilots) still inside the helicopter (this seems to end the discussion about numbers)	44:01
Fire team 2 call radio operator to indicate that the helideck is unusable for rescue operations	44:21
KF calls rig control room to confirm that their FRC is now waterborne	44:30
Radio operator calls AE to indicate that they can now recover their FRC	44:44
AE FRC confirms that their FRC is now on its way back to the ship	44:56
Rescue 911 calls with an ETA of 40 minutes	45:00
OIM requests the ETA information to be confirmed	45:04
RO calls Rescue 911 to relay OIM’s request	45:06
Rescue 911 confirms time and begins discussion about winching the SAR techs to the deck of the rig	45:07
Fire team calls on scene fire commander to indicate that they see the 2 pilots still in the helicopter	45:38
Names and condition of casualties are updated on the focus board	46:16
OIM discusses casualty status and location with team (checking status board)	48:20
Team member indicates that one of the casualties is missing information concerning medical status	48:33
OIM calls a time out in 30 sec	48:55
AE calls rig control room	49:31
Time out is called by OIM (6) Recap information is as follows: ✪ Rescue helicopter will arrive in 40 minutes ✪ Medic needs to be called to update status ✪ Medic is continuing medical treatment ✪ The fire is out ✪ Fire team is confirming that the 2 pilots are still onboard the helicopter ✪ Fire team will attempt to rescue the 2 pilots ✪ Still waiting for helicopter to arrive	49:33
Telephone rings	50:14
Time out continues ✪ JRCC helicopter is to pick up casualty from FPSO and then winch 3 from the rig ✪ OIM asks if anything is missed	50:15
Fire team 2 lead calls control room to indicate that there is concern about starting equipment on the heli-deck with all of the fuel on the deck	51:15
OIM ends time out	51:22
Assessor ends the exercise	51:27

Appendix C
SME Interview Questions (Phase 2)

Question Session (120-180 minutes including break)

The first 5 questions are designed to get a better idea of everyone's background and each person will answer in turn.

1. How many years of offshore experience do you have?

2. When did you receive your OIM or ERL appointment?

3. How many MEM/PICA (or similar) courses have you attended?

4. How many OIM assessments have you had (approximately)?

5. How many times have your assessments been audited by OPITO/Cogent?

The remaining 5 questions are designed to identify key aspects of the MEM/PICA assessment process. The focus group facilitator will explain each of the following questions to ensure that the participants can discuss their experiences and opinion of the assessment process. This section of questions will involve all participants without requiring everyone to take turns:

6. Of the six global assessment aspects of OIM/ERL certification, which do you believe is most important to success during a real-world emergency and why?

7. Please explain which components of the six global assessment criteria you believe influences the assessment of a candidates' performance most and why?

8. How important is the concept of situation awareness to effective emergency management success and why?

9. How effective do you think the assessment process is in predicting performance during a real-world emergency and why?

10. What changes could be made to the assessment process, which would aid in standardization?

Appendix D
Offshore Installation Manager (OIM) and Emergency Response Lead (ERL) Focus Discussion Questions

Question Session (120-180 minutes including break)

The first 5 questions are designed to get a better idea of everyone's background and each person will answer in turn.

1. How many years of offshore experience do you have?

2. When did you receive your OIM or ERL appointment?

3. How many MEM/PICA (or similar) courses have you attended?

4. How many OIM assesses have you had (approximately)?

5. How many times have your assessments been audited by OPITO/Cogent?

The remaining 5 questions are designed to identify key aspects of the MEM/PICA assessment process. The focus discussion facilitator explained each of the following questions to ensure that the participants could discuss their experiences and opinion of the assessment process. This section of questions involved all participants without requiring everyone to take turns:

6. Of the six global assessment aspects of OIM/ERL certification, which do you feel is most important to success during a real-world emergency and why?

7. Please explain what components of the six global assessment criteria do you feel influences the assessment of a candidates' performance the most and why?

8. How important is the concept of situation awareness to effective emergency management success and why?

9. How effective do you think the assessment process is in predicting performance during a real-world emergency and why?

10. What changes could be made to the assessment process, which would aid in standardization?

The last set of questions pertain directly to the development of an electronic Emergency Response Focus Board (ERFB). These questions are designed to gather your opinion related to placement of specific information and ecological application.

11. What information is most important to the management of an offshore emergency?

12. Do you think that the entire ERT should be able to view the OIM's checklist?

13. Do you think that critical information should be centrally located or is it better to spread this information out?

14. Should different colours be used to denote different resources and if so what colours are better for identifying the specific resource?

15. Does the ERFB need to have a picture of the offshore installations?

Appendix E
Demographic Questionnaire

Please complete the following questions. If you are not sure how to answer a particular question, please ask for assistance.

1. Name____________________PLEASE PRINT CLEARLY______________
2. Age______________________?
3. Sex – M ☐ F ☐
4. Do you play computer based strategy games Y☐ N☐?
5. How many years of computer gaming experience do you have________?
6. How many times a week do you play computer games______________?
7. How many hours in a week do you spend reading online text_________?
8. How many years of offshore experience do you have_______________?
9. Have you ever been involved in an emergency situation Y☐ N☐?
10. Have you ever been involved in an emergency situation that required you to help coordinate the movement of personnel or resources Y☐ N☐?

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Appendix F
Cognitive Probe Questions (Used During Simulation Timeout Periods)

The following questions are designed to assess an individual's level of situation awareness. These questions are to be asked during predetermined timeout periods. The timeout periods will be divided into two distinct categories: 1) simulation freeze with information available, and 2) simulation freeze without information available. The second condition will be accomplished by covering the SMARTBoard 680i information by placing a lens cover over the built-in projector. Between three to five questions from the following list will be randomly selected for each simulation freeze; however, certain questions will only be asked during specific simulations.

1. How many minutes will it be before the incoming transport helicopter arrives at the installation?
2. How many people are currently in muster station 1, 2, 3, etc…?
3. How many firefighters from team 1 or team 2 are assembled at the helideck?
4. How many people (crew and passengers) were on the incoming transport helicopter?
5. Is the missing person from the installation, the helicopter or the standby/supply vessel?
6. How many casualties are currently in sickbay?
7. Has JRCC (Joint Rescue Coordination Center) been notified?
8. Where is the standby vessel currently located?
9. Where (how close to your position) will the contact (incoming vessel) be in 10 minutes?
10. If you decide to evacuate personnel, what direction should the lifeboat travel toward?
11. What is the current muster total?
12. How long before the fire is under control?
13. What external resources have been deployed from shore?
14. What is the current status of the well?
15. How will the weather affect the situation in 1 hour?
16. Have the installation personnel being informed of the situation?
17. Has the general alarm been sounded?
18. What evacuation method would you use if you had 2 hours to move everyone?
19. Has the captain of the standby vessel been informed of the situation?
20. Is any information missing from the focus board?

Additional questions may be developed if the need arises.

Appendix G
Emergency Response Situation Awareness Self-Rating Scale

Please answer the following questions true or false and then indicate your level of confidence (low or high) that your selection is correct.

	Assessment	Confidence
1. A total number of 15 people were assembled at muster station 1.	T☐, F☐	Low ☐, High☐
2. All casualties were safely transported to a location where they could be effectively treated.	T☐, F☐	Low ☐, High☐
3. Fire Team 1 had a full compliment of 6 personnel.	T☐, F☐	Low ☐, High☐
4. The standby vessel remained in the same location throughout the entire incident.	T☐, F☐	Low ☐, High☐
5. All personnel were mustered at their appropriate stations.	T☐, F☐	Low ☐, High☐
6. Search and rescue personnel from a military helicopter were used to treat casualties.	T☐, F☐	Low ☐, High☐
7. All shore-based personnel were notified of the situation.	T☐, F☐	Low ☐, High☐
8. All installation personnel have been made aware of emergency response efforts (PA announcements).	T☐, F☐	Low ☐, High☐
9. I was aware of all required information throughout the simulation.	T☐, F☐	Low ☐, High☐
10. All information has been logged on the emergency response focus board.	T☐, F☐	Low ☐, High☐

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Appendix H
Focus Board Usability Questions

The following questions are designed to assess the subject usability ratings of participants regarding the three focus board configurations. These questions are to be asked at the end of the testing session and after the self-rating of situation awareness questionnaire has been completed. The audio recording device should remain on during this question period.

1. How effective was the focus board configuration in keeping you up-to-date? Please mark (dash on the line) the scale below.
   1 = (not at all effective) to **10** = (very effective)

   1 5 10

2. How satisfied were you with the focus board layout on a scale from **1 =** (not satisfied) to **10 =** (very satisfied)?

   1 5 10

3. Could you easily find the information you were looking for?
4. Are there any changes that you would make to the focus board configuration that might aid in finding and remembering key information?

Comments and Remarks: