



**DRDC CR2009-042**

**A NON-INTRUSIVE ALERT SYSTEM FOR MARITIME  
ANOMALIES: LITERATURE REVIEW AND THE  
DEVELOPMENT AND ASSESSMENT OF INTERFACE DESIGN  
CONCEPTS**

**SYSTÈME D'ALERTE NON INTRUSIVE EN CAS  
D'ANOMALIES MARITIMES : EXAMEN DE LA  
DOCUMENTATION ET ÉLABORATION/ÉVALUATION DE  
CONCEPTS D'INTERFACE**

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## Abstract

This project involves the investigation of best practices for the development of design concepts for a visualization aid, specifically an alerting system, which would increase the RMP operators' awareness and understanding of maritime anomalies in the RMP (e.g. vessel not heading to port, grab and dash fishing, etc.). Such an alerting system, however, must make operators aware of anomalies that may be present without impacting on the performance of their primary tasks.

The objectives of this project were (i) to identify and analyse available literature relevant to non-intrusive alert systems, (ii) develop design concepts for a non-intrusive alerting interface to be used in GCCS-M and (iii) obtain feedback from Navy Subject Matter Experts (SMEs) on the suitability of the design options.

The results of the literature review suggest that there is a lack of a unified design approach and associated recommendations for non-intrusive alerting contexts. Furthermore, there was no single paper that definitively addressed the issue of how to design a non-intrusive alerting system. However, we were able to extract relevant concepts from the literature relating to alert/alarm design in general. These concepts, combined with general human factors principles, provided direction for a number of design concepts which were then reviewed and evaluated by subject matter experts.

Future design efforts should work toward developing an alert system interface design in accordance with the design principles listed above, once these design requirements have been validated.

## Résumé

Le projet comprend l'étude des meilleures pratiques applicables à la définition de concepts pour un système d'aide à la visualisation, en l'occurrence un système d'alerte, qui aiderait les opérateurs du TSM à mieux connaître et comprendre les anomalies maritimes indiquées dans le TSM (déroutement d'un navire, braconnage maritime, etc.). Un tel système d'alerte doit toutefois permettre aux opérateurs d'être informés des anomalies éventuelles sans pour autant entraver l'exécution de leurs tâches principales.

Le projet visait les objectifs suivants : (i) identifier et analyser la documentation disponible sur les systèmes d'alerte non intrusive, (ii) élaborer des concepts pour une interface d'alerte non intrusive à utiliser dans le GCCS-M et (iii) obtenir la rétroaction des experts de la Marine sur la valeur des options de conception.

L'examen de la documentation a révélé l'absence d'une approche de conception unifiée et de recommandations associées dans le contexte d'alertes non intrusives. En outre, aucun document n'offrait de solution définitive au problème de la conception d'un système d'alerte non intrusive. Toutefois, on a pu extraire de la documentation des concepts pertinents pour la conception de systèmes d'alerte et d'alarme en général. Ces concepts, associés à des principes généraux touchant les facteurs humains, ont fourni des orientations pour la définition d'un certain nombre de concepts qui ont ensuite été examinés et évalués.

Les recherches futures devraient viser à définir une conception d'interface de système d'alerte conformément aux principes de conception présentés ci-dessus, une fois que ces exigences de conception auront été validées.

## Executive Summary

The RMP, one of the primary outputs of the Regional Joint Operations Centers (RJOCs), is essentially a map of the Canadian coastal waters, with contacts, typically ships, marked on the map. Given the extensive maritime traffic and the large area covered, it is difficult to effectively monitor the RMP to maintain a good understanding of the current situation, including anomalies (e.g. sudden increase in speed, not heading to port of call, etc.). Thus, there is a need for a system that could perform routine checks for anomalous data in the background and then make the information available to operators in a format that makes the anomalies readily comprehensible and gives rise to rapid situation awareness. The crux of the problem is how to implement an alerting system that would make operators aware of anomalies that may be present without impacting on the performance of their primary tasks (i.e. non-intrusive alert).

The objectives of this project were (i) to identify and analyse available literature relevant to non-intrusive alert systems, (ii) develop design concepts for a non-intrusive alerting interface to be used in GCCS-M and (iii) obtain feedback from Navy Subject Matter Experts (SMEs) on the suitability of the design options.

The literature review attempted to uncover human factors models, design guidelines, design concepts and empirical research that could be used to inform the design of the functional elements of an alerting system, including:

- Configuring alert parameters;
- Receiving information on alert states;
- Maintaining awareness and performance on the primary task;
- Comprehending the alert condition;
- Actioning the alert condition; and
- Managing alerts.

**Results:** The results of the literature review suggest that there is a lack of a unified design approach and associated recommendations for non-intrusive alerting contexts. Furthermore, there was no single paper that definitively addressed the issue of how to design a non-intrusive alerting system. However, relevant concepts from the literature relating to alert/alarm design in general were extracted. These concepts, combined with general human factors principles, provided direction for a number of design concepts for a future, non-intrusive alerting interface for maritime anomalies.

A total of four interface design concepts were developed and then reviewed and evaluated by seven subject matter experts. The designs, which were all visual, included an alert indicator, information related to an incoming alert and an alert management window. The design evaluation identified a need to scale the intrusiveness of alerts (i.e. high priority alerts require a more intrusive alert than those of low priority).

**Significance:** Feedback from the SMEs, combined with consideration of general human factors principles, resulted in a list of design requirements for the best way to:

- Alert RMP operator to new incoming alert
- Provide operator with awareness of the number of active alerts in the system
- Provide operator with information specific to an incoming alert
- Provide operator with information on all active alerts in the system



- Enable operator to manage (i.e. action) any active alerts in the system

**Future plans:** In general, future research and development efforts should focus on:

- (i) establishing and validating detailed design requirements for an alerting system,
- (ii) developing an alert system interface design in accordance with the design principles presented in the report,
- (iii) experimentally evaluating alternate design options for an anomaly alert system in the context of the RMP (i.e. representative of user's work environment including the potential number of alerts),
- (iv) basic research on better understanding what constitutes intrusiveness and how it relates to factors such as attention and annoyance, particularly as a function of alert interruption frequency.

## Sommaire

Le Tableau de la situation maritime (TSM), l'un des principaux produits des centres régionaux d'opérations interarmées (CROI), est essentiellement une carte des eaux côtières canadiennes indiquant des contacts, en général des navires. Étant donné l'ampleur du trafic maritime et la vaste zone couverte, il est difficile de contrôler efficacement le TSM de manière à bien comprendre la situation courante, y compris les anomalies (augmentation soudaine de vitesse, déroutement des navires, etc.). Il est donc nécessaire de disposer d'un système capable d'exécuter des vérifications de routine pour déceler les données irrégulières sur l'arrière-plan, puis de transmettre ces informations aux opérateurs sous une forme telle que les anomalies soient immédiatement compréhensibles et qu'on puisse prendre rapidement connaissance de la situation. Le noeud du problème consiste à trouver un moyen de mettre en oeuvre un système d'alerte qui renseigne les opérateurs sur les anomalies possibles sans entraver l'exécution de leurs tâches principales (alerte non intrusive).

Le projet visait les objectifs suivants : (i) identifier et analyser la documentation disponible sur les systèmes d'alerte non intrusive, (ii) élaborer des concepts pour une interface d'alerte non intrusive à utiliser dans le GCCS-M et (iii) obtenir la rétroaction des experts de la Marine sur la valeur des options de conception.

L'examen de la documentation visait à découvrir des modèles de facteurs humains, des orientations, des concepts et des recherches empiriques qui pourraient être utilisés pour guider la conception des éléments fonctionnels d'un système d'alerte, ce qui comprend :

- la configuration des paramètres d'alerte;
- la réception d'information sur les états d'alerte;
- le maintien de la connaissance de la situation et l'exécution des tâches principales;
- la compréhension des états d'alerte;
- l'activation de l'état d'alerte;
- la gestion des alertes.

**Résultats :** L'examen de la documentation a révélé l'absence d'une approche de conception unifiée et de recommandations associées dans le contexte d'alertes non intrusives. En outre, aucun document n'offrait de solution définitive au problème de la conception d'un système d'alerte non intrusive. Toutefois, la documentation a permis d'identifier des concepts pertinents pour la conception de systèmes d'alerte et d'alarme en général. Ces concepts, associés à des principes généraux touchant les facteurs humains, ont fourni des orientations pour la définition d'un certain nombre de concepts pour une future interface d'alerte non intrusive en cas d'anomalies maritimes.

En tout, quatre concepts d'interface ont été définis, puis examinés et évalués par sept experts. Ces concepts, tous de type visuel, comprenaient les suivants : indicateur d'alerte, information liée à une nouvelle alerte et fenêtre de gestion des alertes. L'évaluation de la conception a révélé qu'il fallait prioriser le caractère intrusif des alertes (dans les cas de haute priorité, l'alerte doit être plus intrusive).

**Portée :** En tenant compte de la rétroaction des experts, et de principes généraux touchant les facteurs humains, on a établi une liste des exigences à respecter pour la conception d'un système qui remplira le mieux possible les fonctions suivantes :

- transmettre les nouvelles alertes à l'opérateur du TSM;

- informer l'opérateur du nombre d'alertes actives dans le système;
- fournir à l'opérateur l'information particulière à une nouvelle alerte;
- fournir à l'opérateur l'information relative à toutes les alertes actives dans le système;
- permettre à l'opérateur de gérer (intervention) toutes les alertes actives dans le système

**Recherches futures :** En général, les futurs travaux de recherche et de développement devraient se concentrer sur les tâches suivantes :

- (v) établir et valider des exigences détaillées pour la conception d'un système d'alerte;
- (vi) définir un concept d'interface de système d'alerte conformément aux principes de conception présentés dans le rapport;
- (vii) évaluer expérimentalement différentes options pour la conception d'un système d'alerte en cas d'anomalies dans le contexte du TSM (en tenant compte de l'environnement de travail de l'utilisateur, notamment du nombre éventuel d'alertes);
- (viii) mener des recherches de base visant à mieux comprendre la nature de l'intrusivité et comment celle-ci se rattache à des facteurs tels que l'attention et le dérangement, notamment en fonction de la fréquence des interruptions en cas d'alerte.



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# 1. Introduction

## 1.1 Background

Defence Research and Development Canada (DRDC) has an ongoing Applied Research Project in the Maritime Intelligence, Surveillance, and Reconnaissance (MISR) Thrust on information visualization and management for enhanced domain awareness in maritime security. This is a 4-year Research and Development (R&D) project with the goal of enhancing the “maritime picture” through improved quality of information and novel, adaptive ways of visualizing that information. The DRDC team wants to (i) investigate best practices for the design of new visualization aids for operators that may improve their understanding of issues such as information uncertainty and data anomalies, and (ii) test to see if visualizing this information can help improve analysis and situation awareness of the Recognized Maritime Picture (RMP), decision making based on the RMP, and the RMP operators’ efficiency in such activities.

### 1.1.1 Recognized Maritime Picture

The RMP is one of the primary outputs of the Regional Joint Operations Centers (RJOCs). In its common form, the RMP is a map of the Canadian coastal waters, with contacts, typically ships, marked on the map. Other important outputs from the RJOCs are specific reports on Vessels of Interest (VOI). Although produced by the RJOCs, the RMP and VOI reports are also used by other government agencies (e.g., Department of Fisheries and Oceans, the Royal Canadian Mounted Police and Canadian Navy ships at sea to further their own specific interests). Therefore, it is particularly important that the information produced in the RMP and VOI reports is accurate and reliable.

The term “Recognized Maritime Picture” implies that there is some element of knowledge of the attributes of a contact, such as the vessel’s name, hull number or class (e.g., tanker, fishing boat, warship). A typical RMP plot would show hundreds of contact symbols, which are colour coded using standard North Atlantic Treaty Organization (NATO) conventions for identity (friend, hostile, neutral, unknown) and may also contain a vector arrow to indicate last known direction of movement. Associated with each plot on the map are metadata, which are shown in a tabular data display containing approximately 22 data fields of information concerning the contact. In addition, the tabular report includes detailed information on the reporting source. There are as many as 20-25 reporting sources (Davenport, Widdis and Rafuse, 2005) that could potentially contribute to a contact report. These reporting sources range from highly detailed and accurate reports from Provincial Airlines (PAL) overflights, Canadian Coastguard and Canadian Navy ships at sea as well as detailed information on a ship’s name and position from ships carrying Automatic Identification System (AIS) transponders to single contact reports from radar sources such as High Frequency Surface Wave Radar (HFSWR) and Electronic Intelligence (ELINT).

The many sensor and reporting sources that contribute to the RMP, therefore, push large volumes of data into associated databases. The RMP is constantly being updated, both manually by operators and automatically. Given the extensive maritime traffic and the large area covered, it is difficult to effectively monitor the RMP to maintain a good understanding of the current situation.

### 1.1.2 Maritime anomalies

Anomalies are defined as deviations from the norm (Riveiro, Falkman, & Ziemke, 2008) or targets that are not easily classified (Roy, 2008). The more common types of RMP Anomalies include attribute, movement and VOI-related anomalies.

*Attribute related anomalies:* In the Concept of Operations (CONOPS) for producing the RMP, a *track* refers to one or more contact reports linked together to describe any detected discrete airborne, surface or subsurface object. A track has many attributes, any of which can be missing, incorrect (e.g., misspelled) or inconsistent (changed by different operators, or characterized by different standards/nomenclature/schemas as tracks pass through various RMP management sites). Such problems cause ambiguous tracks in some cases or just bad information on a contact in others. At the moment, the most common alerting method for attribute mismatch is the production of an ambiguous track by Global Command and Control System-Maritime (GCCS-M), a de facto form of alerting that there is a problem with a track, which the operator then must resolve.

*Movement related anomalies include:*

- Unexpected or illogical course and speed changes
- Failure to reach a reported estimated time of arrival (ETA) at a specified point
- Loss of reporting
- Movement that suggests activity of concern, such as very close proximity to other vessels in open waters
- Significant variance in voyage/route compared to historical trace of other recent voyages

*VOI related anomalies:* The Maritime Forces Atlantic (MARLANT) “Alert Table” is a list that extracts key fields (usually vessel name) from RMP messages if the vessel has been previously entered on the list (mostly VOIs). This “alert” prompts operators to contact whoever is listed as the interested agency for the VOI.<sup>1</sup>

### 1.1.3 Detection of anomalies

Detection of anomalies requires identification of whether or not specific behaviours are abnormal. A model of this process has been proposed by Riveiro and colleagues (2008). According to the model, anomaly detection is a complex process, requiring information acquisition (search and detection), analysis and the ability to integrate events within the operator’s situation awareness and mental model of the operational environment. In the present case, this would be bounded by the information provided by existing operational systems (e.g., GCCS-M, the Contact History Database (CHDB)).

Operators who may be required to perform anomaly detection in conjunction with their visualization aids face a number of different challenges. Rhodes (2007) points out two specific problems associated with the detection and prediction of anomalous behaviour. First, normalcy is dependent on the context in question. It is nearly impossible to create a system that recognizes every type of normal and abnormal behaviour. Thus, a system that is always learning and adapting is needed to deal with such complexity. However, such systems need to function reliably without requiring a high level of operator involvement.

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<sup>1</sup> For many operators, this would be their only concept of an alerting method together with the method used to represent ambiguous track generation in GCCS-M.)



In addition to anomaly identification, RJOC operational staff has extremely demanding work responsibilities (Davenport et al., 2005; Matthews, Bruyn, Keeble & Rafuse, 2004) that effectively preclude them from spending time doing detective work at uncovering data anomalies. None of the current job functions or tasks performed at the RJOCs includes any effort directed specifically at anomaly detection or analysis with the possible exception of VOIs (Matthews et al., 2004). Thus, there is a need for a system that could perform routine checks for anomalous data in the background and then make the information available to operators in a format that makes the anomalies readily comprehensible and gives rise to rapid situation awareness. The crux of the problem is how to implement an alerting system that would make operators aware of anomalies that may be present without impacting on the performance of their primary tasks.

## **1.2 Scope and objectives**

The objectives of the project as a whole were (i) to identify and analyse available literature relevant to non-intrusive alert systems, (ii) develop design concepts for a non-intrusive alerting interface to be used in GCCS-M and (iii) obtain feedback from Navy Subject Matter Experts (SMEs) on the suitability of the design options.

The literature review provided direction for a number of design concepts for a future, non-intrusive alerting interface. This alerting system interface must serve the information requirements of operators and improve their situation awareness of anomalies and their meaning for the RMP. Because operators must multi-task and there exists a potential for a large number of data anomalies to occur, the major constraint for the interface design is that it be “non-intrusive”. A total of five design concepts were developed, four of which were demonstrated for naval SMEs in order to gather user feedback.

## **1.3 Non-intrusive alerting**

Non-intrusive alerting is not a clearly defined concept that can be expressed in absolute terms, but is highly context dependent. Essentially, the concept of non-intrusiveness conveys the notion of advising an operator (creating awareness) that an alert condition has occurred in a manner that does not disrupt ongoing task performance. It should be noted that a preliminary search indicated that there is limited literature available that deals specifically with the issue of the intrusiveness of an alert, and how to scale this intrusiveness to a particular set of operational circumstances. Therefore, the review and analysis of much of the following literature was to determine what useful information could be extracted from the literature on more generic aspects of alarm and alerting systems that would be applicable or extensible.

## **1.4 Outline of report**

Sections 2 and 3 describe the basic ontology of an alert system as well as a working definition of non-intrusiveness. These sections are based on the knowledge that was gained by reviewing the literature and provide a framework for discussing the results of the literature review. Section 4 presents the method, results and conclusion of the literature review. In section 5, we provide examples of design concepts for elements of a non-intrusive alerting system for implementation in a GCCS-M environment. This is supplemented by a separate PowerPoint interactive demonstration that allows a cognitive walkthrough of the design alternatives. Section 6 describes the review and assessment of the design concepts by SMEs from RJOC-Atlantic. The final section of the report gives the overall conclusions and recommendations.



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## 2. The Basic Ontology of an Alert system <sup>2</sup>

Prior to reviewing the results of the literature search, we provide in this section an outline of the functional elements of an alerting system which we believe brings a useful and coherent structure or framework for the diverse papers reviewed. These ideas, in themselves, stem from insights gained in the literature review. Our objective is to define the functional elements an alerting system and how they relate to each other.

In addition, certain constraints and assumptions have guided this analysis concerning the role of the operator and the team, as follows:

- The operator has a primary task or tasks to fulfil which are NOT the monitoring or management of alerts;
- The operator does not have any other team members who will monitor or manage alerts; and
- The goal of the operator is to deal with alerts as efficiently as possible and to return promptly to the primary task.

The functional elements of an alerting system serve several different tasks that a user may be required to perform in the set-up, operation and maintenance of an alerting system. These have been adapted, and expanded upon, from McCrickard, Chewar, Somervell and Ndiwalana (2003a) and are outlined below:

- Configuring alert parameters;
- Receiving information on alert states;
- Maintaining awareness and performance on the primary task;
- Comprehending the alert condition;
- Actioning the alert condition; and
- Managing the accumulated alert information.

The elements of the ontology are shown in Figure 1 and are outlined below. Explanation of the colour and line coding is provided in section 2.7.

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<sup>2</sup> The essential meaning of an ontology is that it is a model for describing the world that consists of a set of types, properties, and relationship types. Exactly what is provided around these varies, but they are the essentials of an ontology (Gruber, 1995).

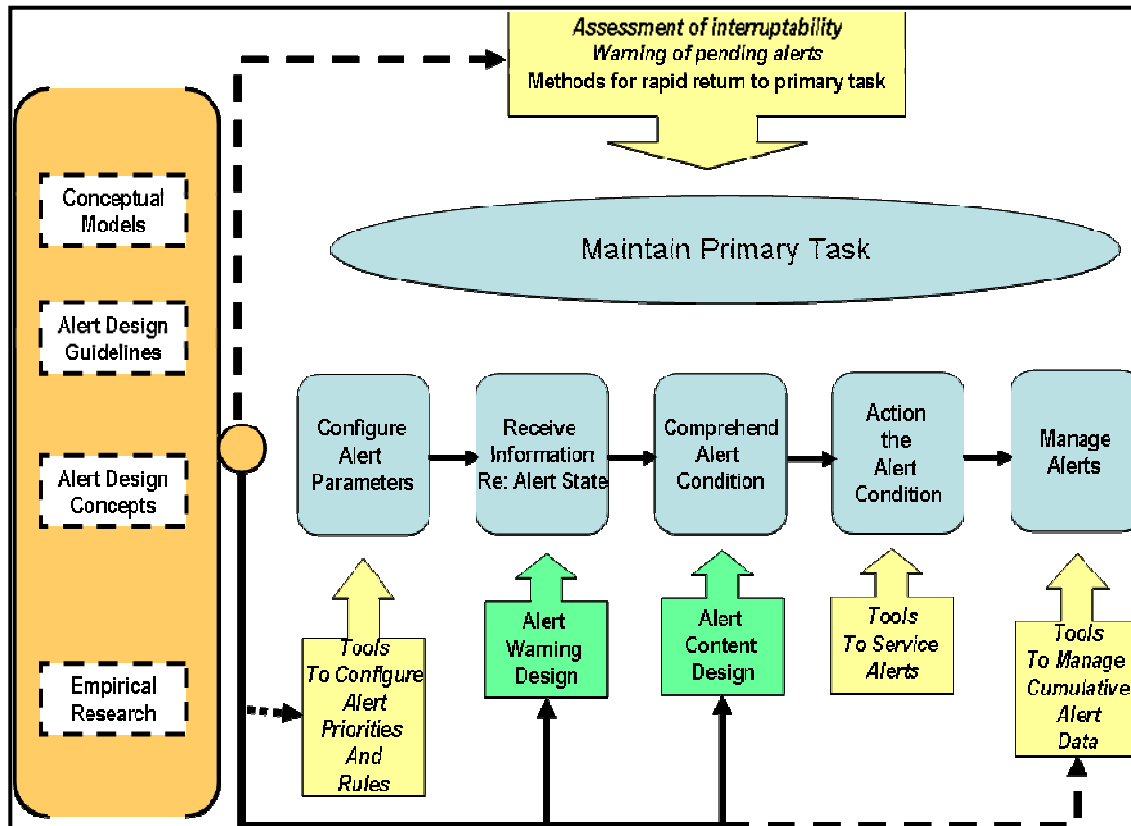


Figure 1: Relationship of literature to the alert ontology

## 2.1 Configure alert parameters

In an operational environment such as the RJOC, the potential exists for many data anomalies to trigger alerts. Some anomalies will be considered to be high priority, others low. In addition, different circumstances may require different rules to be put into place concerning when an alert is brought to the attention of the operator. Therefore, a critical component of the system is a function that allows managers and operators to define the criteria for an alert and to assign different alerting priorities to these events. The interface for this function should allow operators to simply create rules by picking among menu choices, for example:

*“in area (set co-ordinates), if vessels of (type) have speed = (value) then alert with priority (x)”*

For the purposes of the present project, this aspect of an alerting system was considered out of scope to be examined in detail; therefore no specific literature search was conducted on this topic, although one useful paper that emerged from the more general search was reviewed. However, we believe that the ability to set alert parameters that are suitably configured to an operational context represents an important aspect of reducing nuisance alarms. In addition, allowing operators to set categories of alarm priority and matching these categories to the way the alarm state is conveyed, represents an important aspect that is highly relevant to the intrusiveness of the alarm.

## 2.2 Receive information about the alert state

This is the key component of the system and incorporates the means by which an alert state will be brought to the attention of the operator. This function is concerned with just the notification and does not provide details concerning the nature of the condition that gave rise to the alert. However, the alert notification should provide information about the alert priority. The design of the alert indicator is the principle focus of this project

## 2.3 Comprehend the alert condition

Having been notified of an alert, at some point the operator will decide to process the alert and needs further information about the condition(s) that resulted in the alert. This information needs to be provided in a succinct manner that allows the operator to readily comprehend the type of alert. In the case of the RJOC, the interface should allow the operator to rapidly identify the vessel involved and the area of the RMP concerned. This functionality is a secondary point of focus for this project.

## 2.4 Action the alert condition

This is a function that allows the operator to investigate the alert and take whatever action is required. This functionality may be integrated into the interface for an alerting system or may involve other work functions independent of the alert system. It could be considered that this function is not really part of an alerting system at all; however, at some point the operator will return to the primary task, therefore the interface will need to provide suitable functionality to support this transition. While the actioning of an alert was out of scope for this project, the regaining of situation awareness of the primary task was considered important and is dealt with more extensively under the function of *Maintain Primary Task*.

## 2.5 Manage alerts

As alerts accumulate in the operating environment, a new task relating to their management arises for the operator and possibly system manager. The database of these alerts will need to be structured and formatted in such a manner that it permits the operator to quickly determine, for example, how many alerts are in the system, what are their priorities and when they occurred. Simple tools for the sorting and deletion of records will also be required. This aspect of an alerting system was not the primary focus of the literature review, however, some basic functional elements for the interface for such a system have been developed and are shown later in the report in the section on design concepts. This inclusion was thought to be necessary because effective design of the process for alert management may reduce operator worker load for this activity and indirectly mitigate the information processing costs associated with processing the alarm, thereby potentially reducing the overall alarm intrusiveness into the normal workflow.

## 2.6 Maintain primary task

The operator's need to maintain focus on his/her primary task responsibilities is not really part of an alerting system; however it does have implication on the relationship between this primary task and various aspects of the tasks performed in responding to and managing alerts. Some considerations are when to present information about an alert state, i.e., when is the best time to

interrupt the primary task? Should warnings be provided of impending alerts to allow the operator to better prepare and not suddenly lose primary task focus by a surprise alert? A further consideration is how to enable the operator to regain primary task situation awareness after dealing with an alert. The focus of the present project is only on the last of these three questions.

## 2.7 Organisation of the literature and the ontology

In order to structure the literature review in terms of its relevance to the ontology, a classification system was applied that broke the literature down into four main categories:

1. Conceptual models
2. Generic alert system design guidelines
3. Specific design concepts for alerts
4. Relevant empirical research on alert systems

In Figure 1, we show the specific links between these categories and those elements of an alerting system that were the focus of the literature search. The primary areas of interest are shown in green boxes and are linked to the literature review by solid lines. The secondary areas are shown in light yellow and the links are shown by broken lines. Note that there is no link to the “tools to service alerts” function, since this was completely beyond the scope of this project.

## 3. Towards a Working Definition of “Non-intrusiveness”

### 3.1 Defining non-intrusiveness

Prior to considering any design options for a non-intrusive alert system and in order to better understand the literature review, we believe that it is necessary to clarify what is meant by “intrusive” and to develop a working operational definition that will guide the design process, which is described later in the report. As a starting point, we make the assumption that the intrusiveness of an alert or alarm can be defined as an event which, either immediately, or over time, reduces the ability, or potential capacity, to perform a primary task.

With this definition in mind, a central question is then what psychological models are relevant to intrusiveness and how do they predict what would constitute an intrusive or non-intrusive alert. There appear to be two classes of models that are relevant to this issue. The first class of models deals with attention and resource sharing and the second class concerns models of annoyance. Attentional or resource sharing models (e.g., Wickens, 1984) predict interference in cognitive processing of a primary task when an alert competes for common resources. On the other hand, annoyance models would suggest that it is some quality of the alarm (e.g., for auditory alarms, intensity, frequency components, duration and repetition cycle) that produces a psychological state of annoyance that becomes so compelling that attention can no longer be devoted to the primary task (e.g., De-Muer, Botteldooren, Coensel, Berglund, Nilsson & Lercher, 2005).

#### 3.1.1 Predictions of attentional/resource models

According to attention and resource sharing models, an alarm would be considered intrusive if it directly affects the processing of the primary task by sensory interference. For a visual monitoring task this might be a visual alert that occurs at the primary point of visual focus thereby directly interfering with the perception of visual information required to monitor the display. Other examples of this might be the whole display flashing on and off, a visual message that pops up in the middle of the screen or a siren that occurs over an auditory communication network. A second method of interference suggested by the attentional/resource models would be an alarm that competes in a compelling way for attentional resources, but does not in itself directly interfere with the perceptual or cognitive processing of the primary task. That is, the alarm does not directly impede information processing, but rather vies with the primary task for the operator’s attention. An example of this might be a flashing border on all four sides of a visual display. A third method of interference may result from population stereotypes that have developed concerning what alarms look or sound like, for example red flashing lights, sirens or certain iconic symbols (⚠). In this case it is assumed that the semantic content associated with the stimulus immediately overrides ongoing processing and captures attention. In other words, upon perceiving the alarm, the operator immediately knows it is something important and needs attention.

While it is easy to see how such models can suggest the intrusiveness of an alert in such obvious cases, it is less clear how they would predict the intrusiveness of, for example, a ticker style text message that runs along the bottom of the screen.

The general guidance that can be taken from these models is that non-intrusive alarms should not compete for sensory or cognitive processing capacity of the primary task, should not divert attentional resources and should avoid configurations that may trigger over-learned orientation responses because of familiarity and common usage in society.

In developing non-intrusive interfaces for an anomaly alerting system, we have used our knowledge of the RJOC operator's tasks and current system interface to inform the designs such that they do not compete for attentional resources or cognitive processing capacity of the primary task. However, ultimately the degree to which an alert provides the right level of non-intrusiveness should be judged and validated by the end user in the appropriate operational context.

### 3.1.2 Predictions of annoyance models

The only predictive annoyance models that we have found deal largely with noise annoyance and apply to more general societal issues than to cognitive work environments. Such models may take into account factors of the strength of the noise source, frequency, adaptation and appraisal by the human, emotions aroused and cognitive processing. However, we have not found any extensive or compelling data that would suggest specific design guidance, other than the obvious. For example, repetitive sounds or signals will generate an annoyance factor over time. However, the degree to which such annoyance produces degradation in or distraction from primary task performance cannot be specified, nor can one say for how long a repetitive signal would have to continue before it becomes annoying, what level of intensity causes annoyance and how individual differences and experience may influence annoyance "thresholds".

Therefore, we will proceed to use common sense in the interpretation of what could be potentially annoying in an alert and to avoid such design options. However, as noted above, the degree to which an alert provides the right level of non-intrusiveness should ultimately be judged and validated by the end user in the appropriate operational context. A design that we believe to be non-intrusive could ultimately turn out to be the opposite if the underlying anomaly trigger occurs with high frequency in actual operations. This might be the case when there is a data dump from an information source (e.g., PAL flight or AIS Vessel Monitoring System (AVMS) receiver).

### 3.1.3 Summary of principles

The following are the main principles that make an alert intrusive.

- Direct perceptual interference with the ongoing primary task;
- Direct cognitive interference with the primary task;
- Continued presence of a stimulus that by repetitiveness, intensity or quality results in a psychological or emotional state that causes an individual to lose attentional focus on the primary task; and
- The greater the perceptual deviation of the alerting stimulus from the ambient perceptual environment, the more intrusive it will generally be (e.g., providing an auditory alert during a primarily visual task).

It follows from this that non-intrusive alerts must have properties that correspond to the converse of the above principles. That is, a non-intrusive alert must not directly interfere with perceptual or cognitive processing of the primary task; draw the operator's attention away from the primary task due to its repetitiveness, intensity or quality; or differ significantly from the background perceptual



environment. However, as outlined in Section 5, our objective was to design non-intrusive alerts for anomalies that vary in priority level; from low (priority 3) to high (priority 1). Consequently, the priority of the anomalous information must be implied by the level of intrusiveness of the alert itself. That is, alerts for high priority anomalies must be more intrusive than those for low priority information.

In addition to avoiding the above factors that would make an alert intrusive, a key element in alert system design, to minimize (if not avoiding entirely) interference in the primary task due to alarm intrusiveness, is to provide an ability for operators to match alarm priorities to the appropriate level of cognitive and perceptual intrusiveness.



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## 4. Literature Review

### 4.1 Method

This section outlines the methodology used to search the literature as well as select research relevant to the design of non-intrusive alert systems.

#### 4.1.1 Keywords

The following keywords for conducting the literature search were agreed upon with the Technical Authority (TA) and are shown in Table 1.

**Table 1: Keywords**

Core Concept	Priority 1 keywords	Priority 2 keywords
Alerting System Technology	Alarm/warning/alert system Non-intrusive Advisory system Tote board	Auditory/visual alarm Tote
Operator Interface	Design guidelines/concepts Human-computer Operator-machine Interface design User interface Intelligen* Adaptive Etiquette	Human factors Smart
Human Performance	False alarm Attenti* Monitor* Workload Model* Situation* awareness Distract* Disrupt*	Anomaly/change detection Anomal*
Keywords to be searched independently	<i>Alarm/warning/alert overload</i> <i>Missed alarm/warning/alert</i>	

In conducting the search, all Alerting System Technology keywords were paired with Operator Interface keywords and with Human Performance keywords using “AND” logic. The keywords to be searched independently (i.e., alarm/warning/alert overload and missed alarm/warning/alert) were not paired with any other keywords. It was initially proposed that if the literature search using the priority 1 keywords did not produce ideal results, priority 2 keywords would be substituted for priority 1 keywords. However, based upon an abundance of articles found with priority 1 keywords there was no reason to pursue this option.

#### 4.1.2 Databases

**Table 2: Databases searched**

Database	Description
PsycINFO	The PsycINFO database is a collection of electronically stored bibliographic references, often with abstracts or summaries, to psychological literature from the 1800s to the present. The available literature includes material published in 50 countries, but is all presented in English. Books and chapters published worldwide are also covered in the database, as well as technical reports and dissertations from the last several decades.
NTIS	NTIS is an agency for the U.S. Department of Commerce's Technology Administration. It is the official source for government sponsored U.S. and worldwide scientific, technical, engineering and business related information. The 400,000 article database can be searched for free at the <a href="http://www.ntis.gov">www.ntis.gov</a> . Articles can be purchased from NTIS at costs depending on the length of the article.
CISTI	CISTI stands for the Canada Institute for Scientific and Technical Information. It is the library for the National Research Council of Canada and a world source for information in science, technology, engineering and medicine. The database is searchable on-line at <a href="http://cat.cisti.nrc.ca">cat.cisti.nrc.ca</a> . Articles can be ordered from CISTI for a fee of approximately \$12.
STINET	STINET is a publicly-available database ( <a href="http://stinet.dtic.mil">stinet.dtic.mil</a> ) which provides access to citations of documents such as: unclassified unlimited documents that have been entered into the Defence Technology Technical Reports Collection (e.g., dissertations from the Naval Postgraduate School), the Air University Library Index to Military Periodicals, Staff College Automated Military Periodical Index, Department of Defense Index to Specifications and Standards, and Research and Development Descriptive Summaries. The full-text electronic versions of many of these articles are also available from this database.
Google Scholar	The World Wide Web was searched using the Google Scholar search engines ( <a href="http://scholar.google.com">scholar.google.com</a> ).
DRDC Research Reports	DRDC Defence Research Reports is a database of scientific and technical research produced over the past 6- years by and for the Defence Research & Development Canada. It is available online at <a href="http://pubs.drdd.gc.ca/pubdocs/pcow1_e.html">pubs.drdd.gc.ca/pubdocs/pcow1_e.html</a> .

#### 4.1.3 Search strategy

To maintain a record of the process, the following information was documented in a spreadsheet:

- Database searched (e.g., Psych Info);
- Keyword combination (e.g., Non intrusive AND attenti\*);
- Number of hits;
- Number of applicable hits;
- Articles downloaded;
- Articles/books that require purchase; and
- If applicable, where in the article the keywords were searched (i.e., only in the article keywords or anywhere in the article).

#### 4.1.4 Selection and review of articles

Two articles were purchased and 68 articles were downloaded giving a total of 70 relevant articles. Each article was then briefly reviewed and classified according to article theme (i.e., Human performance or Operator interface), source of the article (i.e., keyword search, article provided by the TA, or from another article), and whether the article included theoretical or empirical research.

The research team first used criteria of relevance and quality to evaluate the 70 articles. Relevance was defined as how closely the article relates to the research objectives outlined in the Statement of Work. Specifically, relevance was assigned the following 4 point scale:

- 1 = non-intrusive alerts to inform operators (design/performance) mentioned in the abstract or paper;
- 2 = alerts mentioned in abstract or paper;
- 3 = alerts mentioned in abstract or paper, but not the focus; and
- 4 = no alerts mentioned in abstract but still somewhat relevant.

Quality was defined in terms of where the paper was published using a 3 point scale as follows:

- 1 = journal;
- 2 = technical report, summary or conference paper; and
- 3 = magazine article.

Following the initial search, a more refined search was undertaken to make certain all relevant literature was obtained. This included re-examining all the articles that were rated '1' in terms of relevance (21 in total) and identifying any relevant references and additional relevant keywords that were not included in our original keyword list. This resulted in the addition of the following keywords:

- Notification system;
- Alarm cleanup;
- Nuisance alarm; and
- Pre-alarm.

These keywords were then paired with all Operator Interface and Human Performance keywords and searched in all of the above mentioned databases.

Finally, the research team conducted a search for any articles that cited the 21 most relevant articles. Based on this refined search, 4 new articles were identified, providing a total of 74 articles. These 4 additional articles were also classified and evaluated according to the method described above.

An EndNote database and a spreadsheet with a record of all 74 articles, classification (as described above), relevance and quality rating as well as any relevant notes have been provided to the Scientific Authority. The accompanying endnote database includes the title, year, author, journal and abstract for the 74 articles.

#### **4.1.4.1 Final evaluation criteria**

The research team developed the final criteria to evaluate the articles, based on feedback from the TA. The main concern was that the preliminary criteria would not capture innovative research from other areas (other than the core alert/alarm literature) that might be applicable to the design of non-intrusive alerts. Although this innovative research may not specifically deal with alerts, it could be applied to the warning system. The Quality criteria were maintained for the final search but the relevance criteria were refined to the following 3 point scale:

- 1 = concepts related to alert intrusiveness (including design/performance/models/theory) specifically mentioned in paper;
- 2 = concepts related to alerts were the focus of paper; and
- 3 = concepts related to alerts were not focus of paper.

Articles were then re-evaluated based on the final criteria. As a result, four articles that originally had a lower ranking were found to have concepts in the paper related to alert intrusiveness, while 8 articles received lower relevance scores.

The research team also performed an additional keyword search to address another potentially relevant area, namely human centred adaptive-automation. Thus, the additional following keywords were searched:

- Mission;
- Context;
- Operator; and
- Adaptive.

They were paired with:

- Advisory system;
- False alarm; and
- Intrusiveness.

These keywords were searched in Google Scholar resulting in two new articles related to alert intrusiveness.

In total, there were 24 usable articles obtained from our searches that are related to alert intrusiveness. These articles and 7 more from the TA made up the 31 articles used for the literature review.

## 4.2 Results of the Literature Review

In this section we provide a description and summary evaluation of each of the key papers. The papers are organized first by functional elements of an alerting system (described in the previous section). Within each section, the literature was further broken down into the four main categories described previously (i.e., conceptual models, generic alert system design guidelines, specific design concepts for alerts, relevant empirical research on alert systems).

### 4.2.1 Configure alert parameters

This function encompasses the creation of rules for determining which anomalous events will give rise to an alert, and assigning an alert priority for each rule created.

Of the four categories of literature, we were only able to find relevant papers relating to *generic design guidelines*. Note that some additional information on the setting of trip points and the reduction in nuisance alerts can be found in Brown, O'Hara and Higgins (2000) which is reviewed in detail in section 4.2.2.2.

#### 4.2.1.1 Design Guidelines

##### Configure for individual differences

As computer systems requiring adaptive user interface technologies mature and proliferate into critical applications, Hudlicka and McNeese (2002) argue that it is critical that user interfaces accommodate individual user characteristics. Citing recent research, Hudlicka and McNeese argue that individual differences impact perceptual processes, cognitive processes, motor processes, low-

level processes (e.g., attention and memory) and higher-level processes (e.g., situation assessment, decision making, and judgment). In fact, they state that ignoring individual differences in human-machine systems can lead to non-optimal behaviour at best and critical errors with disastrous consequences at worst.

With respect to configuring alert parameters, one way to address the issue of individual differences is to have operators enter their alert preferences directly into an adaptive interface system. Hucklicka and McNeese (2002) developed just such a system called the Affect and Belief Adaptive Interface System (ABAIS). ABAIS allows users to enter display and modality preferences in a number of categories, which can be seen in Table 3.

**Table 3: Operator information preference profile (Hudlicka & McNeese, 2002)**

Information Category	Options
Preferred means of enhancing visibility	Colour, Size, Blinking
Preferred colour for alerts	Red solid, Red outline
Preferred alert notification modality	Visual, Auditory
Preferred attention capture means	Movement at visual periphery, Shift display to foveal region, Enhance icon visibility, Display arrow pointing to desired icon, Superimpose blinking icon

Although no empirical studies have been conducted using ABAIS, it does highlight the usefulness of allowing operators to control the way in which alerts are configured. Alert settings could be based on operator abilities. For example, operators who have auditory difficulties could choose to have alerts provided visually, or operators who are red/green colour blind could choose alternate colour schemes to report the importance of an alert. Alert setting could also be based on operator preferences. For example, it could be that one operator finds a blinking cursor annoying and would much rather have an audio alert.

### Assessment

While this paper recognises the need for the operator to configure appropriate alert parameters, it is not clear that allowing individual preferences for the design of an alert would be feasible in team or multi-operator environments. If individual members of the RJOC team were to have their own set of preferences, then team situation awareness for the current alerts status would be compromised. Further, supervisors would have greater difficulty in understanding the current alert picture. There is also a danger that individuals left to choose their own preferences would select options that may be inappropriate from a Human Factors (HF) perspective.

### Configure for context

Providing users with the ability to configure alert parameters can also be important in the battlefield. Commanders and staff monitor and analyze a large amount of digital information in the midst of battle planning, preparation, and execution in order to understand what is relevant and critical to their mission. In order to assist the decision-maker to understand and act in battlefield situations, Akin, Green and Arntz (2005) worked to develop the “System to Help Identify and Empower Leader Decisions” (SHIELD). SHIELD monitors digital data streams and alerts a decision-maker to two specific battle situations requiring immediate action. The first situation is

when a friendly unit violates a boundary, thus risking being mistaken for enemy elements by friendly units (“Cross Boundary Violation Alert”). The second situation is when a unit’s plan for using artillery does not match enemy locations determined by an intelligence section (“Fratricide Prevention Alert”). In both situations, SHIELD initiates an alert that displays a text warning and a flashing icon on an “alert map”.

Although helpful, Akin, Green and Arntz (2005) note that alerts can be intrusive. They, therefore, designed SHIELD to allow leaders to be able to control the intrusiveness of alerts. Leaders are able to dismiss an alert from the screen, have an alert be repeated at what may prove to be a more convenient time, or turn off an alert. In addition to these options, they plan on including an intrusiveness filter in future versions of SHIELD. This intrusiveness filter would allow a leader to define when alerts should and should not be displayed (e.g., within a certain limit of known threat locations; if less than 3 alerts are already displayed on the screen). The intrusiveness filter would also allow leaders to turn off audio alerts, which could be especially important if there is a possibility that noise could signal the leader’s presence to the enemy.

### Assessment

The contribution of the paper with respect to alert configuration is useful and provides a good example of an interface that allows users to describe contextual conditions for when an alert may be presented. It should be noted, however, that this does not mitigate the actual *intrusiveness* of that alert when it does occur.

## 4.2.2 Receive information on alert state

An operator receives information on an alert’s state through an **alert warning**, which is defined as the actual mechanisms by which an operator’s attention is captured. Not surprisingly, literature relating to alert warnings was by far the most abundant of any of the alert system functions and included research relating to HF conceptual models, design guidelines, experiments, and design concepts.

### 4.2.2.1 HF models

McCrickard, Chewar, Somervell and Ndiwalana (2003a) suggest that alerting systems should deliver current and critical information to the user in a manner where the user is not interrupted from their primary task. It is assumed that alerting systems are distracting to the user, however, the authors note that it is not known how much they distract the user and if this distraction is negative. McCrickard et al. (2003a) examine the benefits and drawbacks of alert system interface designs. Three critical parameters for modelling alert system user goals and system designs are *interruption*, *reaction* and *comprehension*.

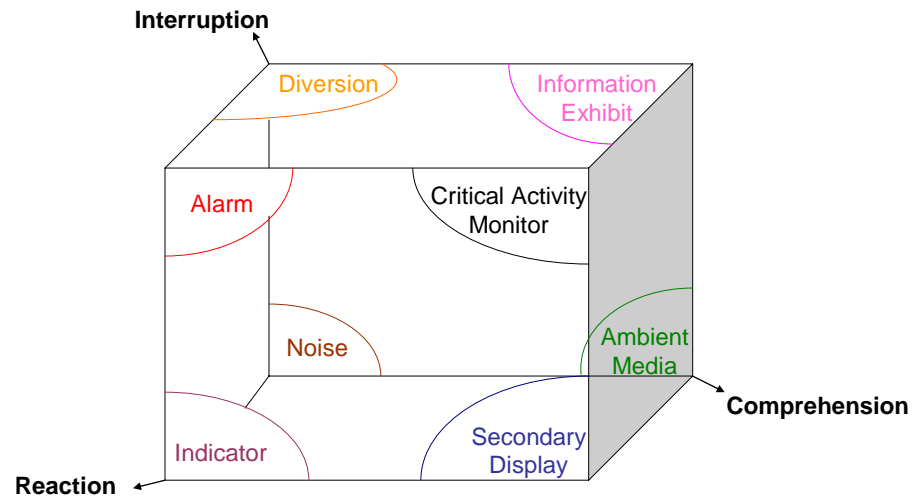
*Interruption* is “an event promoting transition and reallocation of attention focus from a task to the notification” (p. 319). Context plays an important part in interruption. For instance, if the user is driving, the alert (i.e., check engine light) should not be intrusive and interruptive to the main task at hand (i.e., driving safely). However, in the context of the RJOC, an alert informing an operator of a vessel behaving anomalously may require immediate attention and interruption of the main task at hand.

*Reaction* “is the rapid and accurate response to the stimuli provided by notification systems” (p. 319). Reaction can be measured by the time it takes to shift attention, which can be manipulated through designs incorporating colours, shapes and motion.



*Comprehension* is “remembering and making sense of the information” (p. 319) which can be measured through recall and content related questions.

Using this model, combinations of high (1) and low (0) interruption, reaction and comprehension (IRC) were created to categorize the types of alerts, as shown in Figure 2.



**Figure 2: IRC framework (adapted from McCrickard et al., 2003a, p. 321)**

The following table is a list of potential alerts and examples from alert systems according to the IRC framework.

**Table 4: IRC framework alerts and examples (McCrickard et al., 2003a)**

Types of Alerts	IRC Codes	Examples
Critical activity monitor	111 <sup>3</sup>	A system administrator uses a network monitor on the desktop to enable prompt responses and fixes to computer problems
Alarm	110	A businessman relies on a calendar and email alerts
Information exhibit	101	A factory supervisor requires critical updates, while performing daily tasks
Secondary display	011	An editor writes part of a document while monitoring a team progress groupware tool
Diversion	100	A teenager on the home computer enjoys amusing pop-ups
Indicator	010	A tourist uses a GPS (Global Positioning System) to navigate around a new city
Ambient media	001	A telemarketer without a window has changing weather desktop wallpaper
Noise	000	A student doing homework is reassured with internet radio

This table displays the alerts in terms of most interruptive, comprehensive, and requiring reaction, to the least interruptive, comprehensive, and requiring reaction. Using Wickens and Hollands (2000) human information processing stage model, McCrickard et al. (2003a) mapped each of the IRC categories onto the information processing model. This enabled the authors to illustrate that different alert types have different information processing routes. For instance, when people process noise (low interruption, reaction and comprehension), it does not reach their working memory as compared to a diversion (high interruption, low reaction and comprehension) which does reach working memory. The two most relevant alert types that produce a low interruption, but require some type of comprehension, are ambient media and a secondary display. Ambient media is processed through the senses and then enters long term working memory. However, in the case of a secondary display, a selection response must be executed in order to get feedback. This means that a secondary display requires more effort on the part of the operator, but not as much as a high interruption, reaction and comprehension alert (i.e., critical activity monitor) would require.

McCrickard et al. (2003a) performed a case study to test the IRC category framework. The case study involved two separate evaluations, using questionnaire measures, to determine effectiveness. The first study was conducted at Microsoft with the Scope alert system (van Dantzich, Robbins, Horvitz & Czerwinski, 2002; as cited in McCrickard et al., 2003a). The second study was conducted in McCrickard et al.'s lab using the IRC framework. Although the Scope was meant to be used differently than a standard interface, the questionnaire for the Microsoft study had items assessing standard interface issues. Therefore, the results of the Microsoft study were not useful in identifying design strategies. The questionnaire for the lab study, however, was based on the IRC framework. That is, the questions assessed tradeoffs between interruption, reaction and

<sup>3</sup> For example, a critical activity monitor would be high in interruption (I1), high in reaction (R1) and high in comprehension (C1), while an alarm would be high in interruption (I1), high in reaction (R1) and low in comprehension (C0).

comprehension. The questionnaire based on the IRC framework produced better redesign strategies.

The Scope is an alerting system which is located in the bottom right corner of a computer screen and presents symbols according to urgency (urgent items are located closer to the middle than non-urgent items). For an illustration of the Scope alerting system, see McCrickard et al. (2003a)

The Scope is divided into four sections: email inbox, calendar, task list and general alerts. The goals of the Scope system are to direct user attention to urgencies and minimize user attention for incoming non-urgent alerts. According to the IRC framework, the Scope would be similar to an alarm (IRC 110) and ambient display (IRC 001). The results of the studies and ensuing guidelines are summarized in McCrickard et al. (2003a).

The full explanation of the Scope can be found in van Dantzich et al. (2002; as cited in McCrickard et al. 2003a). McCrickard et al. (2003a) conclude that the IRC framework provides a method to evaluate alert systems. The Scope is one of these alert systems that, based on the evaluation, yielded potential redesign strategies such as reducing visual clutter and defining alerts based on shape and colour.

### **Assessment**

In summary, the McCrickard et al. (2003a) model is based on interruption of the alert, reaction to the alert and comprehension of the alert. These parameters create 8 different types of alerts which vary on the IRC levels. For an alert to be non-intrusive it would need to be non-interruptive. A secondary display and ambient media are two types of alerts that may offer a less intrusive way to inform the operator of interesting events. Ambient media allows for comprehension of the material presented, without reaction. Ambient media would be useful in the context of non-urgent alerts or alerts that do not require an action. A secondary display for alerts may not be a viable design solution for RJOC as presently configured.

In terms of applicability to maritime anomaly alerts, the Scope approach may be too extensive for the existing RJOC design space, may require too much operator cognitive processing and may provide more information than is required.

Overall, this paper provides a good conceptual analysis of the human information processing issues that need to be considered with respect to the intrusiveness and comprehensibility of warning indicators.

### **4.2.2.2 Design guidelines**

#### **Nuisance alerts**

In the 1980s, reports of air and train crashes came to light indicating that system operators turned off critical alert or warning indicators prior to the accidents. In his seminal paper, Sorkin (1988) outlined two reasons why he believes operators would disable warning signals. The first reason is that alert signals can be highly-aversive and can interfere with important operator duties (e.g., high-level shrill sound produced by warning whistles, multiple alerts that make it difficult to identify the underlying condition for the alerts). The second reason is that operators perceive false alarm rates to be excessively high. A common sense analysis indicates that operators with high workloads will adopt strategies to ignore or disarm excessive alerts, especially if they are perceived to have high false alarm rates. To deal with these issues, Sorkin recommended a number of changes to alert systems, which include:

- Design alert signals in such a way that they are not overly aversive or disruptive. Possible alert techniques suggested include speech message alerts and special alert codes.
- System designer should consider the effect of the alert rate on the performance of the entire alert system, especially when the operator has a heavy workload.

### **Assessment**

Sorkin's (1988) reasons for operators turning off the alerts are still applicable twenty years later. Constant false alarms provide a false sense of security to an operator whereby it is assumed the alerts are not important enough; thus, they do not receive the operator's attention. Also, designing a less intrusive alerting method can prevent distraction from the primary task. There was considerable research in the area of design guidelines relating to alert warnings; it will be discussed in the following sections.

### **General alert principles**

Shorrock, Scaife and Cousins (2002) developed high-level principles for the design of soft-desk alert systems that could contribute to a philosophy of alert handling. The principles were derived from information gained from two studies regarding the design and evaluation of Air Traffic Management (ATM) commercial-off-the-shelf (COTS) systems software and hardware. These studies resulted in approximately 100 recommendations for alert handling system design. The recommendations were generalized into a smaller set of design principles, which were structured according to Stanton's (1994; as cited in Shorrock, Scaife & Cousins, 2002) model of alert-initiated activities.

Stanton's model consists of six activities:

1. Observation: the detection of an abnormal condition within the system. At this stage, care should be taken to ensure that colour and flash/blink coding support alert monitoring and searching. Excessive use of colour and blinking can de-sensitize an operator and reduce the ability of the alert to gain the operator's attention.
2. Acceptance: acknowledging receipt and awareness of an alert. Alert systems should reduce operator workload to a manageable level – excessive demands for acknowledgement increase workload and operator error.
3. Analysis: prioritization of an alert based on task and system in which it occurs.
4. Investigation: activities that aim to discover the underlying cause of an alert in order to deal with the fault.
5. Correction: the application of the results from the previous stages to address the problem identified by an alert.
6. Monitoring: assessment of the outcome from the Correction stage.

Shorrock et al. (2002) added co-ordination as a seventh activity to the model. Co-ordination is the transfer of information between operators and the application of collaborative efforts to observe, accept, analyze, investigate or correct faults. Their final list of principles for human-centred alert systems classified according to the revised Stanton model can be seen in Table 5.

**Table 5: Model-based principles for human-centred alarm systems  
(Shorrock et al., 2002)**

Observe	
	Alarms should be presented (time stamped) in chronological order, and recorded in a log in the same order.
	Alarms should signal the need for action.
	Alarms should be relevant and worthy of attention in all the plant states and operating conditions.
	Alarms should be detected rapidly in all operating conditions.
	It should be possible to distinguish alarms immediately, i.e. different alarms, different operators, alarm priority.
	The rate at which alarm lists are populated must not exceed the users' information processing capabilities.
	Auditory alarms should contain enough information for observation and initial analysis and no more.
	Alarms should not annoy, startle or distract unnecessarily.
	An indication of the alarm should remain until the operator is aware of the condition.
	The user should have control over automatically updated information so that information important to them at any specific time does not disappear from view.
	It should be possible to switch off an auditory alarm independent of acceptance, but it should repeat after a reasonable period if the fault is not fixed.
	Failure of an element of the alarm system should be made obvious to the operator.
Accept	
	Reduce the number of alarms that require acceptance as far as is practicable.
	Allow multiple selection of alarm entries in alarm lists.
	It should be possible to view the first unaccepted alarm with a minimum of action.
	In multi-user systems, only one user should be able to accept and/or clear alarms displayed at multiple workstations.
	It should only be possible to accept the alarm from where the sufficient alarm information is available.
	It should be possible to accept alarms with a minimum of action (e.g. double click), from the alarm list or mimic.
	Alarm acceptance should be reflected by a change on the visual display, such as a visual marker and the cancellation of attention-getting mechanisms, which prevails until the system state changes.
Analyse	
	Alarm presentation, including conspicuity, should reflect alarm priority, with respect to the severity of consequences associated with the delay in recognising the deviant condition.
	When the number of alarms is large, provide a means to filter the alarm list display by sub-system or by priority.
	Operators should be able to suppress or shelve certain alarms according to system mode and state, and see which alarms have been suppressed or shelves, with facilities to document the reason for suppression or shelving.
	It should not be possible for operators to change priorities of any alarms.
	Automatic signal over-riding should always ensure that the highest priority signal over-rides.
	The coding strategy should be the same or all display elements.
	Facilities should be provided to allow operators to recall the position of a particular alarm (e.g. periodic divider lines).
	Alarm information such as terms, abbreviations and message structure should be familiar to operators and consistent when applied to alarm lists, mimics and message/event logs.
	The number of coding techniques should be at the required minimum, but dual (redundant) coding may be necessary to indicate alarm status and improve accurate analysis (e.g. symbols and colours).
	Alarm information should be positioned so as to be easily read from the normal operating position.
Investigate	
	Alarm point information (e.g., settings, equipment reference) should be available with a minimum of action.
	Information on the likely cause of an alarm should be available.
	A detailed graphical display pertaining to a displayed alarm should be available with a single action.
	When multiple display elements are used, no individual element should be completely obscured by another.
	Visual mimics should be spatially and logically arranged to reflect functional or naturally occurring relationships.
	Navigation between screens should be quick and easy, requiring a minimum of user action.
Correct	

	Every alarm should have a defined response and provide guidance or indication of what response is required.
	If two alarms for the same system have the same response, then consideration should be given to grouping them.
	It should be possible to view status information during fault correction.
	Use cautions for operations that might have detrimental effects.
	Alarm clearance should be indicated on the visual display, both for accepted and unaccepted alarms.
	Local controls should be positioned within reach of the normal operating position.
Monitor	
	No primary principles. However, a number of principles primarily associated with observation become relevant to monitoring.
Coordinate	
	Provide high-level overview displays to show location of operators in system, areas of responsibility, etc.

#### 4.2.2.2.1.1 Assessment

These studies provide a solid and useful analysis of the major principles that should be considered in the design of alert systems, many of which are applicable to considerations for non-intrusive systems. Although not the focus of these papers, no specific implementation guidelines are provided for how these principles should be addressed in terms of concrete design concepts or considerations.

#### **Auditory alerts**

Auditory warnings are used as a means of commanding attention without startling or annoying operators. They are used in domains such as aviation, medicine, and control rooms. Such warnings are meant to convey information about a task or situation, and often must compete with other sensory stimuli in the environment. However, there are problems associated with exposure to loud noise over prolonged periods, including hearing loss, cardiovascular problems (Babisch, 1998; as cited in Edworthy & Hellier, 2002), cognitive problems and performance problems (World Health Organisation, 1993; Smith, 1993; Edworthy, 1997; as cited in Edworthy & Hellier, 2002). In their review of research on auditory warnings in noisy environments, Edworthy and Hellier (2002) make the following suggestions regarding how to deal with issues related to auditory alerts (see Table 6).

Ahlstrom (2003) also conducted work to develop guidelines for auditory alerts within the National Airspace System (NAS). New tools for the NAS are accompanied by new equipment using visual and auditory signals to indicate the status of equipment and of incoming air traffic. The auditory signals are often developed with minimal use of standards or guidelines, or with minimal consideration of the auditory signals on existing equipment. This can result in too many warnings, warnings that are too loud or inaudible, warnings that are confusing, and inappropriate mapping between the warning and its meaning (Meredith & Edworthy, 1994; as cited in Ahlstrom, 2003). Such situations can result in operators disarming or inhibiting alerts, as described by Sorkin (1988).

Ahlstrom (2003) conducted an exploratory study to provide increased understanding and insight into audio alert problems within the NAS. After conducting a literature review, Ahlstrom identified 15 issues associated with auditory alerts in a variety of fields (e.g., hospital emergency rooms, aircraft cockpits). Twenty current and former terminal Air Traffic Control Specialists (ATCS) were then asked to rate each of the 15 issues on an 11 point scale ranging from 0 (not a problem) to 10 (severe problem) on how problematic the issue was from them in their work environment.

**Table 6: Suggestions for auditory alerts (Edworthy & Hellier, 2002)**

Issues	Suggestions
Noisy environments (e.g., factories, cockpits, flight decks)	As ambient noise determines the detectability of auditory warnings, a worst-case spectrum should be used to avoid excessively loud warnings
	Ensure warnings are not too loud as they may be switched off by operators
	Avoid having a number of warnings going off at the same time as they will mask each other
Acoustic	Localizability will be improved by having several audible components in the warning sound, preferably with a fairly low fundamental frequency
	Continuous tones should not be used as warning sounds
Speech vs. non- speech	It is more difficult to produce intelligible speech warnings for a complex noise environment than it is to fit a non-speech warning to the same noise spectrum
	Speech warnings can create problems in certain environments. For example, a verbal warning in a hospital ward may cause worry or panic by patients and relatives, whereas a nonverbal warning would not
	Warning sounds can be designed to mimic speech in some way. For example, in an emergency room environment the warning sound for "cardiovascular" can contain 6 pulses, the same as the word, with a pitch pattern consisting of 3 pulses at one pitch followed by 3 at a lower level. Such a warning is easily learned and retained
	Speech warnings may interfere with ongoing information processing which involves language (Wickens & Hollands Information Processing Model, 2000)
Warning design protocols	Warnings must be designed so as to attract attention without causing stress and annoyance
False alarms	Design alert systems with high accuracy rates. False alarms provide information of no use whatsoever, serve to increase the noise levels within an environment, and over time will lower performance on a task
Number of auditory warnings	Individually different alerts for top-priority situations only
	Use specific sounds to identify the category of risk
	Focus on functions rather than equipment. For example, assign specific alerts to specific medical functions rather than to pieces of equipment (as equipment changes frequently in health care)

Participants were also provided the following comments on specific problems with auditory alerts in their work environment:

- Alerts can be annoying at times (e.g., alert continues to sound even after it has been located);
- Alerts for different problems sound similar and are easily confused;
- Too many false alarms. After a while, alerts start to lose their meaning;
- Alerts can interfere with voice communications;
- Some systems should have auditory alerts but do not;
- Alerts that are too loud cause stress, frustration and hearing loss.



In response to these findings, Ahlstrom (2003) provided recommendations to be considered for future alerts used by terminal area operators:

- Alerting and warning systems should be unambiguous, with a clear indication of the cause for the alert. This can be accomplished by using varying frequency and/or modulation, and periodicity should differ (i.e., avoid continuous signals);
- The criteria for conditions causing frequent false alarms should be evaluated and effort should be made to reduce the number of irrelevant alerts;
- Systems should have a simple, consistent means for turning off non-critical auditory alerts without erasing any displayed message accompanying the auditory signal. The system could also include a sensing mechanism that automatically shuts off the auditory portion of an alert when it no longer provides useful information;
- Strategies should be used to maximize the ability to locate auditory alerts. These include avoiding mid frequencies, positioning alerts to the side rather than in the front or in the back of the operator, minimizing hard surfaces in order to decrease echoes, and providing a centralized alert panel or window indicating the alert status for most alerts;
- When operators are required to identify an alert based on the auditory portion alone, the number of signals to be identified should not exceed four. Up to nine alerts can be used if they are presented regularly, and up to 12 alerts can be used if relative discrimination (rather than absolute identification) is used.

#### *4.2.2.2.1.2 Assessment*

These papers outline many of the critical design and implementation issues with respect to auditory alerts. The first three of Ahlstrom's recommendations for auditory alerts would also be generically applicable to the implementation of other forms of alerting.

### **Nuclear control room**

Within the nuclear industry, the goal of computer-based alert systems is to assist operators by processing alert data and improving the presentation of alert information. Brown, O'Hara and Higgins (2000) conducted an investigation to update and revise the Nuclear Regulatory Commission's (NRC) guidance for reviewing alert system designs. The resulting revisions were based on NRC research on the effects of alert system design characteristics on operator performance and on research examining the introduction of computer-based human-system interface systems into Nuclear Power Plants. Some of the revised guidelines that would be applicable to naval anomaly detection include setpoint determination, assured functionality, alert reduction, alert signal validation, parameter stability, and alert-status separation.

#### *Setpoint Determination and Nuisance Alert Avoidance*

The determination of alert setpoints should consider the trade-off between the timely alerting of an operator to off-normal conditions and the creation of nuisance alerts caused by establishing setpoints so close to the "normal" operating values that occasional excursions of no real consequence are to be expected.



### *Assured Functionality under High Alert Condition*

The alert processing system should ensure that alerts which require immediate operator action or indicate a threat to safety functions are presented in a manner that supports rapid detection and understanding by the operator under all alert loading conditions.

### *Alert Reduction*

The number of alert messages presented to the crew during off-normal conditions should be reduced by alert processing techniques (from a no-processing baseline) to support the crew's ability to detect, understand, and act upon alerts that are important to the plant condition within the necessary time.

### *Alert Signal Validation*

Sensor and other input signals should be validated to ensure that spurious alerts are not presented to plant personnel, due to sensor or processing system failure.

### *Parameter Stability Processing*

The alert system should incorporate the capability to apply time filtering, time delay, or deadbanding<sup>4</sup> to the alert inputs to allow filtering of noise signals and to eliminate unneeded momentary alerts.

### *Alert-Status Separation*

Status indications, messages that indicate the status of plant systems but are not intended to alert the operator to the need to take action, generally should not be presented via the alert system display because they increase the demands on the operators for reading and evaluating alert system messages.

#### *4.2.2.2.1.3 Assessment*

Although the nuclear industry is different from the operational environment of the RJOC, many of the same issues may be applicable, for example, Brown et al.'s (2000) recommendations relating to reducing the number of alerts, rapid detection of alerts, and presenting only meaningful alerts. These recommendations would, in theory, reduce the workload of the operator and make the overall alerting system less intrusive.

### **Graphic user interface design for alerts**

A man-machine interface (MMI) is the way in which an operator controls a system and traditionally contains manual buttons, controls, switches, and a monitor through a closed-circuit television. When switching to a graphic user interface (GUI) from a MMI, some mistakes can occur that can adversely impact human performance. A common mistake is the MMI display is shrunk onto the GUI. Although it maintains familiarity for the user, it can result in usability issues, which can lead to efficiency and safety problems.

Han, Yang and Im (2007) created a six-phase approach to develop a method for GUI design. The six phases include:

1. UI design guidelines collection for process control rooms<sup>5</sup>

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<sup>4</sup> Deadband is a specified area where the alert would not go off.

2. Usability inspection<sup>5</sup>
3. Design rules and guidelines development
4. User interface design and prototyping
5. Usability testing and evaluation
6. Final prototypes and design specs.

For the first step, Han et al. (2007) conducted an extensive review of design guidelines for any GUIs used in a process control room. Consequently, they organized approximately 1500 guidelines into 14 chapters and 70 sections. These guideline principles covered topics such as aesthetics, attention, cognitive issues, consistency, display issues, feedback, forgiveness, memory issues, metaphors, simplicity, system messages and help, user control, and user differences.

Han et al. (2007) then analyzed current user interfaces in a process control room and operator tasks to identify usability problems and define design requirements for a new interface. This new process control room interface prototype takes into account all the current problems experienced by operators. Operator manuals were reviewed and operators were interviewed. Twenty-two operators participated in one-on-one interviews answering questions assessing tasks, alerts systems and requirements. Overall, the usability inspection resulted in the identification of 500 usability problems by 4 practitioners. The most frequently found problems related to attention (e.g., warning signals not salient), consistency (e.g., different terminologies), cognitive issues (e.g., pictures on screens different from actual layout of equipment), memory issues (e.g., same colours have different meanings) and simplicity (e.g., too many colours used). Selected problems are shown in Table 7.

**Table 7: Identified problems and design requirements (Han et al., 2007)**

Alert System Problems	Usability Problems	Operator's Requirements
Warnings are not categorized by urgency	Screens are complex	Unnecessary or redundant interface elements should be removed, and the layout should be reorganized
Irregular situations may not be informed to operators	Each screen has different layouts and different methods of information presentation or visualization	Consistent screen layouts and visualization should be designed
Warning signals are not attracting the operator's attention	Too many colors are used on a screen	The color-coding scheme should be developed, and the meaning of colour should be easily understandable
Visual alerts are not presented with auditory alerts	Only one window can be activated at a time	The multi-window function should be available
	Only the mouse can be used to move between input fields	A 'Tab' key should also be available as a method of moving between input fields
	System status changes cannot be detected before opening and looking at related screens directly	All the status changes should be automatically informed on the screen that the operators mainly use

<sup>5</sup> This step can be skipped if a requirements analysis already exists

Once the usability problems and operator requirements were identified, Han et al. (2007) created design rules and specific design guidelines for the new interface. Design rules are defined as major premises that designers should always keep in mind when designing. Guidelines refer to the specific methods designers should follow when designing individual interface elements. Design rules were categorized into improvement of task efficiency or reduction of task errors. Each rule was accompanied with several specific design guidelines. Design guidelines generated by Han et al. (2007) addressed critical problems of alert design and colour-coding, as shown in Table 8.

**Table 8: Examples of guidelines (Han et al., 2007)**

Design Categories	Guidelines
Alert Design	
Attention	Warning should be easily distinguished from the background. For example, visual signals should be bright on a dark screen, and vice versa
Hazard information	A warning signal should contain hazard information. However, not too much hazard information should be included in just one signal
Consequences information	Consequences information should follow the hazard information. However, if operators can infer the consequences from the hazard information, they do not need to be included in the warning signal
Instructions	Information on instructions should not include a too difficult or impossible method to perform. That is, instruction methods as easy as possible should be included
Comprehension	If operators' capability, knowledge, and experience levels are various, warning signals should be easy so that operators who have the lowest capability or experience level can understand them
Motivation	Warning signals should induce operators to read or listen to them and to react to them
Brevity	Alert information should not exceed two phrases or sentences
Durability	Warnings that inform operators of the instantaneous change of process or signals that do not need special reactions should not last for a long time
Colour Design	
General considerations	Colours are used for supporting search tasks, highlighting, or indicating status of the system
Foreground colour	Do not use blue, magenta, or a shade of pink in displaying information that the user must read
Colour contrast	Exaggerate lightness differences between foreground and background colours, and avoid using colours of similar lightness adjacent to one another, even if they differ in saturation or hue
Colours of interface elements	Do not design a colour icon that is substantially different from the black-and-white icon. When a colour is added to an icon, it is best to leave the one-pixel black outline and other black lines that form the icon, and fill the icon in with colour

As can be seen in Table 8, Han et al. (2007) provide a number of recommendations for alert system design. For example, warnings should be contrasted with background information (e.g., bright warning on a dark screen, vice versa), and should be colour coded (red, yellow, green, white), but

not in shades of blue or pink. Important for reducing the intrusiveness of alerts are the recommendations that information in the warnings should be easily interpretable and should not exceed 2 sentences, and warnings that do not require an operator's reaction should not last a long time.

#### 4.2.2.2.1.4 Assessment

Although the recommendations and guidelines outlined by Han et al. (2007) are not specific to creating less intrusive alerts, the following recommendations can be generalized for the design of less intrusive alerting systems:

- Decrease the disruptiveness and intrusiveness of alerts.
- Consider the effect of the alert rate on the operator. Alert processing techniques should be used to reduce the number of alert messages as this will improve ability to detect, understand and act upon important alerts.
- Be cautious of alert set points. They should be set at a level to avoid nuisance and false alarms. False alarms do not provide useful information and over time will lower performance on a task.
- Do not present status indications through an alert system display. This increases the demands on an operator for reading and evaluating the message.
- Auditory alerts should use specific sounds to identify the category of risk. This will aid an operator's ability to identify alerts.
- Operators should be able to turn off non-critical alerts without erasing information.
- The auditory portion of an alert should shut-off automatically when it no longer provides useful information.
- Operators should be able to distinguish alerts immediately (e.g., different alerts, alert priority).
- The rate at which alert lists are populated must not exceed the users' information processing capabilities.
- Alert acceptance should be reflected by a change on the visual display, such as a visual marker and the cancellation of attention-getting mechanisms, which prevails until the system state changes.
- Alert presentation, including conspicuity, should reflect alert priority, with respect to the severity of consequences associated with delay in recognizing the deviant condition.
- Operators should be able to suppress or shelve certain alerts according to system mode and state, and see which alerts have been suppressed or shelved, with facilities to document the reason for suppression or shelving.
- A detailed graphical display pertaining to a displayed alert should be available with a single action.

It should be noted that many of the recommendations are in the form of general principles (e.g., matching alert conspicuity with alert priority) and there is a lack of specific recommendations on how the principle would be implemented in an interface.

#### **4.2.2.3 Empirical research**

This section, which reviews empirical research related to alert warnings, is divided into visual, visual and auditory, and predictive alerting system, which relates to the actual alerting system itself and how it can predict the operator's actions.

##### **Visual Alerts**

There are many variations of visual alerts such as text, picture, symbols and icons which may vary in size, colour and position. While developing a pre-alert system that would reduce the frequency of alerts, Hwang, Lin, Liang, Yenn and Hsu (2008) examined whether these pre-alerts should be text or graphic. The idea behind testing both formats was to determine if an operator is more inclined to disregard one format compared to another (e.g., too annoying, not comprehensive, not noticeable), which would in turn lead to more alerts going off. The results of this experiment (see Section 4.2.4.2 Warning of impending alert) showed no significant differences in the text and graphic pre-alert types for reducing the number of alerts. However, with the graphic types, the operators had significantly more correct answers when asked questions about the alerted task. Although both forms of pre-alert systems would be a benefit to the operator, the graphic display includes more information, but requires more space and greater changes to be implemented in the control room. Therefore, Hwang et al. (2008) recommended the text type pre-alert to be implemented in control rooms.

McCrickard, Catrambone, Chewar and Stasko (2003b) considered variations of animated text for computer alert systems. Specifically, McCrickard et al. (2003b) examined the visual aspect of an alert, and its effect on interruption, reaction, and comprehension<sup>6</sup>. There were three forms of animated texts: a smooth ticker (information shifted horizontally), a fading display (information fades), and a rapid serial visual presentation (RSVP)-style "blast" (displays information without smooth animation). Information came in the form of changing news, weather, stocks and sports information. The primary task for participants was searching the World Wide Web for information to answer questions that were asked of them. The alerted task was to monitor the news/weather/stocks/sports information (presented by animated text) and answer questions relating to the message displayed. For example, while participants were trying to answer the question, "In what year was Mount Rushmore carved," they also had to monitor the weather alerts and press a button when the weather temperature dropped below 30 degrees. At the end of the session, participants were asked to complete awareness questions which assessed the amount of information they recalled from the alerted task (i.e., monitoring news/weather/stocks/sports information). Results did not report a specific text type which yielded the fastest response times, rather strengths and weaknesses were found for each method of animation (see Table 9).

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<sup>6</sup> Interruption, reaction and comprehension were defined previously in Section 4.2.1.

**Table 9: Results for operator tasks: Study 1 (McCrickard et al., 2003b)**

Tasks	Measurement	Best	Worst
Browsing speed	The time the information appeared on the screen until the participant typed in the correct answer and pressed OK	Control then ticker	Fade & blast
Browsing comprehension	The number of incorrect answers	Control then blast	Ticker & fade
Link selections	The number of times a participant pressed the Back button	Ticker then fade	Control & blast
Reaction time to alert	The time the alert appeared on the screen until the participant acknowledged it by pressing a button	Blast (34 seconds)	Ticker (54 seconds)
Basic awareness hit rate	Recognition of information in the alert	Ticker	Fade
Detailed awareness rate	The recognition of correct and incorrect answers	Ticker	Fade & blast
Basic awareness false alarm rate	Information participants reported seeing that was not actually presented	Fade	Ticker
Detailed awareness false alarm rates	Confidence in understanding information that was not actually understood	Ticker	Fade & blast
Participant's preference	Most user friendly and least intrusive	Ticker	Blast

McCrickard et al. (2003b) recommended the ticker as the best choice for maintaining awareness, minimizing interruption, facilitating reaction and facilitating comprehension.

A second experiment by McCrickard et al. (2003b) examined the impact that alert display size and animation speed would have on performance. This experiment only used the ticker text and fade text, as the blast type was rated as the least favourite by participants in the first experiment. Results are shown in Table 10.

**Table 10: Results for operator tasks: Study 2 (McCrickard et al., 2003b)**

Tasks	Measurement	Best	Worst
Browsing speed	The time the information appeared on the screen until the participant typed in the correct answer and pressed OK	Slow ticker or any slow	Small ticker or any small
Browsing comprehension	The number of incorrect answers	Small fade	Small ticker
Link selections	The number of times a participant pressed the Back button	-	Small ticker
Reaction time to alert	The time the alert appeared on the screen until the participant acknowledged it by pressing a button	Fade	Normal or slow ticker
Basic awareness hit rate	Recognition of information categories in the alert	Small ticker	Slow ticker
Detailed awareness rate	The recognition of correct and incorrect answers	Small fade	Small ticker & fade
Basic awareness false alarm rate	Information participant's reported seeing that was not actually presented	Slow ticker	Small ticker & fade
Detailed awareness false alarm rates	Confidence in understanding information that was not actually understood	Slow fade	Small fade
Participant's preference	Most user friendly and least intrusive	-	-

Based on these results, McCrickard (2003b) recommended that the slow fade may be the best overall alert type.

In summary, all three text types did not significantly interrupt the user from the primary task, but still alerted them to important information. Fade, blasts, and small displays were better for rapid identification of the information compared to tickers or other size displays, but worse for comprehension and recall. Overall, alerts that travel across the screen horizontally were found to be the least intrusive and yield the best performance results. However, when the alert text was varied in size and speed, the text that appeared slowly and faded slowly was the best type to use. The finding with respect to ticker style alerts provides guidance to the development of a similar design concept for the present project.

The operational definition of alert intrusiveness in terms of the relationship between a primary task and the alerting stimulus is useful and will assist in the development of non-intrusive alerts concepts.

### **Visual and Auditory**

The literature is mixed regarding performance for salient (e.g., auditory) versus less salient (e.g., visual) cues. Banbury, Macken, Tremblay and Jones (2001; as cited in Colcombe & Wickens, 2006) found that discrete auditory stimuli, such as those used in alerts, tend to corrupt memory processes more than visual cues. On the other hand, Helmick-Rich, Burke, Gilad and Hancock (2004; as cited in Colcombe & Wickens, 2006) found that people were more likely to comply with an auditory cue compared to a visual cue. It therefore appears that the degree of disruption due to alerted tasks is a complicated relationship between the characteristics of the ongoing task, the alerted task, and the operator's strategies and skills. Auditory alerts appear to be more interrupting



than visual alerts, but do not always impose a cost to ongoing tasks. Colcombe and Wickens (2006) were interested in the way in which parameters of a primary task made them more or less interruptible from an alert, and in turn, how the characteristics of the alert mediated the costs of interruptions to primary tasks.

For study 1, participants were warned, visually or auditorily, for potential collision threats from a Cockpit Displays of Traffic Information (CDTI) display. Participants were in one of the following conditions: stable tracking, unstable tracking condition, binary alert (normal state or high-level alert), likelihood alert (normal state, mid-level or high-level alert). Results showed participants were faster to detect auditory alerts than visual alerts. Tracking performance was better in the binary alerting condition than the likelihood alerting condition. Subsequent studies replicated the binary and likelihood finding, but found response times faster for visual than auditory alerts.

Colcombe and Wickens (2006) stated that the binary alert was generally more effective than the likelihood alert. However, this was based on participants responding to the binary alert faster than the mid-level likelihood alert, without taking into consideration comprehension or interruption. No urgency distinction was made with binary alerts and, thus, operators must treat each alert as if it is high-level. Auditory alerts generally supported better conflict detection response than did a visual alert. However, the impact of modality on the concurrent task was modulated by the nature of the task (visual tracking was more disrupted by the auditory alert than by a visual alert).

Similarly, Krausman, Elliot and Pettitt (2005) examined visual, auditory and tactile alerts on platoon leader decision making. To a limited extent, the military has implemented a multi-sensory information presentation approach in that system designers are using auditory and visual displays. However, there are situations in which a soldier's visual and auditory channels are heavily loaded. Therefore, tactile presentations may also be beneficial. Krausman et al. (2005) had twelve infantry officers participate in 3 different scenarios. In each scenario participants played the role of platoon leaders (PL) mounted inside a vehicle. During the scenario, participants sat in front of a primary display, map display, and Unmanned Aerial Vehicle (UAV) display to perform tactical communications and monitor activity on the display. Approximately 9 of the communications sent to the participant in each scenario were preceded by a visual, audio, or tactile alert. Table 11 describes the presentation of each alert.

**Table 11: Recommendations for design for a platoon leader alert (Krausman et al., 2005)**

Alert purpose	Alert presentation
To alert platoon leader to an incoming message	Visual alert – solid red box appears on bottom portion of communications console of primary display Auditory alert – “beep” from headset Tactile alert – “buzz” from tactical armband

Participants received only one type of alert in each scenario (e.g., visual alerts in scenario 1, audio alerts in scenario 2, and tactile alerts in scenario 3). Alerts were continuous and stopped when the participant clicked the “show message” button to receive the information. After each scenario, participants rated and ranked the effectiveness, helpfulness, and necessity of the alerts.

Overall, visual alerts were the least effective method of alerting participants. Response times were significantly longer for visual alerts than for auditory or tactile alerts; no significant differences



were found between auditory and tactile alert response times. Participants also rated visual alerts as the less effective method of getting their attention. When ranking alerts, participants ranked auditory alerts to be the most effective method of getting their attention followed by tactile alerts and visual alerts, respectively. Tactile alerts were ranked as the most helpful type of alert, followed by auditory alerts and visual alerts, respectively. However, participants noted that caution should be exercised when implementing auditory and tactile alerts in combat vehicles because alerts might be hard to detect in combat environments (e.g., multiple radio nets might mask the sound of an auditory alert, tactile alerts might be missed in a moving vehicle due to vehicle vibrations). Participants suggested that a combination of alerts might be the most effective option.

Steeferkerk, Esch-Bussemakers and Neerincx (2007) designed a context-aware alert system. This system varied visual and auditory methods, and reported that participants preferred an auditory signal for low urgency messages. More details about this study can be found in Section 4.2.3.2.

In summary, the experiments investigating visual alerts recommend alerts that have a slow fade text. Visual alerts that are not recommended include the blast alert and graphical pre-alerts. In general, it was found that auditory alerts support better detection than visual alerts. Experiments investigating auditory alerts recommend an auditory alert for all types of urgencies, and that these alerts vary the presentation based on urgency.

### **Predictive Alerting System**

While the previous sections addressed visual and auditory alerts, this section presents empirical research related to a predictive alerting system, which can aid the operator in certain tasks. Mitchell (1998) considered the issues surrounding intelligent aids and associates in an operational setting. Intelligent aids and associates, such as displays of up-to-date information about operations, are a type of computer technology that is designed to help operators. Mitchell states that an operator's immediate response after hearing an alert may be to shut it off, followed by identifying what triggered the alert. Often times software updates follow well behind changes in operational requirements such that by the time software updates are finally introduced, certain alerts may have become extinct or irrelevant. A common issue is that alerts are assumed to be extinct or irrelevant, thus are ignored by operators. To address these issues, Mitchell (1998) designed a system to prevent alert overload, in turn, increasing alert usefulness.

The Operator Function Model Expert System (OFMspert) performs many functions, but the most relevant to the present project is the activity tracking device, whereby the system tracks the operator's activities. The computer would track the activity by asking "*What is the operator doing? Why is the operator doing that? What will the operator do next?*" (p. 31). The latter question was posed as a way for the system to predict or infer the intent of the operator. Actions that can be interpreted include cognitive actions (i.e., situation assessment) and perceptual actions (i.e., scanning for alerts). Although not discussed in the paper, the system could presumably predict the operator's future actions, thus presenting an alert at an appropriate time. An alert that is presented to the operator at an appropriate time, would not only be less intrusive, but also more useful. Another useful capability of the system is that it can explain recommendations to an operator, which could reduce the operator's cognitive workload.

The National Aeronautics and Space Administration (NASA) Goddard Space Flight Center (GSFC) was chosen to illustrate the application of the OFMspert. The Multisatellite Operations Control Center (MSOCC) is a system in GSFC that monitors the use and effectiveness of computer systems shared by satellites. Several steps were taken for the design methodology, but the implementation of intelligent aids and associates was of interest for this review. Specifically,

inferring the intent of the operator to reasonably predict their activities and interpret their actions was examined. The OFMspert implementation in MSOCC was studied by Jones, Mitchell and Rubin (1990; as cited in Mitchell, 1998). The experiment evaluated the previous Saisi and Mitchell MSOCC data and verbal protocols from two control participants. Every action had an interpretation from the OFMspert, the participants or a domain expert (from the Saisi and Mitchell MSOCC data). Results showed significantly good matches for system commands and display requests. However, there were poor matches for planning and browsing. Another implementation of the OFMspert was performed by Callantine, Mitchell and Palmer (1997; 1998) and looked at the Boeing B-757 flight deck (as cited in Mitchell, 1998). Results showed the OFMspert correctly interpreted 92% of the actions, when compared with 10 certified pilots. Those that were not correct related to browsing actions.

### **Assessment**

This section, which describes empirical research relating to alert warnings, considers both the visual and auditory components of an alert, as well as how to reduce the operator's workload. For the visual component of the alert, a slow fade text is recommended. For the auditory component of the alert, a sound for low, medium and high urgencies should be presented with the alert and the sound should vary according to urgency. Lastly, there is a recommendation of having a predictive adaptive system which can infer the actions of the operator. This prediction can allow the operators to be interrupted with a medium or low urgency alert during periods of low workload.

The OFMspert technology is a decade old and perhaps could be modified to fit the needs of the maritime domain. Presumably, if this system can track the activities of an operator and predict what actions they will perform, specifically alert scanning; it can have some merit as part of an alerting system. Predicting operator's actions in tandem with an alerting system could predict when the operator's workload could be interrupted with an alert. This is especially the case when the operator is already scanning for alerts. Combining the OFMspert with a warning system could be beneficial in that operators are being alerted when their workload allows for it, and the rest of their time is spent on the primary task, except during cases of emergency. However, the major limitation of this approach concerns the accuracy with which the system is able to determine the suitable time for presenting alert information. Even small errors would likely result in operators becoming frustrated with low level alerts that arrive when they are busy and important alerts arriving too late.

#### **4.2.2.4 Design concepts**

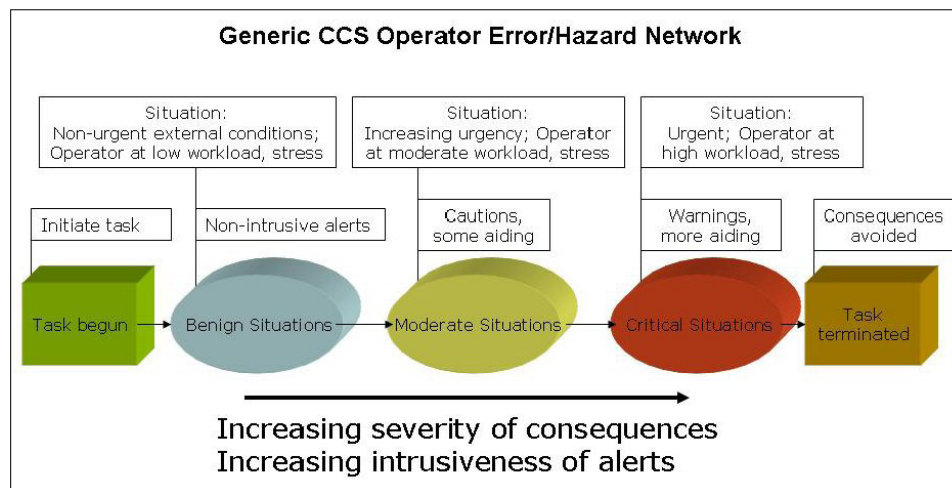
The literature provided a number of specific design concepts for reducing the intrusiveness of alert warnings. These concepts are related to information presentation, limiting operator information overload, maintaining situation awareness, and reducing the number of alerts.

### **Information presentation**

A key design for reducing the intrusiveness of alerts can be found in Hautamaki, Bagnall and Small's (2006) research on the Hazard Monitor and Intelligent Alerting System (HMIAS). This system was designed to improve information presentation to combat system (CS) operators using the Combat Control System (CCS). The CCS was designed to help CS operators form a tactical picture of the maritime environment, especially surface and subsurface vessel locations. Included in the CCS is an alert system to notify operators of conditions that violate expected operating ranges. Originally the alert system indicated isolated incidents but did not convey the severity of the situation as a whole to the operator. Over the years, improvements to the CCS have incorporated a great deal of disjointed but related information. However, Hautamaki et al. (2006)

point out that there is still room for improvement. In particular, the researchers argue that the Alert Manager window on the Tactical Control and Weapons Control interface has a method for presenting alerts that is too subtle. This subtle alerting mechanism has led to situations in which operators were so focused on an ongoing task that they failed to notice other safety alerts. In addition, Hautamaki et al. (2006) argue that the CCS method of organizing safety alerts by occurrence or contact number makes it difficult for operators to identify the most severe alerts.

To address these issues, Hautamaki et al. (2006) developed the Hazard Monitor and Intelligent Alerting System (HMIAS) to improve the overall CCS. HMIAS monitors for, prevents, traps, and captures operator errors in order to prevent the negative consequences associated with errors (see Figure 3 for a generic Hazard Network).



**Figure 3: Hazard Network (Hautamaki et al., 2006, p. 7)**

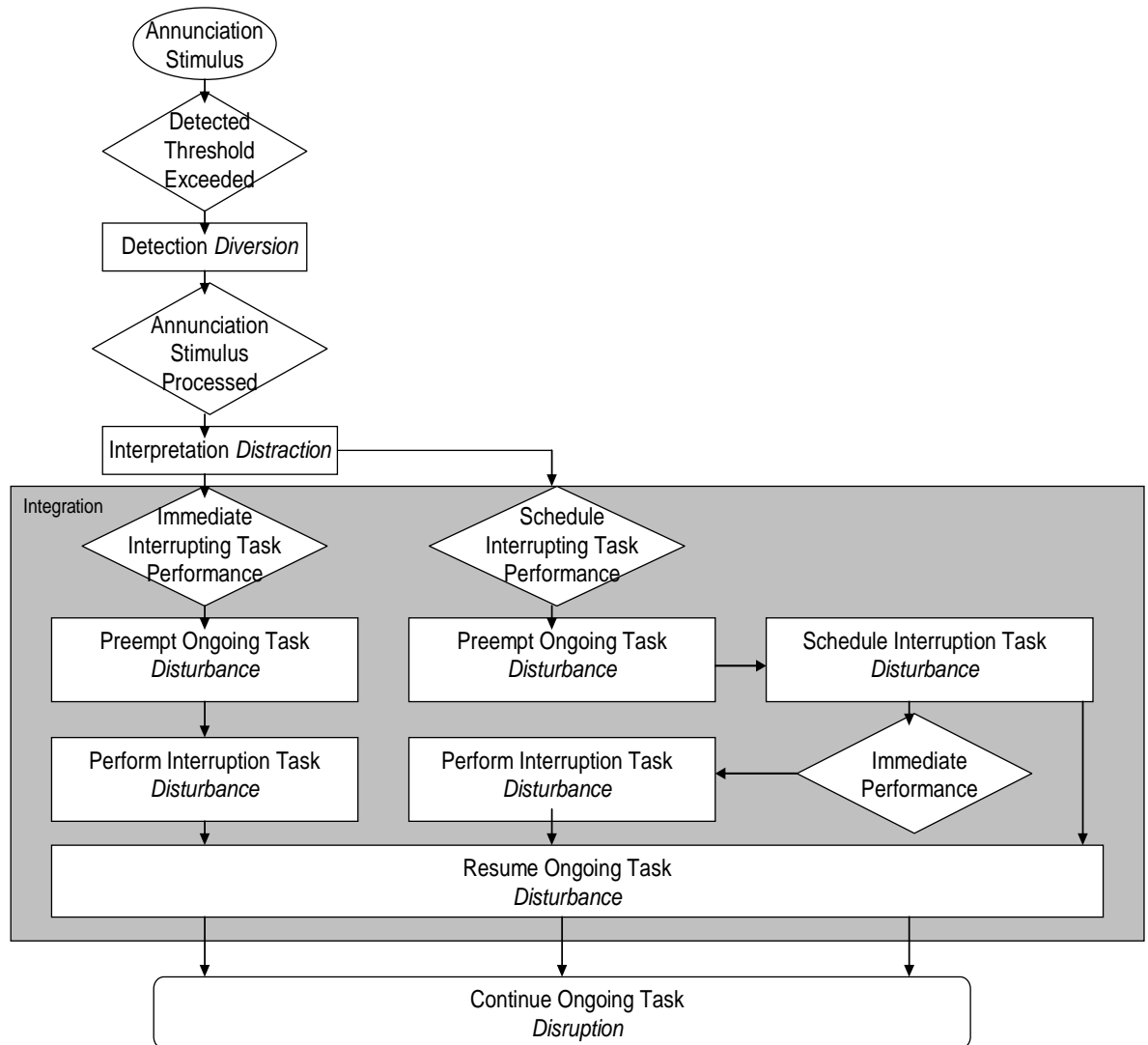
HMIAS monitors system states for hazards, and alerts operators to the hazards in a timely, context sensitive and multi-modal manner. For example, an initial alert is presented in the form of text on the operator's screen. If the alert is not acknowledged in a sufficient time period, and the condition persists or worsens, the alert is presented as flashing text, which then proceeds to an audible alert, followed by the addition of verbal instructions.

To study the effectiveness of HMIAS, Hautamaki et al. (2006) simulated a mission in which sonar personnel, fire control personnel (including CS operators and CS supervisor), and the Officer of the Deck in a Virginia Class submarine control room track an unfriendly quiet diesel submarine through a strait while remaining undetected. During the mission, operators encounter commercial vessels, deep-draft tankers, and fishing trawlers. After 20 minutes, the scenario concludes when a controlled close aboard encounter with a deep-draft tanker requires an evasive manoeuvre. Participants were tasked with continuously hunting for the best system solution for contacts using target motion analysis. Those assigned to the baseline condition used only current CCS alerts, whereas those assigned to the experimental condition used CCS alerts with HMIAS technology.

Results indicate that HMIAS enhances operator performance. What is of particular importance to less intrusive alert technology is the HMIAS hazard network. As events monitored by the system increase in severity of consequences, the intrusiveness of the alerts also increase. This allows the operator to easily assess the urgency of an alert and be able to quickly and easily identify the alerts that require immediate attention.



McFarlane and Latorella (2002) identified some less intrusive methods for presenting alert warnings in their review of interruption management literature. Interruptions are prevalent in many working environments in which humans and computers interact with reactions being both positive and negative. For example, interruptions can provide important information, but they can also cause stress and hinder performance. McFarlane and Latorella (2002) discuss the Aegis weapon system used by the navy as an example. This system interrupts users through an alert tool that presents messages and task assignments on an ongoing basis. Although operators must be informed of the alerts, the alerts are in fact interruptions, occurring several per minute during high-stress operations. McFarlane and Latorella (2002) provide guidelines based upon Latorella's Interruption Management Stage Model (1996, 1998; as cited in McFarlane & Latorella, 2002). This model explores the process of human interruption in a work environment, as shown in Figure 4.



**Figure 4: Interruption Management Stage Model (adapted from McFarlane & Latorella, 2002, p. 16)**

McFarlane and Latorella (2002) propose four design solutions to deal with interruption: immediate interruption, negotiated interruption, mediated interruption, and scheduled interruption.

- Immediate interruption is required by some tasks. When tasks require this type of interruption, some implementations may make it easier for the operator to resume his or her primary task. For instance, Lee (1992; as cited in McFarlane & Latorella, 2002) found that an active window with an animated border produced less confusion upon resuming a task than an active window with a fixed border. Similar to this, Davies, Findlay and Lambert (1989; as cited in McFarlane & Latorella, 2002) reported that reminders are a useful technique in recovering from interruption. Another design technique to enhance performance of responding to the alert is

when information (e.g., numbers) is presented in the same location on the screen, rather than in dispersed areas.

- Negotiated interruption is that which is controlled by the human. Woods (1995, as cited in McFarlane & Latorella, 2002) hypothesized that humans are better than computers when it comes to diverting attention. Thus, Woods proposes that alerts should be subtle enough to let the human decide when to direct their attention to a secondary task. For instance, displaying alerts separately from the primary task, but in a visible way, allows users to attend to the task if they choose, or ignore it (Lieberman, 1997; as cited in McFarlane & Latorella, 2002). Oberg and Notkin (1992; as cited in McFarlane & Latorella, 2002) created a system design where the alert would pop up near the operator's cursor position. Alerts were also colour coded so that the older an alert was, the more saturated in colour it appeared; urgent alerts changed darker faster than non-urgent alerts. Although this system was not compared to other designs, anecdotes attest to the system's usefulness. Shneiderman (1992; as cited in McFarlane & Latorella, 2002) listed various techniques to obtain user attention, namely intensity, marking, size, choice of fonts, inverse video, blinking, colour, colour blinking, and audio.
- Mediated interruption gives control over the interruption to a third source, or mediator (e.g., a personal digital assistant, an answering machine, etc). Czerwinski, Cutrell and Horvitz (2000; as cited in McFarlane & Latorella, 2002) suggested that the system should queue alerts until the user has a natural break. Similar to this, a program that can predict what the user would do next, can interrupt with relevant information at the appropriate time (e.g., Hammer & Small, 1995; as cited in McFarlane & Latorella, 2002).
- Scheduled interruption can be thought of as a predetermined time where an operator allows for distractions. Alerts to anomalous information received from regularly scheduled Maritime Patrol Aircraft (MPA) flights are examples of interruptions that may be most relevant to the RJOC operators.

Toet (2006) also identified some less intrusive methods for presenting alert warnings in his review of the literature on gaze direction tracking. The author suggests that an alert system that is informed of the operator's gaze direction will be able to present information to that operator in a way that will maximize responsiveness. Specifically, the interface can reduce visual clutter, enhance the operator's attentive capacity and direct the operator's attention. For the computer to perform the action of eye tracking, a non-intrusive video-based tracking system must be installed to monitor the operator's gaze and direct attention.

Of particular interest for this review are the techniques used to present visual information on the display screen. These techniques include non-distortion, distortion and gaze contingent techniques.

#### *Non-Distortion Oriented Techniques*

A semi-transparency (multi-layer displays) allows operators to quickly shift their attention. The display shows two different views (layers), one in the foreground (e.g., overview) and one in the background (e.g., detailed map). Operators can shift their attention between the two views best when views were 50-70% transparent.

#### *Distortion-Oriented Techniques*

These techniques combine a detailed (full size or enlarged) representation of the regions of interest with a less detailed (compressed) representation of the remaining regions to draw the operator's attention to the critical information. Studies have shown that participants who use distortion techniques are faster at navigation (Gutwin & Fedak, 2004; as cited in Toet, 2006).



### *Gaze Contingent Displays*

These displays include multiresolution displays, stereoscopic displays, and guiding displays. Multiresolution and stereoscopic displays track the user's gaze and enhance the area being attended. Attention guiding displays, however, use a non-intrusive method to direct the user's gaze to critical information. For example, overlaying red dots on a video clip will attract the user's attention. Attentive interfaces, such as perceptual intelligent interfaces, can adapt their behaviour according to the user. The interface tracks the operator's interactions over time, thus predicting their future actions.

The distortion, non-distortion and gaze contingent displays can be effective for non-intrusive alerting systems. The semi-transparency technique allows operators to quickly and easily shift their attention between tasks. Similar to the fade technique described by McCrickard et al. (2003b), semi-transparent alerts that pop up in the foreground of the display draw attention without being intrusive. Attention guiding displays can be less intrusive methods for directing eye gaze to critical information by directing an operator's attention to the information by overlapping red dots. Lastly, eye contact displays can prevent irritating alerts by silencing once an operator looks at them.

#### *4.2.2.4.1.1 Assessment*

Hautamaki et al. (2006) provide a useful model for presenting alert information to operators in a timely, context sensitive and multi-modal manner. In particular, they propose that alerts become more intrusive as the severity of the alert consequences increase. For example, an initial alert is presented in the form of text on the operator's screen. If the alert is not acknowledged in a sufficient time period, and the condition persists or worsens, the alert is presented as a flashing text. The alert then proceeds to an audible alert, followed by the addition of verbal instructions. While there may be no comparable operational requirements in the RJOCs that would require temporal changes in the alert to signify increased urgency, the example categories of "intrusiveness" do provide some specific design options that may be applicable.

Some of the methods described by McFarlane and Latorella (2002) could potentially be used in a less intrusive alerting system for example, making alerts subtle and presenting them in such a way that they are visibly separate from the main task but still visible to the user and providing coding of alert priority. More questionable is the suggestion to present alert information in the same area of the display as the primary task, which could potentially result in attention being immediately drawn away. Also the accuracy and the reliability of the technology to predict breaks in operator tasking or reduced workload remains unproven, thus recommendations for design concepts based upon this would appear premature.

The methods proposed in Toet's (2006) paper would have limited applicability to an operational environment, where technology for detecting gaze direction cannot be realistically implemented. Although the multi layer or fish eye methods are not compatible with existing constraints within GCCS-M, the use of semi-transparent designs for an alerting system could be feasible.

### **Limit operator information overload**

Limiting information overload of the operator is an essential feature of a non-intrusive alerting system. In discussion of a soft-desk control room, Dicken (1999) proposed some ideas for limiting operator information overload. His review was based on the trend in process plants to replace hard-desk operator interfaces (i.e., horse shoe control desk which includes dials, meters, chart recorder, knobs, and buttons) with soft-desk operator interfaces (i.e., computer-based Visual Display Units with management software and user displays). In the past, plant operators were typically in charge

and ‘drove’ the plant; however with increasing automation, the operator has evolved from driving the plant to being driven by alerts. With the increasing dependence on alert systems, unacceptable problems such as generation rates, nuisance alerts, and poor performance during alert floods have arisen. Consequently, Dicken (1999) provided a careful look at important design concepts that should be considered when switching from hard- to soft-desk alert system facilities. First, he noted that alert lists are prime operating tools for soft-desk systems (see Section 4.2.5 Manage Alerts for detailed information). The system indicates an alert by flashing one of three colours, which corresponds to urgency and matches the list of alerts. To prevent visual overload, alerts are grouped and are attached to the same plant item icon. For example, alerts relating to a single mill are grouped together.

Grootjen, Bierman and Neerincx (2006) also proposed some ideas for limiting operator information overload. Over multiple projects, Grootjen et al. (2006) identified problems in process control such as information type, information volume, task integration, increased autonomy, increased complexity, low personal costs, low training costs and legislative constraints (for more details, see Grootjen et al., 2006). To address these problems, Grootjen et al. (2006) designed an interface to optimize the operator’s cognitive task load (CTL) by transferring a task or part of a task to another person. This adaptive user interface was designed to:

- Show only the categories with active alerts (empty categories are not shown). The interface contains the operator’s alerts and the alerts of other operators;
- Show only the buttons that are relevant for the alerts the operator handles;
- Provide operators with an icon that allows them to redirect alerts to other operators.

Grootjen et al. (2006) evaluated the effectiveness of the interface. While participants worked in pairs to solve problems, they were presented with a number of different alerts. Participants received no task allocation (TA) support, task allocation advice from the system, or a notice that the system had reallocated the task. Overall, Grootjen et al.’s (2006) adaptive interface was rated positively. Participants reported that the allocation interface was pleasant to use, not difficult, useful, and allowed them to solve problems faster and better. The reallocation of alerts was not found to require a lot of effort or be confusing. For the automatic alert group, automatic TA of alerts was found to moderately disturb their normal way of working and was rated as moderately annoying. For the advice group, the TA advice was not reported to disturb their normal way of working.

#### 4.2.2.4.1.2 *Assessment*

With respect to alert intrusiveness, Grootjen et al.’s (2006) adaptive interface offers some useful functions. However, the focus of the work is primarily on process control types of tasks and their associated interfaces, which have little direct comparability to RJOC operators working with GCCS-M.

### **Maintain situation awareness of primary task**

Maintaining or enhancing situation awareness of the primary task is another important design feature of an alert warning system. McFarlane and Berger (2004) were concerned with an operator’s ability to maintain situation awareness while using notification systems. Automatic notification systems constantly monitor and generate alerts, but these alerts often interrupt other activities. Although people do not generally perform sustained, simultaneous, multi-channel sampling well on their own, they can do so when provided with specific interface support. An alert-based information stream can deliver tasks and information to support the operator’s ability to a)



constantly monitor a dynamic environment, b) collaborate and communicate with other people in the system, and c) supervise background autonomous services. The Human Alerting and Interruption Logistics (HAIL) technology was developed to improve an operator's ability to maintain situation awareness during high rates of alerting. The HAIL user interface is designed to improve an operator's ability to process alerts and to reduce the number of interruptions during complex, stressful tactical situations. Compared to the Identification Supervisor (IS) operator for the Aegis Weapon System, HAIL is said to reduce the number of operator interruptions, improve operator situation awareness for each alert and status information, improve control of alerts requiring action responses, and assist in returning to the operator's original task. For an illustration of the current Aegis alert processing system and the HAIL-enhanced Aegis processing system, see McFarlane and Berger (2004).

Rather than displaying alerts in a single window, the HAIL system pre-processes alerts and displays them in the appropriate window. Operators are then able to negotiate their response to the alert by choosing to:

- Surface the alert (i.e., make it visible);
- Defer alert and surface next alert;
- Complete alert and surface next alert;
- Defer alert; or
- Complete alert.

McFarlane and Berger (2004) tested the effectiveness of HAIL with experienced naval operators in an operator simulation using an Aegis alerting system and a HAIL-enhanced Aegis alerting system. In general, results of the HAIL technology were positive. McFarlane and Berger (2004) conclude that HAIL increases warfighter performance by providing operators immunity to the effects of trash alerts, fewer interruptions, better alert situation awareness, and easier recovery of non-alert work after handling an alert. Operators reported that HAIL made it easier for them to distinguish between noise alerts and important alerts.

#### *4.2.2.4.1.3 Assessment*

This paper provides some relevant concepts for providing operators with separate functionality for alert actions, alert information and alert management. One caution to be remembered is that this system was designed for more dynamic tactical maritime displays than is the case with GCCS-M, where data is updated at a slower rate (i.e., more time-late data) and tactical decisions and responses do not have to be made with battlefield urgency.

#### **Alert reduction**

Ahnlund, Bergquist and Spaanenburg (2003) argue that many alerts are distractive and do not alert the operator to important information. One way to potentially reduce the intrusiveness of alerts and their impact on primary task performance is to reduce the number of alerts to which operators must attend. In particular, nuisance alerts are problematic because they unnecessarily overload operators with alerts, which increases operator workload and has been known to cause operators to turn off alert systems altogether (Sorkin, 1988). Ahnlund, Bergquist and Spaanenburg (2003) designed an alarm cleanup methodology and computerized tool to remove nuisance alerts from user interfaces that would not interfere with overall operations.

The alarm cleanup method uses a software program called the Alarm Cleanup Toolbox (ACT). ACT helps tune alert limits and develops algorithms to reduce the number of alerts. To perform an alarm clean up, the following steps are applied:

- “Extract signal data during normal operation. This is the difficult part since most control systems are installed without a logging device.
- Extract information about the signals, such as the current alert limits and the applied signal processing methods.
- Examine the control system’s built-in functions and programmable capabilities.
- Perform an off-line analysis of the signals using ACT.
- Discuss and validate the suggested alert reduction methods and implementation decisions with the operators and personnel with process knowledge.
- Implement the discussed improvements into the control system” (p. 8).

To validate the ACT and alarm clean up method, researchers implemented this technology at a bio-fuelled District Heating Plant (FFC). They were able to track every alert to determine if the alert was removed or delayed. Results showed there were 83% fewer alerts while using ACT.

Chyssler, Burschka, Semling, Lingvall and Burbeck (2004) were also interested in alert and false alarm reduction, specifically within the security field. With respect to security, issues such as alert reduction, false alarm reduction, information correlation, and preventable total service collapse need to be considered. Chyssler et al. (2004) examined alert and false alarm reduction through improving the quality of Intrusion Detection Systems (IDS). According to Chyssler et al. (2004), alerts can be interpreted by their severity, number, frequency, variety, uniqueness and payload. The authors present an architecture that incorporates IDS.

The IDS performs the following tasks:

- Static filtering: A system can produce many irrelevant messages, including false alarms. Tuning a Large Complex Critical Infrastructure (LCCI) is dependent on a static network. Known problems in the system are handled by static filters. These filters omit irrelevant data either by ignoring or deleting the alert. Deleted alerts are permanently removed from the system. Ignored alerts are saved, but not forwarded to the next agent.
- Adaptive filtering: Unknown problems in the system are handled by adaptive filters. These filters categorize messages as interesting or uninteresting.
- Aggregation: Aggregation is the combining of frequent alerts into one alert. This reduces the operator’s workload and lessens the intrusiveness of the alerts.
- Correlation: The correlation agent analyzes the data and determines whether the alert is interesting or uninteresting by comparing the sum to a determined threshold.

Chyssler et al. (2004) applied this architecture to a realistic Internet Protocol (IP) environment where the network experienced internet attacks. Results showed that static filtering reduced the frequency of alerts and that messages were combined into one alert when there was more than a 65% similarity.

Overall, the method described by Chyssler et al. (2004) shows promising results to reduce the number of alerts and false alarms experienced by operators. Although the study is in the context of

computer networks and internet attacks, it can be applied to the maritime domain. Static filtering (i.e., ignoring or deleting alerts), adaptive filtering (i.e., classifying alerts as interesting or uninteresting), aggregation (i.e., combining frequent alerts into one alert) and correlation (i.e., determining if the vector is interesting or uninteresting using algorithms) data show that when implemented, these techniques can greatly reduce the number of alerts and false alarms.

#### 4.2.2.4.1.4 Assessment

The focus of these papers is the reduction in nuisance and other non-critical alerts through smart technology. As such, these papers will be of more interest to those who will be responsible for the development of the technology and algorithms that will determine which data anomaly conditions in the RMP will merit being brought to the attention of operators., They do not apply directly to the current project where the focus is on interface design approaches to minimise alert intrusiveness.

#### 4.2.2.5 Summary

The following table summarizes some of the key recommendations and design principles from the literature on alert warnings or indicators that are potentially relevant to the design and implementation of initial alert warnings for the RJOC operators.

**Table 12: Summary**

Form of literature	Issue	Recommendations or design principles
Models	Alert display	Define alerts by colour and shape
	Low interruption	Alerts that are low in interruption are the secondary display and ambient media
Design Guidelines	Operator workload	Keep set points at a level to avoid nuisance and false alarms
		Operators should be able to suppress or shelve certain alerts
		The rate at which alert lists are populated must not exceed the users' information processing capabilities
		Operators should be able to turn off non-critical alerts without erasing information
	Alert display	Do not present status indications through an alert system display
		Alert acceptance should be reflected by a change on the visual display
		Alert presentation should use specific sounds/colours/etc. to identify the category of risk and priority
		The auditory portion of an alert should shut-off automatically when it no longer provides useful information
Empirical Research	Alert display	Slow fade text
		Voice warning
		High urgency=sharp sound, medium urgency=soft sound
	Predictive system	A system which predicts the operator's actions to interrupt when appropriate

Form of literature	Issue	Recommendations or design principles
Design Concepts	Operator workload	Allow operators the ability to control alert responses through negotiated interruption or surfacing the alert
	Alert display	Use alert pop ups near cursor position
		Colour code alerts by length of time on the screen with alerts getting darker in colour the longer they are on the screen (note: this assumes certain display photometric properties that may or may not be applicable in the RJOCS)
		Use visual distortion techniques to draw operator attention to critical information
		Show only active alerts

### 4.2.3 Comprehend alert information content

Whereas the previous section dealt with issues relating to bringing an alert to the attention of an operator, this section examines relevant research on how to represent the semantic information associated with the conditions that gave rise to the alert. That is, how information should be structured to provide immediate situation awareness of the cause and conditions of the alert. Research relating to alert information content was in the form of design guidelines, empirical research and design concepts.

#### 4.2.3.1 Design guidelines

Miller (2005) examined the role of trust and etiquette in adaptive automation. “Etiquette” embodies unwritten codes that define the roles and acceptable behaviour of participants in a social setting. Etiquette rules define the expectations and interpretations of other people’s behaviour. Therefore, etiquette can serve a role in human-computer interaction. For instance, a system using familiar domain jargon indicates that it is experienced with the domain and should be accorded the trust reserved for those in that domain. Etiquette can also define polite and rude behaviours. Humans are prone to interpret computer behaviour similarly to human behaviour (Reeves & Nass, 1996; as cited in Miller, 2005), thus, systems are likely to elicit the same negative or positive reactions if they hold to or defy established etiquette. Therefore, the information content of an alert should comply with system characteristics and jargon with which operators are familiar.

Miller (2005) defined the following guidelines for adaptive automation. The system needs to:

- Infer tasks;
- Allow operator’s to over rule the system;
- Adapt automation behaviours; and
- Adapt information presentation.

Adapting information presentation can be done by:

- Communicating about ongoing and future tasks;
- Using similar domain jargon;
- Using text format to report context and tasks; and

- Overall, maintaining similar human-to-human etiquette.

#### **Assessment**

Miller's (2005) guidelines are based on a study which used etiquette and gained a favourable response from operators. The four bullet points relating to adaptive automation support the notion of having a function in an alerting system that allows local user configuration. The second set of bullets deal more with ensuring that the mode of the communication is consistent with existing operational concepts, language and procedures. In this case, we believe these principles should also be extended to cover the maintenance of existing "human to system to human etiquette".

#### **4.2.3.2 Empirical research**

The literature review uncovered one article describing empirical research relating to alert information content. Steefkerk, Esch-Bussemakers and Neerincx (2007) designed a context-aware alert system and described the system's implementation. Alert systems should direct the user to important and clear information to allow for quick interpretation and reaction. A prototype was designed on a personal digital assistant (PDA) using visual, auditory and information condensing effects. The alert information included in the prototype varied according to the user's workload. In low workload situations, the full message (i.e., providing all the information) was presented to the user. Conversely when workload was high, only a summary message was presented to the user, with the exception of high urgency messages. Further, in order to prevent interruption of the user while attending to the PDA, an icon appeared when a new message was received, rather than the full alert. This context-aware prototype in which only a summary message is presented in high workload conditions was compared to a non-adaptive prototype which alerted the user with full messages regardless of workload.

Results showed that more targets were remembered in the high workload context for those using the adaptive prototype than those who used the non-adaptive prototype. No significant differences were found in terms of the number of correctly remembered messages. Participants who used the adaptive system reported the messages to be less intrusive than those who used the non-adaptive system, especially during high workload conditions. Adaptive systems were also rated as less interruptive and irritating than non-adaptive systems and were generally preferred. Overall, results showed that a system which presented all the information related to the alert during periods of low workload and a summary of the information during high workload was preferred.

#### **Assessment**

This study has limited applicability to the present project in the sense that it is based on an assumption that there will be appropriate technology available to assess ongoing operator workload. However, the design concept of providing summary, rather than detailed, alert information in certain conditions may be applicable and will be pursued in the design of a maritime anomaly alerting system for RJOC operators.

#### **4.2.3.3 Design concepts**

As described previously, Dicken (1999) discussed the problems that could arise when switching from hard to soft-desks. Dicken also reported how the information related to the alert should be displayed. There are features available to the operator to limit the overload of information. The operator has the option of retrieving more information regarding the alert. This comes in the form of a point and click picklist. The picklist has a number of options that give operators the ability to retrieve more information relevant to the alert, at a time that is convenient to them. The difference

between a picklist and an alert list is that the former allows the operator to progressively select further layers of information concerning the alerting state as the situation and time available merit.

### **Assessment**

The merit of this approach is that it would minimize workload by allowing operators to have control over what information is needed at certain times. Thus, the general concept that may be applied to an alert information window is to structure information hierarchically, thereby allowing users progressively more detailed information at lower levels, which can be simply accessed by point and click approaches.

#### **4.2.4 Maintain primary task**

This section focuses on the operator's ability to perform his or her primary task while being presented with alerts. Research suggests that there are three features of an alerting system that will support an operator's ability to main their primary task: assessing the interruptibility of the operator, preparing an operator for an upcoming alert, and facilitating the operator's return to the primary task. This section is therefore further subdivided according to these three features.

##### **4.2.4.1 Assessment of interruptibility**

This section describes literature relating to human factors and the assessment of interruptibility in the design of an alert system. Of the four categories of literature, we were only able to find relevant papers relating to *generic design guidelines*.

### **Design guidelines**

The assessment of interruptibility relates to the impact an alert has on the performance of the operator. The goal is to minimize interruption to maintain performance and situation awareness. The literature provides some evidence that emotional states have a major impact on perception, cognition, and motor processes, which in turn, impact performance. Belief states (i.e., assessment of the current situation) have also been found to impact decision making and response selection. Given the impact that affect and beliefs have on performance, the following authors have looked at how to adapt information presentation to the individual belief states of operators.

The Affective and Belief Adaptive Interface System (ABAIS) developed by Hudlicka and McNeese (2002), was designed to address individual differences. Specifically, ABAIS uses an adaptive methodology framework capable of adapting the user interface and information to an operator's current affective state, key personality traits, situation specific beliefs, and preferences. In particular, the ABAIS system architecture uses an adaptive methodology consisting of the following four modules:

1. **User State Assessment:** identifies the user's affective state and task relevant beliefs (e.g., level of anxiety). The User State Assessment module receives information about the operator and task context to identify the operator's predominant affective state and situation-relevant beliefs.
2. **Impact Prediction:** identifies the effect of operator state on performance (e.g., focus on threatening stimuli). The Impact Prediction module inputs the identified affective state and operator beliefs to determine, using rule-based reasoning, the impact on task performance.
3. **Strategy Selection:** selects a compensatory strategy (e.g., presentation of additional information to reduce ambiguity). The Strategy Selection module receives the predicted



impact as input and selects a compensatory strategy to counteract resulting performance biases.

4. GUI/Decision Support System (DSS) Adaptation: modifies the user interface content and format to improve detection, recognition, and assimilation of incoming data to enhance situation awareness. The GUI/DSS module implements a selected compensatory strategy in terms of specific GUI modifications. GUI modifications are based on individual user preferences for information presentation (e.g., blinking, colour change, size change of relevant display or icon).

Prior to using ABAIS, each operator must provide background information (e.g., individual history information, baseline physiological or diagnostic data). Categories of information include personality, skill, individual history and adaptation preferences. The information is then used to perform a Cognitive, Affective, Personality Task Analysis (CAPTA) to produce a comprehensive description of possible behaviours and behaviour states associated with specific user states, traits and beliefs.

Once the user affective and belief states are identified and their likely impact is predicated, ABAIS identifies a compensatory strategy and selects a means of implementing this strategy in terms of specific user interface modifications. This strategy is defined based on stable performance biases and the current task context. Once the compensatory strategy has been identified, ABAIS implements this strategy in terms of specific modifications to the user's interface. Modifications of the interface to present the information can be made by:

- Modifying the GUI icons in terms of attributes (e.g., changing colour or size) or modify the icon appearance itself.
- Modifying the display as a whole by changing size, location, appearance, or contents.
- Implementing changes to the GUI as a whole or insert additional display elements designed to focus attention on particular areas. For example, reconfigure entire set of instruments to reflect a different system model and insert attention-capturing and attention-directing elements designed to direct the user's attention to a particular icon or display.
- Inserting new or modifying existing alert and alert notifications, or adding an icon to a display to represent new information. An example of a notification level adaptation includes adding text regarding desired focus of attention, or adding an icon to a display to represent new information.

The ABAIS technology could prove very useful in reducing alert intrusiveness. Prior to presenting information to an operator, the system takes into consideration the operator's stable beliefs, current affective state, and information presentation preferences. Combining this information potentially provides users with information in the most effective and least intrusive manner. We use the term "potentially" because the ABAIS has not yet been empirically tested with operators.

#### 4.2.4.1.1.1 *Assessment*

The fundamental assumption of this paper is that affective states can be reliably and accurately assessed and modelled to provide clear parameters for selecting appropriate alert configurations and parameters. This approach is therefore highly speculative and subject to potentially serious operational consequences, if not implemented with a very high level of accuracy and reliability.

Other than gross examples, the paper does not provide any insight or concepts on exactly how different emotional or other states would be mapped onto specific alert designs.

#### **4.2.4.2 Warning of impending alert**

This section describes the literature related to how to prepare operators for an impending alert by providing an advanced warning. Of the four categories of papers, only *empirical research* was found.

##### **Empirical research**

Hwang, Lin, Liang, Yenn and Hsu (2008) developed a pre-alert system that would reduce the frequency of alerts and examined whether these pre-alerts should be a text or a graphic. Reducing the numbers of alerts is done by aiding the operator in identifying faults before the alert is activated. This method has been applied to many industries and has shown positive results in power plant control rooms. Hwang et al. (2008) designed the pre-alert system based on the following 5 rules in deciding whether or not a system is out of control:

1. “Any one point falls outside the upper control limits (UCL) or lower control limits (LCL);
2. Seven points in a row are continually increasing (or decreasing);
3. Cyclical patterns of points occur;
4. Two out of three consecutive points fall beyond the two sigma limit;
5. A run of five points falls beyond the one-sigma limit (Aft, 1998)” (as cited in Hwang et al., 2008, p. 2).

The pre-alerts were in the form of a text or graphic. The text alert turned black to yellow and was accompanied by a “ding” sound when the value changed 7 times (dropped or rose consecutively; Rule 2). This text changed from yellow to red and was accompanied with an alert when the value was outside the parameters (Rule 1). The other type of pre-alert was graphical which was designed to provide trend information of the situation. The original alert did not include the pre-alert function.

Twenty-six graduate students and staff of National Tsing Hua University were randomly assigned to 13 groups which included a reactor operator (RO), assistant reactor operator (ARO) and a supervisor. The primary task of the RO and ARO was to monitor 6 critical parameters (vessel pressure, level, reactor feedwater pump turbine vibration, discharge pressure, turbine vibration or generator vibration). The RO monitored the parameters of the core flow and power during the 12 minute shutdown (normal state). During shutdown, the ARO closed and opened valves and pumps. During the load rejection (abnormal state), 5 alerts went off. The RO had to search for 10 items and find solutions in 10 minutes. The alerted task was deciding if the presented values were greater than or less than each other. Participants then filled out a questionnaire assessing their perceived mental workload.

Overall results showed that the pre-alert type significantly reduced the number of alerts and the mental workload of the operator and maintained situation awareness. There were no significant differences found between the text and graphic pre-alert types for reducing the number of alerts. However, for the alerted task, operators had significantly more correct answers when deciding if the presented numbers were greater or less than each other when the alert was graphic compared to textual. The operator had significantly more correct answers during shutdown (normal state) than



in load reduction (abnormal state). Also, the ARO had significantly more correct answers than the RO during load reduction (abnormal state).

In summary, Hwang et al. (2008) discovered that a pre-alert system would reduce the number of alerts, thus reducing the intrusiveness experienced by the operators. Although both types of pre-alert systems would be a benefit to the operator, Hwang et al. (2008) recommend the text type pre-alert to be implemented in control rooms.

#### 4.2.4.2.1.1 *Assessment*

The generalisability of this paper to the operations room remains unknown, since the major thrust is to reduce the number of alerts (presumably in a context where this is a serious problem for operators). If the alert frequency is high, the use of an auditory alert may still result in nuisance alerts for the operator. In addition, the use of trend data to cue the alert may not be applicable to the maritime anomaly context.

Note that the paper by Mitchell (1998) reviewed in section 4.2.2.3 also has some relevance to the issue of interruptibility.

#### 4.2.4.3 ***Facilitate return to primary task***

This section examines relevant research on how to best support an operator in returning to his/her primary task after attending to an alert. That is, what should be considered in the design of an alert system (which may draw the operator's attention away from the primary task) so that the operator can easily and quickly return to his/her primary task? We were only able to find research in the form of *design concepts* rather than models, design guidelines or empirical research.

##### **Design concepts**

After attending to an alert, operators must typically return to their primary task. This can be problematic for operators as interruptions to deal with alerts are associated with increased errors, reduced efficiency, and increased stress (McFarlane & Latorella, 2002). In addition, interruptions such as attending to an alert can reduce an operator's situation awareness of the primary task domain. Operators may experience a "resumption lag" once they return to a primary task because they then have to work to re-acquire situation awareness, retrieve suspended task goals, and perform required actions (Monsel, 2003; as cited in St. John, Smallman & Manes, 2005). Returning to a primary task after an interruption can be particularly difficult if the primary task requires the operator to monitor a screen and detect changes. As noted by Smallman and St. John (2005), humans have remarkable difficulty identifying changes, which is particularly true when operators are distracted or interrupted. The longer the disruption, the more problematic it will be for operators to detect changes because their memory of the state prior to the alert will decay. Smallman and St. John (2003) argue that current methods of displaying information only add to an operator's difficulties when returning to primary tasks because current displays show information in real time, which require operators to remember and mentally integrate previous information with current information. This forces operators to determine for themselves whether or not changes have occurred. In order to address the effects associated with reduced situation awareness (e.g., tunnel vision, resumption lag) and to improve change detection ability, Smallman developed the Change History Explicit (CHEX) human computer interface tool.

The CHEX tool augments human attention by detecting significant changes to a situation and logging these changes into a table, which can be sorted and filtered by the operator according to specific variables (e.g., significance, change type, age). Table entries are linked back to objects in

the geographical display. In order to evaluate the usefulness of the CHEX tool, Smallman and St. John (2003; St. John, Smallman & Manes, 2005) conducted a series of studies comparing the CHEX tool to conventional displays.

In the first study, Smallman and St. John (2003) had 80 university students monitor a Geoplot containing a high density of aircrafts (40) or a low density (13). The aircraft slowly moved about an Own-ship signal, changing direction, speed, and turning on and off their fire-control radar (FCR). The participant's task was to identify aircrafts that turned critically threatening, as quickly as possible. Aircrafts on the Geoplot were assigned an "interest score" to reflect their potential significance to the operator; ten interest points were assigned to aircraft that were 1) flying fast, 2) flying towards own-ship, and 3) had FCR turned on. Once an aircraft had a score of 30, it was defined as a "critical aircraft". Aircrafts with interest scores of 10 or greater were shown in yellow, whereas those with interest scores of less than 10 were faded. Within each density condition, participants used one of four different change awareness human-computer interaction (HCI) schemes, 1) a baseline of the Geoplot and CRO, 2) baseline plus a static, chronologically sorted Change History Table, 3) baseline plus Change History Table and red circle alerts around all aircraft with changes (circles could be removed by selecting the aircraft), or 4) baseline plus CHEX (a sortable Change History Table linked to the Geoplot). Participants conducted both monitoring and reconstruction tasks. For the monitoring task, participants had to indicate when an aircraft became critical and how many changes the aircraft had made. For the reconstruction task, participants performed mental arithmetic for a minute while the scenario continued to play out of view then returned to the display to indicate when an aircraft became critical and the number of changes. The authors found that adding a Change History Table and change alert circles improved performance in terms of the percent of correctly identified critical aircrafts, but the greatest improvement in performance was seen when the participants were using CHEX in the high density condition. Participants in the CHEX condition had an 80% improvement in change identification speed compared to the baseline condition.

In the second study, St. John, Smallman, and Manes (2005) were interested in evaluating the design space of situation awareness recovery tools by comparing CHEX against an alternative tool, Instant Replay. Instant Replay allows operators to return to a monitoring task after an interruption and replay the missed period at high speed to quickly search for any changes to the situation. Participants were allocated into one of five conditions: Baseline (map and the aircraft data display in the lower right corner of the screen), Basic Replay (allowed participants to restart the scenario from the beginning of the last interruption), Explicit Replay (automatically detected and marked significant changes by adding small red triangles to the aircraft symbols and a "pop" sound), Explicit Markers (removed the replay function but kept the red triangles and pop sounds), and CHEX (included a table that logged the time, aircraft identification number, and a short description of the change). For a screenshot of the CHEX display, refer to St. John et al. (2005).

Each scenario, contained aircrafts moving slowly in the display, interruptions, and changes. Participants response times using the CHEX tool were significantly faster than the other tools, and 57% faster than the Baseline condition. Participants in the CHEX condition also produced fewer misses and fewer errors than participants in any of the other conditions. Participants in the Explicit Markers condition produced few misses, but a high number of errors and moderate response times. Participants in the Baseline condition produced high miss rates, high error rates, and slow response times. Participants in the Basic Replay condition had the slowest response times.

McFarlane and Latorella (2002) reviewed the tools that could improve an operators' ability to return to primary tasks by designing user interfaces to present reminders about the existence and

state of interrupted activities. Marlin et al. (1991; as cited in McFarlane & Latorella, 2002) designed a user interface that specifically allowed users to suspend and resume activities. Specifically, this design allows users to explicitly mark when an interruption occurred, which allows the computer to generate appropriate recovery support. Rouncefield (1994; as cited in McFarlane & Latorella, 2002) used a similar method in paper-based offices by having workers mark their work context before leaving to handle an interruption. These markers were found to facilitate recovery of prior work contexts when people returned to their prior tasks. This could be implemented in a computer environment by noting interruptions on an electronic notepad that constantly displays a list of interrupted activities (Cypher, 1986; as cited in McFarlane & Latorella, 2002). Finally, Lee (1992; as cited in McFarlane & Latorella, 2002) found that marking the primary task window with an animated border, instead of a static border, reduced the confusion about which window was active when operators resumed a task after an interruption.

#### 4.2.4.3.1.1 *Assessment*

While the problems associated with recovering situation awareness and quickly resuming a primary task that was interrupted by an alert are not the primary focus of the present project, these papers provide some concrete suggestions that could be implemented into a future operator interface.

- Include a table of significant recent changes.
- Automatically highlight all changes to a tracked vessel when a change is selected. When a change occurs, a pop sounds and a new row is added to the top of the table. Selecting a row highlights the row in yellow, highlights the aircraft on the map with a yellow circle, and presents the aircraft's data in the data display.
- Automatically link and highlight between the "Change Table" and the Geoplot when a vessel in either display is selected. This allows for faster critical vessel identification because operators do not have to search the Geoplot to find the location of the relevant vessel.
- Including the ability to sort the "change table" as needed by the operator.

The following aids, while not suited to the current implementation of GCCS or Concept of Operations in the RJOCs, may also have merit in allowing operators to quickly regain situation awareness of the primary task:

- Electronically marking primary tasks before attending to an alert;
- Using an electronic notepad to display interrupted activities; and
- Mark interrupted task windows with an animated border to allow for quick identification of interrupted tasks.

Finally, it should be noted that the operational environments that the authors of the above studies had in mind are characterised by multi-tasking on a single or multiple displays, highly dynamic data inputs and the often need for a rapid operator response. For the most part, these are not characteristics that would apply to the RJOCs, except under occasional and special circumstances.

## 4.2.5 **Manage Alerts**

Although not the primary focus of the literature review, several papers were found relating to human factors and the management of alerts in the form of *design concepts*. Since these could have

potential relevance for the prototype design phase of the project, they have been included in the review.

#### **4.2.5.1 Design concepts**

It is becoming increasingly important to introduce intelligent alert handling capability in order to manage alert systems. Liu et al. (2003) developed an Intelligent Alarm Management System (IAMS) for suppressing nuisance alerts and for providing advisory information to help panel operators focus and respond quickly to important alert information. IAMS was developed to incorporate special-purpose algorithms, process knowledge, and control system expertise. It consists of a graphical user interface (GUI), a Data I/O function, an Alarm/Trend/Knowledge Database and six sub-blocks:

1. Statistical analysis: counts alert numbers in real time for different time periods, tags, message types, and alert statuses.
2. Nuisance HI/LO analysis: analyzes high or low alerts and suppresses those that are repeating.
3. IOP (Input Open) analysis: identifies the cause of input open alerts and suppresses those that are nuisance alerts.
4. Criticality analysis: gives a criticality tag of very important, important, less important, or calculation-related to each alert message.
5. Standing alert analysis: shows standing alerts, warns of ramping alerts, and resets standing alerts.
6. Monitor & recover: shows changes to distributed control system (DCS) alert settings and restores alert setting when the nuisance status is cleared.

In order to aid operators in making appropriate responses to information, IAMS provides operators with advisory information that:

- Informs operators which alerts are emergent or critical;
- Provides operators with early warning for alerts that will lead to violations of high-high or low-low limits;
- Provides online maintenance reports; and
- Provides alert statistics.

All information is provided to the operator through a GUI. The GUI displays guidance information, criticality, statistics, and an alert management overview, and allows operators to suppress nuisance IOP alerts. The operator controls the alert suppression by clicking the SPR button to enable and the RST button to disable the alert suppression function. The IAMS system also allows operators to obtain a control loop status report over the last work shift (SFT), obtain maintenance information (MTN), monitor alert information such as setting changes (MON), suppress nuisance IOP alerts (IOP), as well as guidance information and alerts that have occurred (GID). Operators also have access to all, calculation-related, ordinary, important, or critical alert messages (CRIT, CAL, ORD, IMP, EMG, respectively). Alert statistics reports can be easily generated for the last 10 seconds, 5 minutes, hour, day, or a special time period (SEC, MIN, HR, DAY, SPE, respectively).

The IAMS not only allows operators to suppress nuisance alerts, it allows them to manage the non-nuisance alerts. This alert management system maintains operator situation awareness by providing the necessary information to the operators at their convenience.

Another non intrusive alert management method mentioned in the literature is an alert list. Riveiro, Falkman and Ziemke (2008) and Dicken (1999) used an alert list in their design of an alert system.

An alert list is an alert management component of an alerting system, designed to manage alerts that have been presented to an operator. Riveiro et al. (2008) designed an anomaly detection system which includes an alert list. The interface display of the anomaly detection system includes a geographical map, controls, detailed information, and the alert list (shown in the bottom left hand corner). This list is shown in detail in Figure 5.

<b>Boat 1208</b> (PosX, PosY) Prob. Main reason Alert age <input type="button" value="Report"/> <input type="button" value="Delete"/>	<b>Boat 0950</b> (PosX, PosY) Prob. Main reason Alert age <input type="button" value="Report"/> <input type="button" value="Delete"/>	<b>Boat 1133</b> (PosX, PosY) Prob. Main reason Alert age <input type="button" value="Report"/> <input type="button" value="Delete"/>	<b>Boat 0448</b> (PosX, PosY) Prob. Main reason Alert age <input type="button" value="Report"/> <input type="button" value="Delete"/>	<b>Boat 6809</b> (PosX, PosY) Prob. Main reason Alert age <input type="button" value="Report"/> <input type="button" value="Delete"/>
HF 1398 6543332, 133256890 Swedish Malmö			12:25:12 F1005 reported 12:29:06 HF9012 reported	

**Figure 5: Alert list (Riveiro et al., 2008, p. 6; © 2008IEEE)**

When a vessel is considered anomalous, it is given an identification number and a coloured ellipse, reflecting the probability of the anomaly. A card appears on the alert list containing information such as the object identification (ID), coordinates, probability, main reason, age of alert, and delete/report buttons. By pressing any of these buttons, the operator can obtain more information regarding the alert. The object ID is the object identification number, which identifies each vessel accordingly. The object ID is also highlighted with an urgency colour indicating the probability of the anomaly (red, orange, yellow). The probability of the alert identifies the probability that the alert is anomalous. The position of the ship is given by x- and y-coordinates. Every alert is time-stamped which allows the operator to determine how old the alert is compared to the other alerts. Finally, each alert on the list contains a report and delete button the operator can click to perform the intended action.

Dicken (1999) discussed an alert list in the context of a recent operator desk change, from a hard-to soft-desk. A hard-desk can be described as a horse shoe control desk which includes dials, meters, chart recorder, knobs, and buttons. It consists of a back panel where the indicators can be found along with alerts. A soft-desk is a hard-desk incorporated with Visual Display Unit (VDU) screens. Along with this modernization of the standard hard desk, alert systems have also been changed to include alert management software and user displays.

As described by Dicken (1999), the alert interface has two options for soft-desk set up, 1) the standard VDU alert interface, or 2) the alert display and acceptance interface. The latter option is performed by pointing and clicking a mouse on a standard screen. This option also has an alert list as a secondary backup which can be displayed on any screen and is permanently on due to necessity. These lists are limited to a single chronological alert list and are unusable during emergencies. Recommended improvements to the alert list are done by: 1) showing alerts on pages rather than scrolling, 2) keeping the alerts in the same order (no shuffling), 3) adding new alerts to the bottom of the list, 4) removing alerts only by operator action, 5) having a flashing marker,

rather than the alert text flashing, and 6) prioritizing alerts by colour. Dicken (1999) notes that these lists should be filtered, especially during an alert flood. Filters such as priority, category (category rectangles are displayed on the bottom of the list), named list (alerts associated with a task are built into a filter), modes (plant modes, e.g., stable operation, start up), and unaccepted (alerts that have not been accepted) can be useful to prevent operator overload.

The alert list also contains a “shelve” option for the inevitable nuisance alerts. Until these are serviced and fixed, operators can choose to ‘shelve’ these alerts to limit their intrusiveness. This shelving option allows operators to ignore false or nuisance alerts that should not be deleted and should not take time away from the primary task. However, unlike ignoring alerts, the shelving option would not remind the operators of the alert because operators are still responsible for the shelved alert list.

### Assessment

This paper provides a good description of the issues concerning the management of alerts and potential design solutions. It shows that an alert management system could be one method to ease operator workload and maintain situation awareness. An alert management system can organize alerts into a coherent list which the operator can access at any time to obtain more information. The suggested information contained in these lists are vessel ID number, position, urgency of alert, age of alert, and action buttons (ignore, delete, report, shelve). Alerts on the list should be colour coded according to urgency and this colour should match the actual alert (e.g., red for high urgency, orange for medium urgency, yellow for low urgency). The list should also include a detailed history of all alerts, including those shelved, deleted and reported. Lastly, this list should contain all the information found in the actual alert, including links to pertinent information.

There was some lack of detail concerning the implementation of the alert list in both Riveiro et al. (2008) and Dicken (1999) although it should be acknowledged that this was not the main focus of either paper. For example the following issues were not addressed: can an alert list contain a shelved/deleted/reported/ignored list or should they be treated separately? Do the alert lists include alerts that are 1 hour old, 1 day old, 1 week old, etc.? Can an alert system display all the alerts in an appropriate manner without looking cluttered, or are there a maximum number of alerts that can be listed? Further, maritime operators may have a large number of alerts present over the course of a watch, which could pose a problem in terms of where and how the alert list should be displayed. In the example provided, the alert list looks like it could fit 7 alerts across the screen, but the paper does not give any indication of what happens to the alert list when it becomes full.

In addition, it is probable that operators would find the alert list more manageable and they would have improved situation awareness if the list were able to be sorted by alert severity. These questions and more need to be examined thoroughly before the appropriate functionality and design requirements for an operational context can be determined.

Finally, the paper assumes that operators can usefully comprehend categories of alert probability, which remains an assumption for which current empirical experimentation provides no clear guidelines.



## 4.3 Conclusions

### 4.3.1 State of current knowledge

The following summary table shows the number of papers found and reviewed for each of the main functional aspects of an alert system categorised according to paper type (see Table 13).

**Table 13: Literature in the report**

	Configure Alert parameters	Receive Information on Alert State	Alert Information Content	Maintain Primary Task	Alert Management	Total
Models	0	1	0	0	0	1
Guidelines	0	6	1	0	0	7
Experiments	0	7	1	1	0	9
Design Concepts	2	9	1	5	3	20
<b>Total</b>	<b>2</b>	<b>23</b>	<b>3</b>	<b>6</b>	<b>3</b>	<b>37</b>

Overall, the largest subset of papers was about design concepts, and the majority of these focused on how to indicate to the user that an alert or alarm had occurred. It was somewhat disappointing to find so few papers that provided conceptual guidance for the design of alert systems and how little empirical research had been done to test the validity or generalisability of design options. One central theme was evident in several papers, namely, the importance of designing alert systems to minimise the operator's mental workload and to reduce the potential for annoyance.

While we found some empirical research on alerts and their potential impact on operator performance, there is a lack of research explicitly related to non-intrusive alerts. This may be because much of the literature has focused on the traditional problem of how to make an alert *intrusive* or salient enough to *catch the attention* of the operator.

Recent attention has turned to the issue of how a high number of false or nuisance alarms can degrade system and/or operator performance. This has resulted in a body of research attempting to decrease nuisance and false alarms. Within this body of research are design guidelines and concepts that may also be useful in reducing the overall intrusiveness of alerts. To that end, a number of researchers (e.g., Edworthy & Hellier, 2002; Brown et al., 2002; Chyssler et al., 2004; Ahnlund et al., 2003) have recommended ways to reduce the number of alerts an operator is exposed to on a daily basis.

Using the ontology outlined earlier in the paper as a reference point, we have extracted from the literature a number of design principles for each of the main alerting system components, as shown in Table 14.

**Table 14: Alert design principles**

Alert system parameters	Considerations	Specific design recommendations	Comment
Configure alert parameters	Operator preferences (individual differences)	Interrupt the operator according to their preferences (i.e., colour, size, time, modality, movement)	This guideline should be treated with caution to ensure that operators are not provided with the freedom to create HF inappropriate designs.
Receive Information on Alert State	Visual	Colour – differ by priority (e.g., red=high urgency, orange=moderate urgency, green=low urgency) and length of time on screen	Need specific guidelines for time on screen or duty cycle for flashing alarms.  Colour coding implemented in design prototypes.
		Size of alert icon – larger icons for higher priority alerts	Need specific guidelines on size of alert and how this relates to the display size and the size of windows.
		Solid v. blinking icons	Need specific guidelines on blink rates
		Change display when alert has been accepted/actioned (e.g., remove alert from screen, visual marker to note it has been accepted)	
		Pop-up alert near cursor	This may be too intrusive for some tasks.  Not suitable for RJOC context
		Slow fade v. blast or ticker alerts	Need specifications on the dynamics of the fade
		Movement at visual periphery	May be too general a recommendation without specifying primary tasks for which this would be appropriate.  Not suitable for RJOC



Alert system parameters	Considerations	Specific design recommendations	Comment
			context
		Shift display to foveal region	This would have to be implemented with caution because of the potential to impact adversely on the situation awareness of the primary task.  Not suitable for RJOC context.
		Display arrows pointing to alert	Not suitable for RJOC context
		Visual distortion techniques	This would have to be implemented with caution because of the potential to impact adversely on the situation awareness of the primary task.  Not suitable for RJOC context.
	Auditory ( <i>NOTE: none deemed suitable for RJOC context</i> )	Voice saying "Conflict Conflict"	Limited application
		High urgency=sharp sound, medium urgency=soft sounds	Need to define frequency and amplitude characteristics more specifically.
		Use specific sounds to identify category of risk	Potential impact on increased need for training.
		Automatically shut-off auditory portion of alert when it no longer provides useful information	
	Other modalities	Tactile and olfactory	Tactile may be suitable for warning individual operators who are away from their workstation. Need guidelines and research on the vibrotactile profile and its perceived urgency.  Olfactory unsuitable

Alert system parameters	Considerations	Specific design recommendations	Comment
			for most environments.
Alert Information Content	Adaptable to workload	High workload=summarized information, low workload=full information, high urgency=full information	Assumes that system is able to assess workload.  Not suitable for RJOC context.
	Direct operator /constrain information	Use picklists.  Buttons relating to the schematics, control panel, trends, point information, actions, procedures, and history of the alert	Not suitable for RJOC context.
	Maintain situation awareness	Ability to gain information of a vessel by clicking on the vessel on the RMP	Highly relevant to RJOC. Implemented in design prototypes.
Maintain Primary Task	Assess Interruptibility	The system accounts for user's beliefs, affect, preferences, ongoing task priorities	Technology not yet available to ensure the level of accuracy required in estimating interruptibility.
	Pre-alert	Use text rather than graph	Not applicable to RJOC
	Return to primary task	Include a sortable table of recent changes in the situation while operator was away.	More suitable for more highly dynamic information environments than the RMP.
		Restore task window to former look	While generally advocating this approach, we caution that depending on the context there is potential for operator disorientation if the picture/RMP suddenly changes focus/range etc without operator input.
	Marking primary task	Electronically mark task before attending to an alert	Not applicable to RJOC
		Electronic notepad to record interrupted activities	Not applicable to RJOC
		Mark interrupted task window	Not applicable to

Alert system parameters	Considerations	Specific design recommendations	Comment
		with an animated border	RJOC
Alert Management	Alert list	Provide sortable lists of alerts that show: alert priority, alert context, time of alert and relevant information concerning contact details. Functionality to re-order and delete.	Implemented in design prototypes
		Provide detailed history of all alerts (shelved, deleted and time actioned)	Relevant to RJOC but not in scope of present work.
		Not to exceed user's information processing capabilities	Too general to be useful!
	Etiquette	Communicating about ongoing and future tasks	This is more applicable to highly dynamic task contexts.
		Using similar domain jargon	Ensure that design approaches are consistent with RJOC CONOPS and GCCS style.

Our general assessment is that the above represents a somewhat piecemeal and haphazard collection of principles and guidelines, as might be expected since they are an agglomeration from many different papers with quite different application environments and goals. Clearly, there is a lack of a unified design approach and associated recommendations for non-intrusive alerting contexts. However, the detailed guidelines found in Shorrock et al (2002) and Han et al (2007) provide a good starting point for an integrated guidance document, which would then need to be extended and made more context relevant to the RJOCs. In addition, there would be a need to make this guidance more specific than statements such as “alarms should signal the need for action”, “alarms should be detected rapidly...”, “alarms should not annoy, startle or distract unnecessarily” etc. Thus, while these recommendations are sound, there is a lack of information on how they are to be implemented as specific design guidelines.

#### 4.3.2 Gaps in the literature

In general, there was a common theme in the literature relating to alert system design, namely appropriate ways to alert an operator of the situation at hand. Capturing an operator's attention requires shifting attention to the alert and often times away from the primary task, although not necessarily for a significant period of time. One could argue that the very nature of an alert is to be intrusive. Although the literature presented various methods to lessen the intrusiveness of the alert system, the notion of an explicit ‘non-intrusive’ alert was not mentioned. Further, the impetus for designing less intrusive alerts appears to be minimizing operator annoyance rather than cognitive demands.

As shown in Table 14 in the previous section, literature in the form of models that could be used to inform the design of a maritime anomaly alert system was minimal. It is clear that the potential impact of poorly designed alerts or alarms on operator performance and behaviour (e.g., turning off nuisance alerts) has been recognized and a number of design concepts have resulted. However, normative models that describe the relationship between alert system parameters and human cognition do not appear to exist. Such models would be extremely valuable in providing a theoretical foundation for the design of an alert system. At present, the most suitable models are generic cognitive information processing approaches those that focus on attention sharing and resource competition. While not the focus of the present work, models of alert annoyance have some relevance to the design of auditory alerts, although they also may lack the specificity to inform design approaches.

The majority of the literature that was found related to the alerting cue itself with little focus on the other functional components of an alerting system. Although there is a relation between the alert presentation and the alert information content, most research focused on how to present an alert to an operator, rather than the information that should be included in the alert, when to present the alert (interruption), how to configure the alerts and how to manage old and new alerts.

The literature does provide, however, some reasonable guidance in reducing the frequency of alarms and configuring alarms to an operator's local priorities.

There is a significant gap in the literature when it comes to concepts relevant to non-intrusive alert design guidelines. That is, recognition of the need to capture the operator's attention while not interfering with cognitive processing of the primary task was not the impetus behind the majority of the guidelines. There were a few applicable design guidelines that were found relevant to the alert state and the alert information content and these guided some of the design concepts that were developed.

Few articles investigated and compared different modalities of alerts. Given the pervasiveness of visual interfaces, it is not surprising that visual alerts were the focus of the bulk of the literature. However, there is research to suggest that auditory and tactile alerts may be useful and perhaps even more appropriate than visual alerts in certain contexts. Factors relating to the intrusiveness of auditory and tactile alerts, however, were beyond the scope of this review and would need to be further investigated.

In conclusion, there was no single paper that definitively addressed the issue of how to design a non-intrusive alerting system. Nor, did we find a comprehensive body of information that could provide specific answers on how to scale the intrusiveness of alerts. Thus, the conclusions we have reached concerning design for non-intrusiveness are based upon relevant concepts extracted from the more general alert/alarm literature. In doing so, it should be pointed out that many of the recommendations lacked the specificity to inform design approaches.

The following table summarises our assessment of the state of the art of the knowledge base, and what future studies may need to be done in order to provide a comprehensive set of guidelines for the implementation of non-intrusive alerts to operational contexts where such an approach is merited.

**Table 15: Summary of literature relevance and need for research**

Alert Function	Comment
Configure alert parameters	<p>There are some useful generic guidelines available to guide the design of interfaces that would allow operators to configure alert parameters and priorities. Examples of interfaces for rapid selection of rules and configuration are available.</p> <p>Research question - what is the appropriate number of alert priorities?</p>
Receive information on alert state	<p>While there is abundant information on the various ways an alert can be brought to the attention of the operator, there is little research on how this can be done non-intrusively.</p> <p>Research is needed to determine the relative intrusiveness of a range of design parameters pertaining to the alert size, location and dynamics.</p> <p>More refined information processing models need to be developed to allow a better understanding of how attention and intrusiveness are related.</p>
Comprehend alert condition	<p>There is a solid base of information available in the general alarm/alert literature. In an RMP context, there is a need to examine trade-offs between implementing the information within the RMP window and/or providing a separate window.</p>
Action the alert condition	Beyond the scope of the present project
Manage Alerts	<p>Some useful general principles are found in the literature.</p> <p>In the context of the RJOC, analysis needs to be performed of the information requirements for an alert management system for data anomalies. May also need to consider how this would integrate within the overall "alert" system within the centre.</p>
<b>Maintain primary task</b>	
Assessment of interruptibility	<p>The technology for this is not proven and has the potential for creating adverse operator reactions. The human factors literature in this area was not a priority for this project. However, computer scientists have been interested in this problem and have developed some interesting models.<sup>7</sup></p>
Warning of impending alerts	<p>This literature is probably of more relevance to more highly dynamic information environments than the RJOC.</p>
Methods for return to primary task	<p>General principles for rapid regain of situation awareness are applicable.</p> <p>Research questions: should RMP be refocused/ranged as before the alert was serviced? Does changing RMP focus between primary task and actioning the alert cause loss of situation awareness. Is there a need to alert operators to any change in RMP status on return from alert?</p>

<sup>7</sup> See, for example, Gievska, S. and Sibert, J. Using task context variables for selecting the best timing for interrupting users. ACM International Conference Proceedings, vol 121, 2005.



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## 5. The Design Development Process

### 5.1 Development of design concepts

Based on a review of the literature, and bounded by the primary focus of the project, we concentrated on developing design ideas for two primary functional elements of an alert system:

1. An *alert indicator* which appears superimposed upon the GCCS window and is designed to advise of new alerts non-intrusively; and
2. An *alert information window* (AIW) which allows operators to obtain details on specific alerts and to manage alert lists.

#### 5.1.1 The alert indicator

With factors outlined in the previous section in mind, we developed design concepts that map onto three levels of importance of the information that triggers the alarm. Our discussions with an SME and our own analysis of potential requirements suggest that three priority levels represent an appropriate balance of information categories.

For each information category (i.e., attribute, movement and VOI related) we have provided operational examples of RMP anomalies taken from Davenport (2008) which have been sorted into the three priority levels by an SME. There are four basic information requirements for all alert concepts:

1. To bring to the attention of the operator that an alert has occurred;
2. To provide an indication of the alert priority;
3. To provide a cumulative numerical indication of how many outstanding alerts are in the system (i.e., have not been processed or cleared); and
4. To update the cumulative alert indicator when an alert has been cleared.

There are several coding schemes that could be potentially used to visually indicate urgency level, including factors such as:

- Colour stereotypes
- Colour/luminance increments from the background
- Size of the alerting stimulus
- Rate of flashing
- Locus on the display

Considerations for the design of a visual alert indicator for each of the three priority levels are outlined in the next section.

In terms of other modalities to indicate alerts, auditory alarms were not considered as we concluded that the perceptual deviation from the operator's primary task (i.e., a visual monitoring task) would

be too great and they would therefore be too intrusive. Further, it is anticipated that auditory alarms would be disruptive to other operators in the RJOC.

A tactile interface, on the other hand, may be feasible in that it can be isolated to the individual operator and therefore not disruptive to other operators. Furthermore, the intrusiveness of a tactile alert can be altered to imply a specific level of priority of information. Considerations for the design of a tactile alert indicator for each of the three priority levels are outlined in Section 5.1.3.

#### **5.1.1.1 Priority 1 alerts**

A priority 1 alert is an anomaly that is of critical significance. It will require operator attention at the earliest opportunity and may require temporary suspension of the primary task. The occurrence of the alert should be readily perceivable while an operator performs a primary task. The alert should clearly signal that it is of high priority. Some examples of priority 1 anomalies are:

- Grab and dash fishing - a foreign fishing boat moves from the international zone to Canadian waters (where it is forbidden from fishing) for a few hours just before leaving for its home port.
- Not heading for port - a vessel is heading in a direction where there is no harbour, or is not heading toward its declared destination. Cargo and Ferry vessels always go from one port to another port, and generally by the shortest available route.
- Changes destination - a cargo ship changes course in mid-journey or possibly even reverses its heading and returning to port.
- Heading into danger - a ship is heading toward a natural obstacle such as ice or non-navigable water.
- Regulatory infraction - a ship enters, without permission, a regulated zone such as the Northwest Passage, where ships must register their plans and receive permission to proceed.
- Infringing a closed zone - a ship is in a zone of the ocean that is closed to its type of commercial activity, whether for environmental, wildlife protection, or national security reasons.

#### **5.1.1.2 Priority 2 alerts**

A priority 2 alert is an anomaly for which the related information is important but can be dealt with as soon as primary task activity permits. The occurrence of the alert should be readily perceivable while an operator performs a primary task. The alert should clearly signal that it is of intermediate priority. Some examples of anomalies are:

- Unexplained high speed - a ship that is claiming (e.g., in call-ins or on AIS) to be a normal merchant ship suddenly starts travelling at a high speed more typical of a passenger ship or warship.
- Speed too slow - a Cargo, Passenger, or Ferry is observed going slowly. As these vessels generally go as fast as they safely can, it may be an indicator of a problem.
- Loitering - a cargo ship stops outside of or far from a harbour, or steams very slowly, rather than proceeding directly into port.



- Outside historical route - a ship that historically follows a consistent route, is deviating or slowing down for no apparent reason.
- Outside shipping lane - a ship that should be in a shipping lane is instead travelling outside the lane. Ships approaching port enter a “Vessel Traffic Management” zone and are required to stay within designated shipping routes.
- Zone mismatch to activity - a ship’s location does not match its claimed activity, where that activity can only be carried out in specific regions of the sea, due either to regulations or to physical requirements of the activity itself.
- Littoral rendezvous - many small crafts converge on a larger ship, and then the small crafts spread out at high speeds to many different ports.

#### **5.1.1.3 Priority 3 alerts**

A priority 3 alert is an anomaly for which the related information is less important and will be attended to as time and resources permit. The occurrence of the alert should not be as readily perceivable as priority 1 and 2 alerts and should not draw attention to its occurrence. It should be perceivable only when the operator needs to check for alerts. The perceptual properties of the alert should clearly indicate that it is of lowest priority. Some examples of priority 3 anomalies are:

- Track ends - a ship track ends in mid-ocean. A ship track will normally not end, except at a harbour or by the ship leaving Canadian waters.
- Proximity to infrastructure - a ship approaches or loiters around Canadian infrastructure, such as oil production equipment, sub sea pipelines, communication cables, etc.

Again, we want to emphasize that the above does not constitute a definitive set of anomalies that may be of interest, nor is the specific priority classification being recommended for adoption. These assumptions were made simply to facilitate the development of design concepts.

#### **5.1.2 Visual design concepts**

Many of the concepts to be described have used colour and/or luminance coding as one basic approach to differentiating priority. Based on existing population stereotypes, the priority coding is as follows:

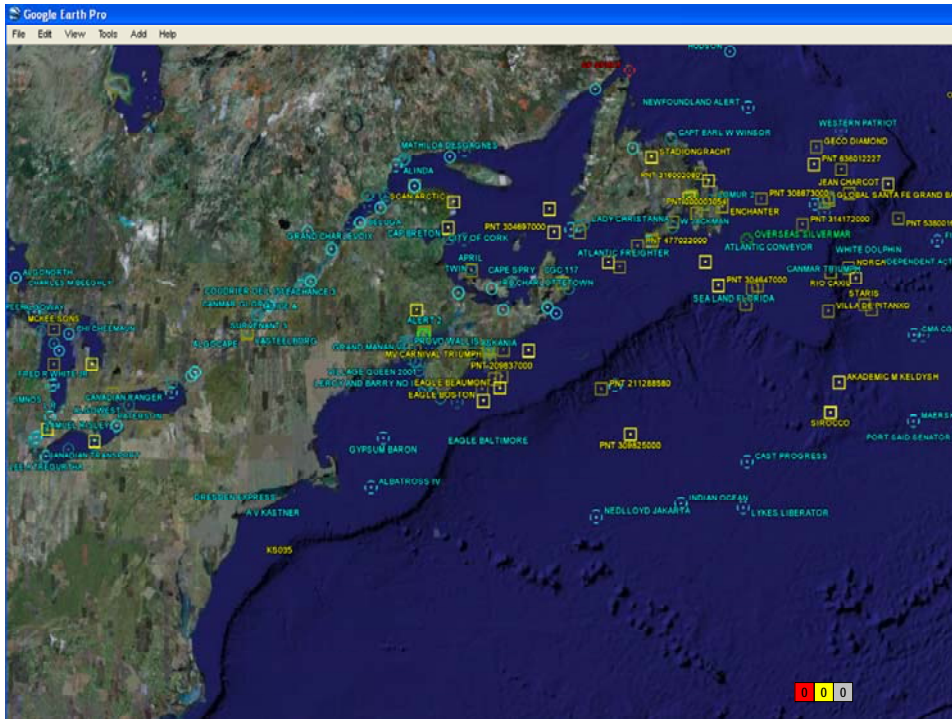
- Priority 1: red sector of the spectrum
- Priority 2: yellow-orange sector of the spectrum
- Priority 3: unsaturated, neutral areas of the spectrum (e.g., grey)

The use of red is considered acceptable, even though red is used in GCCS to code VOI, hostile and suspect tracks, since there is unlikely to be any possible confusion because of where the red alert is located and the shape and context in which it appears.

A second general principle is to locate the alerting stimulus in the periphery of the display towards the right. We did consider locating it on the menu bar at the top of the screen, but this area is already cluttered and we believed that the spatial separation from the menu bar would in fact encourage cognitive separation, so that typical menu intensive tasks would not be compromised by the adjacent proximity of alerts. Similarly, the alerts themselves would be more salient (enough to capture the operator’s attention without being intrusive) by being spatially separated.

Five different designs have been created and will be discussed in details next.

#### 5.1.2.1 Design 1: Cumulative Total Indicator



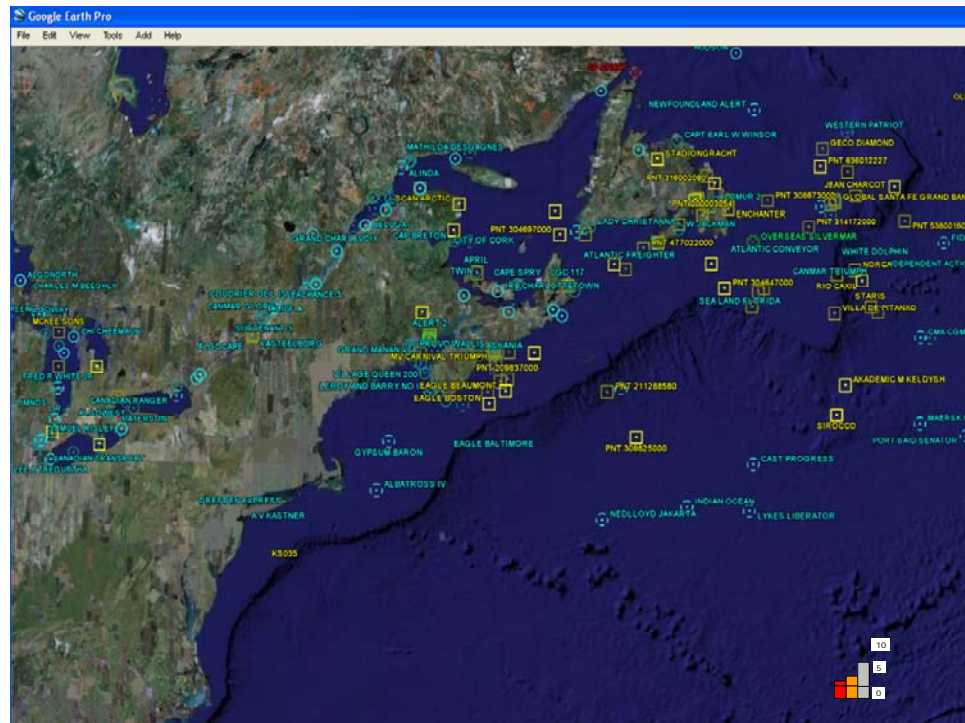
**Figure 6: Design 1: Cumulative Total Indicator**

The alert category is indicated by colour. For priority 1 alerts, the number in the red box increments and the box blinks at rate of 2 Hz. The flashing continues until the operator acknowledges the alert by clicking on it. This takes the operator to the Alert Information Window (AIW). When the operator has finished processing the alert, either one of two conditions exist. One, the alert has been dealt with and is no longer of interest, in which case the counter resets to n (number of current outstanding alerts) - 1. Or two, the alert remains in the system, and the indicator no longer flashes and stays at the current value, in which case the next alert would increment this value and flash until attended to by the operator.

For priority 2 alerts, the number in the yellow box increments and the box blinks at an approximate rate of .25-.5 Hz. The flashing continues until the operator acknowledges the alert by clicking on it. The remaining functionality is the same as a Priority 1 alert.

On a new priority 3 alert, the number in the grey box simply increments. When the operator has processed the alert, the number decreases to n-1.

### 5.1.2.2 Design 2: Vertical Cumulative Indicator



**Figure 7: Design 2: Vertical Cumulative Indicator**

This design concept is similar to design 1, except the count of outstanding alerts is indicated by a vertical progress bar. The above example shows several outstanding alerts in all three priority categories. A vertical scale provides an indication of the number of alerts.

A priority 1 alert is shown in this design by the number 1 blinking red at a rate of 2 Hz and the associated red vertical bar incrementing in height. The flashing of the number 1 to red continues until the operator acknowledges the alert by clicking on it. This takes the operator to the AIW. When the operator has finished processing the alert, one of two conditions will exist. The alert has been dealt with and is no longer of interest, in which case the vertical bar decrements by one unit, or the alert remains in the system, and the indicator bar stays at the current height; in either case the box background reverts to grey. The next alert would again increment the height of the bar and the box would flash red again until attended to.

A priority 2 alert is shown in this design by the number 2 in the second box blinking yellow at an approximate rate of .25-.5 Hz. and the vertical bar incrementing in height. The flashing continues until the operator acknowledges the alert by clicking on it. The remaining functionality is the same as a Priority 1 alert.

On a new priority 3 alert, the vertical bar simply increments. When the operator has processed the alert, the number decreases to the current outstanding number minus 1, or remains the same if the alert is not deleted.









On a new priority 1 alert, the border of the dotted triangle skews toward the priority 1 axis showing an increase in the number of high priority alerts. The dotted triangle also turns red and flashes at a rate of approximately 5 Hz. The triangle remains red and flashing until the operator acknowledges the alarm by clicking it. The number of active priority 1 alerts, as indicated by the size and shape of the dotted triangle, would remain unchanged until individual alerts are processed.

Upon an incoming priority 2 alert, the border of the dotted triangle skews toward the priority 2 axis showing an increase in the number of medium priority alerts. The dotted triangle also turns orange and flashes at a rate of approximately 0.5 Hz. The triangle remains orange and flashing until the operator acknowledges the alert by clicking it. The number of active priority 2 alerts, as indicated by the size and shape of the dotted triangle, would remain unchanged until individual alerts are processed.

On a new priority 3 alert, the border of the dotted triangle skews toward the priority 3 axis showing an increase in the number of low priority alerts. The dotted triangle also turns grey but does not flash. The operator would only notice this increment if he/she was looking directly at the display at moment it changes shape and colour. Therefore, the operator would be required to intentionally seek out active priority 3 alerts rather than directly being made aware of new alerts. The number of active priority 3 alerts, as indicated by the size and shape of the dotted triangle, would remain unchanged until individual alerts are processed.

### **5.1.3 Tactile design concept**

This design concept assumes that the RJOC operator could carry a pager-type device that would transmit the alerts. The design is based on a brief review of literature on the use of tactons for mobile phone alerts to imply priority (Brown & Kaaresoja, 2006). Generally, priority can be implied by the number, duration and intensity of pulses. That is, higher priority alerts would be indicated by more, longer and more intense pulses.

On a new priority 1 alert, the pager would receive two pulses of approximately 30 milliseconds in duration. The intensity of the pulse would be approximately 1.38 V. The pulses would repeat until the operator acknowledges the alarm by clicking it. Interrogating and processing the alarm would have to be done on the operator's computer workstation.

On a new priority 2 alert the pager would receive one pulse of approximately 10 milliseconds in duration. The intensity of the pulse would be approximately 0.98 V. The pulse would repeat until the operator acknowledges the alarm by clicking it. Interrogating and processing the alarm would have to be done on the operator's computer workstation. The operator would not receive priority 3 alerts via the pager. He/she would therefore have to be at their workstation looking at the screen and intentionally seeking out priority 3 alerts.

### **5.1.4 The alert information window**

The purpose of the Alert Information Window (AIW) window is to provide the operator with specific information about the alert details and to manage alert lists. It is not a window for problem solving or analysis which we assume will take place using existing functionality in the RJOCs.

For the AIW, only visual designs were considered. An initial design for an AIW window is shown in Figure 11.

	#Alerts	Track#	Name	Alert	Time
<b>Priority 1</b>	<b>3</b>				
<input type="button" value="RMP"/>		4689	CP SPIRIT	Heading into danger	09:48
<input type="button" value="RMP"/>		3193	EAGLE BOSTON	Changes destination	10:17
<input type="button" value="RMP"/>		4745	OVERSEAS SILVAMAR	Grab and dash fishing	14:21
<input type="button" value="Priority 2"/>	<b>8</b>				
<input type="button" value="Priority 3"/>	<b>9</b>				

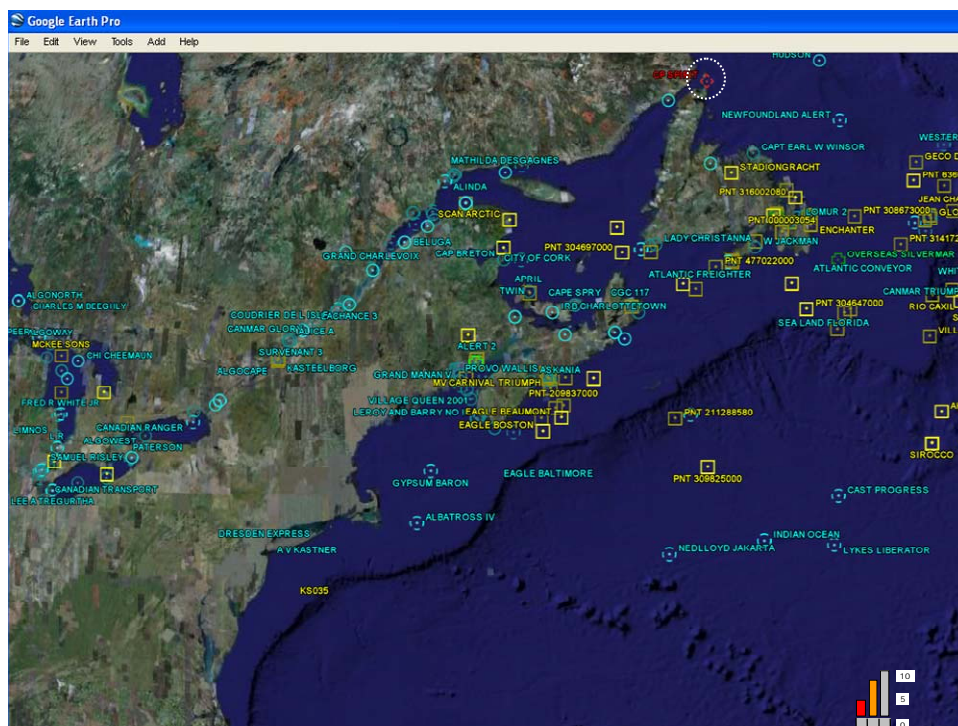
**Figure 11: Alert Information Window**

The window comprises separate areas for each alert priority with the priority level colour coded. Within each category, there is a field for the number of alerts in the system. The information provided includes track number, name of the contact, the specific nature of the anomaly, and time of the report that gave rise to the anomaly.

The above example shows what would happen if the operator had selected a priority 1 alert in the RMP window. The priority 1 section is expanded to show all alerts and the most recent alert, that caused the alert indicator to flash, is highlighted. It is important to note that the operator could select another alert in the priority 1 list or another alert category (in which case that section would be automatically expanded to show all of the tracks within that category). At this point the operator may choose to refer back to the RMP to see the location of the alert and the context by clicking the RMP button on the track line. When this happens, the GCCS RMP window is brought back showing the contact in question highlighted, as shown in Figure 12 (see concentric broken circle around the contact of interest in the upper part of the RMP).<sup>8</sup>

<sup>8</sup> In the PowerPoint presentation for the SMEs, this concentric circle shrinks and expands dynamically around the track symbol to better enable the operator to locate the track in question.





**Figure 12: RMP track highlight**

When the operator has finished analysis on the track of interest, she/he can return back to the AIW (by clicking on the AI indicator) and decide to either leave the track in the system or to clear the alert by way of the CLEAR button. This would then result in the track being deleted from the alert list, as shown in Figure 13.

	#Alerts	Track#	Name	Alert	Time
Priority 1	2				
RMP		3193	EAGLE BOSTON	Changes destination	10:17
RMP		4745	OVERSEAS SILVAMAR	Grab and dash fishing	14:21
+	Priority 2	8			
+	Priority 3	9			

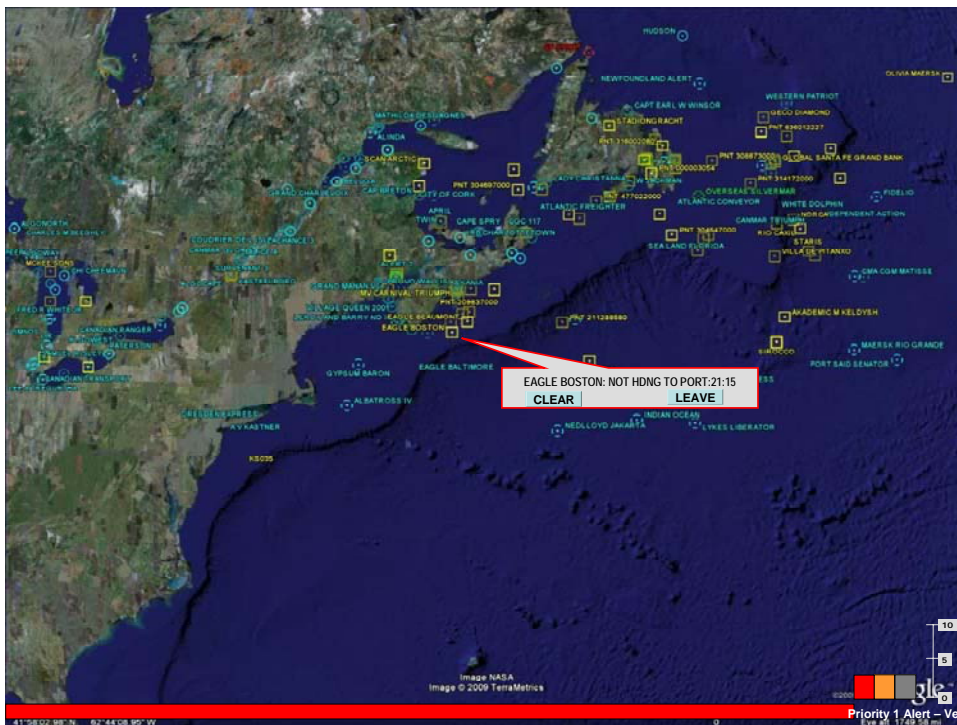
Clear Done

**Figure 13: Alert Information Window after a track is deleted**

The operator may choose to process other alerts in the system, or return to the RMP via the button DONE at the bottom of the window.

### 5.1.5 The RMP pop up box

The purpose of this box is to provide the operator with a shortened version of the information about the alert. The AIW provides full information regarding each alert and allows operators to manage all the alerts in the system. The RMP pop up box on the other hand, allows operators a quick and easy method to clear an alert or leave it in the system. The pop up box appears when the operator acknowledges (i.e. clicks on) the indicator for an incoming alert. This was designed as a second method to present operators with relevant information. The research team did not come across any literature regarding this concept. As shown in Figure 14, a pop up box was designed to include the name of the vessel (e.g., Eagle Boston), reason for the alert (e.g., Not heading to port), and time of alert (e.g., 21:15), as well as action buttons (i.e., Clear or Leave).



**Figure 14: RMP pop up box**

The box's border would be outlined in the same colour as the priority of the alert, in this case, red for priority 1. If the operator chose to CLEAR the alert, the system would delete the alert and the counter would return back to the previous number, in this case, back to 1. If the operator chose to leave the alert in the system, the counter would remain the same, in this case, stay at 2.

## **6. Evaluation and Review of Design Concepts by Subject Matter Experts**

### **6.1 Preparation for Design Evaluation and Review**

Following the development of the design concepts, a consultative process was begun with the Scientific Authority to determine which concepts should be taken forward for review by Subject Matter Experts (SMEs). As a result, it was decided that the polygon design (because it was thought to non-intuitive) nor the tactile design (because it was considered impractical) would be explored further.

In preparation for the evaluation, the individual design elements (alert indicator, alert information window, alert track highlighter and RMP pop up box) were incorporated into a PowerPoint demonstration concept that would simulate the functionality of an alerting system. Each demonstration comprised a new alert initiation (all three priority levels considered sequentially), acknowledgment of the alert, getting information on the alert and clearing the alert.

To evaluate the designs, questionnaires were constructed to address issues such as the usability and utility of the design, ease of comprehension and overall preferences.

An ethical protocol was submitted to and approved by the Human Research Ethics Committee at DRDC Toronto. The approved ethics protocol is included in Annex A.

### **6.2 Method**

The following section outlines the methodology used in reviewing and evaluating the anomaly alert system design concepts with SMEs.

#### **6.2.1 Date and Location of SME Evaluation**

SME evaluations were conducted in the MAPLE lab at DRDC Atlantic from February 23-26, 2009.

#### **6.2.2 Participants**

Seven Subject Matter Experts (SMEs) were recruited to participate in an assessment of the non-intrusive alerting designs. There were 2 Lt(N), 2 retired CF personnel, 2 operators, and a civilian. Combined related experience included a Common Operational Picture Officer, Watch Officer, Surveillance Officers, Bridge Watch Keeper, and Surveillance Database Operators. There were 6 men and 1 woman.

#### **6.2.3 Materials**

Trial participants were presented with PowerPoint representations of the various design concepts, which demonstrated with animation how the basic functionality would work. The concepts were presented in the following order:

1. Cumulative total indicator with pop-up window (Figure 6)

2. Cumulative total indicator with AIW (Figure 6)
3. Vertical cumulative indicator with pop-up window (Figure 7)
4. Vertical cumulative indicator with AIW (Figure 7)
5. Horizontal indicator bar with pop-up window (Figure 8)
6. Horizontal indicator bar with AIW (Figure 8)
7. Ticker and fading bar with pop-up window (Figure 14)
8. Ticker and fading bar with AIW (Figure 9)

All participants reviewed the design concepts in the same order which means that a potential order effect could not be determined. However, the presence or absence of an order effect was believed to be inconsequential for this exploratory research.

Part of the evaluation of the designs was accomplished by a five part questionnaire. The first section included demographic questions such as name, rank, number of years experience, etc. The second part of the questionnaire included 15 questions related to the usability and usefulness of a non-intrusive alerting system in general. SMEs were asked to select the rating (on a 5-point scale) they felt most appropriate. Example questions included “These alerts would enhance our knowledge of anomalies” and “This alerting system would be difficult to use.”

The third section of the questionnaire assessed participant’s attitudes towards each non-intrusive alert design. Again, SMEs were asked to select the rating (on a 7-point scale) they felt most appropriate. Example questions included “The number of alerts was easy to comprehend” and “The priorities of the alerts were easy to comprehend.”

The fourth part of the questionnaire assessed the level of preference for each alert design across three dimensions; overall effectiveness in bringing alerts to the operator’s attention, the method in which different alert priorities are presented, and the degree to which all of the required information about an alert is presented. For each dimension, participants were asked to rank each of the four designs; with ‘1’ indicating the most preferred and ‘4’ the least preferred.

The final section of the questionnaire included open-ended questions related to each alert design. For each alert design, participants were asked if they thought the design should be implemented (Yes=1, No=2). They were then asked to list their likes and dislikes for each design. For the final question in this section, participants were asked to rate the intrusiveness of the design based on a 7-point scale (where 1=Not at all Intrusive, 7=Extremely Intrusive). Details of the questionnaires and interview questions can be found Annexes B and C.

#### **6.2.4 Procedure**

Each SME participated individually in a walkthrough of each of the designs using the PowerPoint presentation on a computer screen, and then completed the usability questionnaire and answered a number of follow up questions in an interview. Sessions lasted on average one hour.

Two members of the research team lead the walkthroughs, one leading the process and the other taking notes and audio recording participant responses. Participants were first asked to read a pre-experiment information sheet and then read and sign a voluntary consent form (see Annex A). A member of the research team then described the goals of the project as well as goals of an alert system in general. She then presented a definition of non-intrusive alerts, an overview of the alert

designs, and a basic description of the method to be used for the walkthrough. After the introduction, participants were asked if they had any questions before they were shown each alert design in detail. A member of the research team then walked participants through the four alert designs, each with the RMP pop-up box and then with the AIW. At different points during the walkthrough, participants were questioned relating to the topics such as priority levels, setting alert trip points and parameters for alerts. Participants were allowed to ask questions and make comments throughout the walkthroughs.

After the walkthroughs, participants were asked to complete the five part questionnaire. Participants were then asked some general follow up questions that were not previously addressed during the walkthroughs. If desired, participants were able to revisit the different design concepts during the questionnaire and general discussion phases.

The interviewers used the following points to guide the discussion, asking questions when necessary (depending on what had already been discussed during the presentation of the design concepts):

- Operator's attendance at their desk
- Frequency of alerts (by priority)
- Priority 1 alerts being intrusive
- Ignoring alerts
- Priority indications
- Alert colour scheme (e.g., red, orange, yellow, grey)
- Font (e.g., size, colour)
- Terminology
- Alert Information Window
- Intuitive versus not intuitive
- Intrusiveness of alerts
- Auditory/tactile alerts
- Flexibility in the location of ticker and horizontal indicator bar
- RMP centred on contact
- Information in the RMP pop up box
- Ability to return to primary task
- Shift change over problems

A summary of individual participant responses are provided in detail in Section 6.2.3.

## 6.3 Results

### 6.3.1 Questionnaire data

The questionnaire data are divided into two sections: quantitative and qualitative. With the exception of the intrusiveness ratings, the majority of questionnaire responses were ratings on a 5-point scale. A 7-point scale was used for intrusiveness ratings as the perception of intrusiveness was of primary concern for this project and so it was thought that detecting finer distinctions between people would be desirable. Results suggest, however, that a 5-point scale would likely have been suitable. In addition to rating scales, participants were also asked to rank the designs, and provide their likes and dislikes of each design in an open ended format.



### 6.3.2 Quantitative data

#### 6.3.2.1 General Non-Intrusive Design Questions

The Usability and Usefulness Questionnaire assessed participants attitudes on the usefulness of a general non-intrusive alerting system (see Table 16).

**Table 16: Mean ratings for Usability and Usefulness of Non-Intrusive Alerting System**

Statement	Answer <sup>9</sup>	Mean	St. Dev.	Range (scale = 1-5)
These alerts would enhance our knowledge of anomalies	Strongly agree	4.6	.53	4-5
This alerting system would be used on a daily basis	Strongly agree	4.9	.38	4-5
Tasks can be performed in a straightforward manner using this alerting system	Strongly agree	4.6	.79	3-5
The thinking required to use this alerting system requires significant effort	Disagree	1.9	.38	1-2
This alerting system would be difficult to use	Strongly Disagree/Disagree	2.0	1.41	1-5
This alerting system will improve my situation awareness	Agree	4.4	.53	4-5
This alerting system would make it easier to identify anomalies	Strongly agree	4.7	.49	4-5
I would find this alert system useful	Disagree	1.7	.49	1-2
I would not ignore alerts while using this technology	Agree	4.0	1.00	2-5
The Alert Information Window (AIW) was confusing	Disagree	2.1	.38	2-3
It was easy to learn how the AIW was represented	Strongly agree	4.7	.49	4-5
The AIW had all the necessary information	Disagree	2.9	1.07	2-4
It was easy navigating between the RMP and the AIW	Agree	4.1	.38	4-5
I prefer clearing and deferring alerts directly from the RMP	Undecided	3.1	1.07	2-5
I prefer using the AIW to clear or defer alerts	Undecided	3.1	1.07	2-5

As shown in Table 16, participants showed generally favourable attitudes towards a non-intrusive alerting system. Specifically, participants strongly agreed that the non-intrusive alerting system would enhance their knowledge of maritime anomalies (Mean = 4.6), be used on a daily basis (Mean = 4.9), perform tasks in a straightforward manner (Mean = 4.6), and make it easier to

<sup>9</sup> Scale descriptor is based on the most frequent rating (mode).

identify anomalies (Mean = 4.7). Despite these positive answers, participants reported that they would not find the alert system useful (Mean = 1.7). This rating is somewhat surprising and participant comments shed no light on the reasons that may have led to this rating. Therefore, the way in which operators consider the potential usefulness of an alerting system for maritime anomalies clearly needs to be addressed in future work. Participants were also undecided about whether the Alert Information Window (AIW) had all the necessary information and whether they preferred clearing alerts directly from the RMP or the AIW. Follow up interview questions covered these issues and will be discussed in Section 6.2.4.

### 6.3.2.2 Specific Design Questions

The rest of the questions assessed the participant's attitudes regarding each specific alerting design. The following table shows the means and standard deviations for each question.

**Table 17: Mean Ratings for the Alert Design Questions**

Statement & Design	Answer <sup>10</sup>	Mean	St. Dev.	Range (scale = 1-5)
<b>The number of alerts were easy to comprehend</b>				
Design 1: Cumulative Total Indicator	Strongly agree	4.7	.49	4-5
Design 2: Vertical Cumulative Indicator	Agree	3.9	.69	3-5
Design 3: Horizontal Indicator Bar	Agree	3.9	1.07	2-5
Design 4: Ticker & Fading Bar	Agree	4.1	.06	3-5
<b>The presence of an alert was easy to recognize</b>				
Design 1: Cumulative Total Indicator	Agree	4.3	.49	4-5
Design 2: Vertical Cumulative Indicator	Agree	3.9	.90	2-5
Design 3: Horizontal Indicator Bar	Agree	3.7	1.25	2-5
Design 4: Ticker & Fading Bar	Strongly Agree	4.4	1.13	2-5
<b>The priorities of the alerts were easy to comprehend</b>				
Design 1: Cumulative Total Indicator	Strongly agree	4.6	.53	4-5
Design 2: Vertical Cumulative Indicator	Agree	4.4	.53	4-5
Design 3: Horizontal Indicator Bar	Agree	3.9	1.07	2-5
Design 4: Ticker & Fading Bar	Strongly Agree	4.4	.79	3-5
<b>It was easy to find the relevant anomaly</b>				
Design 1: Cumulative Total Indicator	Agree	4.1	.69	3-5
Design 2: Vertical Cumulative Indicator	Agree	4.0	.58	3-5
Design 3: Horizontal Indicator Bar	Agree	4.1	.69	3-5
Design 4: Ticker & Fading Bar	Strongly Agree/Agree	4.3	.76	3-5
<b>It was easy to find information on anomalies</b>				
Design 1: Cumulative Total Indicator	Agree	4.3	.49	4-5

<sup>10</sup> Scale descriptor is based on the most frequent rating (mode).

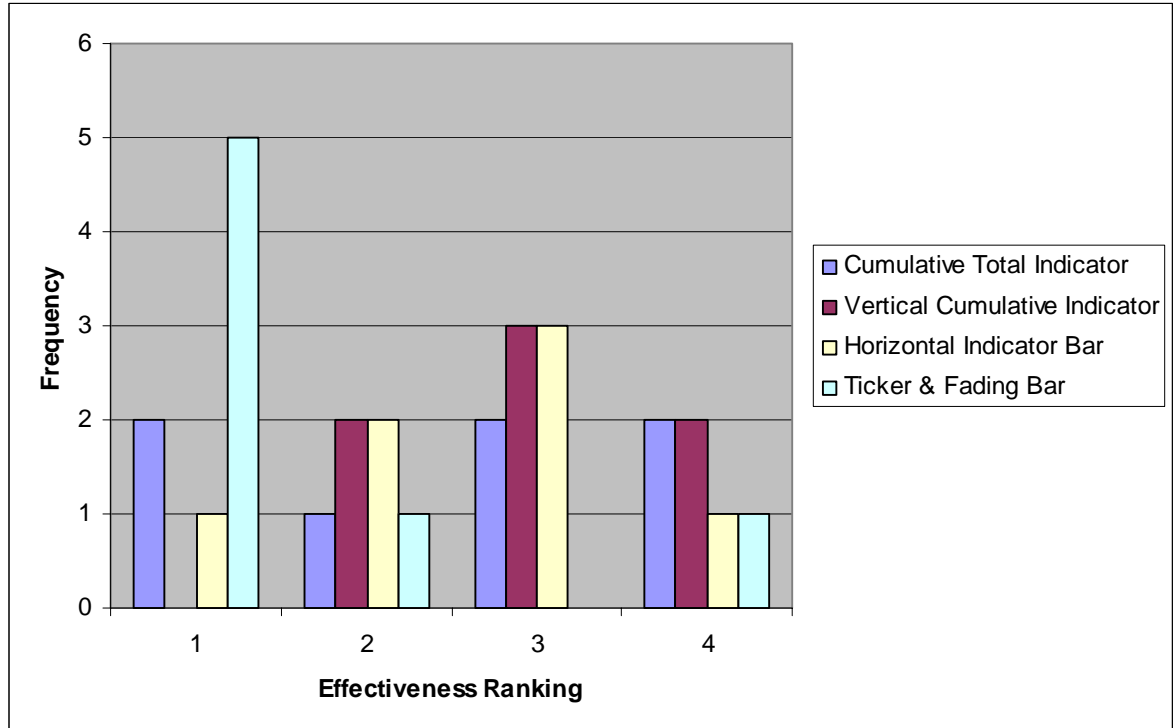
Statement & Design	Answer <sup>10</sup>	Mean	St. Dev.	Range (scale = 1-5)
Design 2: Vertical Cumulative Indicator	Agree	3.9	.38	3-4
Design 3: Horizontal Indicator Bar	Agree	4.0	.58	3-5
Design 4: Ticker & Fading Bar	Agree	4.1	.69	3-5
<b>The alerting design enhanced my situation awareness of maritime anomalies</b>				
Design 1: Cumulative Total Indicator	Agree	4.1	.38	4-5
Design 2: Vertical Cumulative Indicator	Agree	4.0	.58	3-5
Design 3: Horizontal Indicator Bar	Agree	4.0	.58	3-5
Design 4: Ticker & Fading Bar	Strongly agree	4.6	.53	4-5
<b>The appearance of the alerts is compatible with my current interface</b>				
Design 1: Cumulative Total Indicator	Strongly Agree	4.0	1.15	2-5
Design 2: Vertical Cumulative Indicator	Agree	3.6	.98	2-5
Design 3: Horizontal Indicator Bar	Undecided/Agree	3.3	.76	2-4
Design 4: Ticker & Fading Bar	Agree	4.0	1.00	2-5

A parametric one-way Analysis of Variance (ANOVAs) and non-parametric tests were conducted and revealed no significant differences in ratings between the four alert designs for any of the above questions. As a result, this section presents only observations on the trends in the data, which need to be validated through further experimentation.

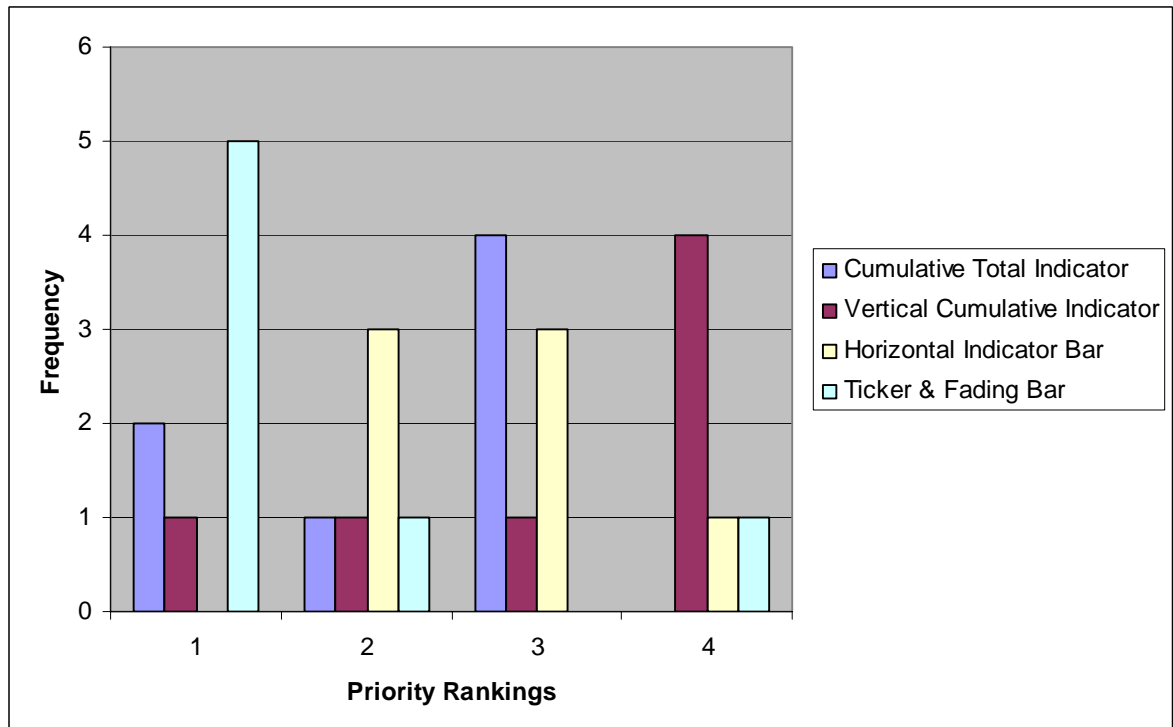
Participants rated the Cumulative Total Indicator as the easiest to comprehend, while the Vertical Cumulative Indicator and the Horizontal Indicator Bar were equally more difficult to comprehend. The presence of new alerts was easiest to recognize in the Ticker and Fading Bar, followed by the Cumulative Total Indicator, the Vertical Cumulative Indicator, and then the Horizontal Indicator Bar. Alert priorities in the Cumulative Total Indicator were easiest to comprehend, and most difficult in the Horizontal Indicator Bar. The results also suggest that participants found that the Ticker and Fading Bar was the easiest design in which to find the anomaly, while the Vertical Cumulative Indicator was the most difficult. The Cumulative Total Indicator was rated the easiest to find the relevant information pertaining to the anomaly, while the Vertical Cumulative Indicator was rated the hardest to find the information. The Ticker and Fading Bar enhanced the operator's situation awareness of maritime anomalies (i.e., incoming alerts and total number of active alerts in the system), while the Vertical Cumulative Indicator and the Horizontal Indicator Bar were tied for least likely to enhance situation awareness. Lastly, the Cumulative Total Indicator and the Ticker and Fading Bar were rated the most compatible with the current interface, while the Horizontal Indicator Bar was rated the least compatible.

Participants were also asked to rank the designs in order of preference (i.e., 1, 2, 3 and 4) from the perspective of alert priorities (Figure 15), the degree to which the design grabbed the attention of the operator (Figure 16), and providing relevant information without distraction (Figure 17). All three figures show a frequency count of the specific rank for each of the four alert design concepts.

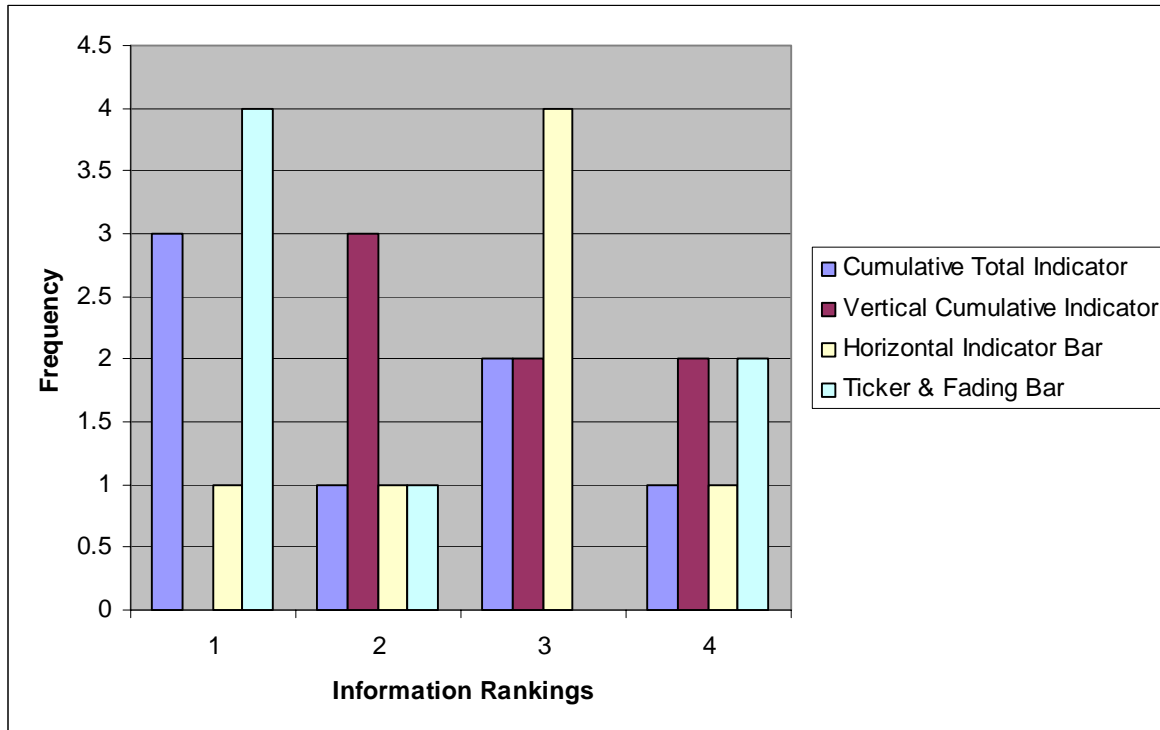




**Figure 15: Subject rankings for effectiveness in bringing alerts to my attention**



**Figure 16: Subject rankings for methods for representing the priorities**



**Figure 17: Subject rankings for providing required information without distraction**

Kruskal-Wallis ANOVA and Chi-Square analyses revealed no significant differences between the four alert designs in terms of effectiveness in bringing alerts to the operator's attention, methods of representing priorities and providing required information without distraction. Though not statistically significant, a trend analysis suggests that the Ticker and Fading Bar was the preferred design for all of these three features while the Vertical Cumulative Indicator was the least preferred. Further empirical research is needed to verify this trend.

### 6.3.2.3 Implementation and intrusiveness

Participants were asked if each design should be implemented and they were also asked to rate the intrusiveness, as shown in Table 18.

**Table 18: Mean ratings for design implementation and intrusiveness**

Statement & Design	Answer <sup>11</sup>	Means	St. Dev.	Range
<b>Should the design be implemented</b>				
Design 1: Cumulative Total Indicator	Yes	1.3	.49	1-2
Design 2: Vertical Cumulative Indicator	No	1.9	.38	1-2
Design 3: Horizontal Indicator Bar	No	1.6	.53	1-2
Design 4: Ticker & Fading Bar	Yes	1.0	.00	1
<b>Intrusiveness<sup>12</sup> (scale = 1-7)</b>				
Design 1: Cumulative Total Indicator	Not at all intrusive	2.1	.90	1-4
Design 2: Vertical Cumulative Indicator	Somewhat intrusive	2.9	1.07	1-4
Design 3: Horizontal Indicator Bar	Somewhat intrusive	3.7	1.60	1-5
Design 4: Ticker & Fading Bar	Somewhat intrusive	3.1	1.46	1-5

A one-way parametric ANOVA and non-parametric tests revealed no significant differences between the four alert designs in terms of which design should be implemented or the intrusiveness of each design. Though not statistically significant, all participants felt that the Ticker and Fading Bar (Mean = 1.0) should be implemented and all but two participants felt that the Cumulative Total Indicator (Mean = 1.3) should be implemented. On the other hand, only one participant indicated that the Vertical Cumulative Indicator (Mean = 1.9) should be implemented and three felt that the Horizontal Indicator Bar (Mean = 1.6) should be implemented<sup>13</sup>.

Although not statistically significant, participants rated all four designs as not at all intrusive or somewhat intrusive. The horizontal indicator bar was rated the most intrusive and the cumulative total indicator the least intrusive. Interestingly, as noted above, all participants felt that the Ticker and Fading Bar should be implemented even though it did not receive the least intrusive rating.

In summary, the Cumulative Total Indicator and the Ticker and Fading Bar were rated more favourably than the Vertical Cumulative Indicator and the Horizontal Indicator Bar. Specifically, in comparing the rank ordering of the designs, the Ticker and Fading Bar was preferred over all other designs, while the Vertical Cumulative Indicator was the least preferred. What is interesting to note is the Ticker and Fading Bar includes the Vertical Cumulative Indicator scale with the only difference being priority colour in the boxes. Based on discussions, participants preferred the actual ticker/fading bar that appeared at the bottom of the screen, rather than the scale, which will be discussed later.

### 6.3.3 Qualitative data

The following table shows the participants' qualitative assessments of each alert design.

<sup>11</sup> Scale descriptor is based on the most frequent rating (mode).

<sup>12</sup> The intrusiveness was on a 7-point scale (1 = Not at all intrusive, 4 = Somewhat intrusive, 7 = Extremely intrusive)

<sup>13</sup> Yes was considered a 1, while No was considered a 2.

**Table 19: Likes and Dislikes of Alert Designs**

Design	Likes	Dislikes	Comments
1: Cumulative Total Indicator	Simple and clear; uses less screen; numeric total subtle but effective	No hover feature for listing alerts without leaving RMP	This feature did not exist for any of the design concepts, but could be readily implemented.
	Unobtrusive; not overbearing but available as a quick visual reference	This is not good for operators that sit for hours in front of this system	Comments made during the discussion suggest that this design may be more easily ignored by operators especially over long periods
	Exact priority of each alert; unobtrusive display	Not as immediately visible as the ticker/bar	
	Compact, clear number	Small numbers could create a change in priority for an operator, contrary to command's need	Number boxes could easily be made larger
	Dead simple	No immediate visual of number of each type of alert without focusing on small numbers. Also, location should be able to be moved at will	The size and location of alert could easily be changed in future versions. Also numbers could easily be made larger.
	Does not fill the RMP with unnecessary info		
2: Vertical Cumulative Indicator	Visual and numerical representation of alert number and type; small display	Number scale could be confused with alert totals or other data	Unsure what is meant by this comment, especially "other data"
	Not too intrusive	Location should be able to be moved at will	
	Fairly simple	Difficult to determine number of alerts in bar	
	Not annoying	Scale would have to change as alerts increase	
		Can become complacent	
		Does not give accurate info on alerts	
		This is not good for operators that sit for hours in front of this system	Comments made during the discussion suggest that this design may be more easily ignored by operators especially over long periods
3: Horizontal Indicator Bar	Easy to interpret; unsure if the colour saturation is prominent enough when alerts increase	Takes up too much screen; scale changes with number s alerts; don't like gradual colour change	But occupies about the same amount of screen as the ticker design.

Design	Likes	Dislikes	Comments
	Catches your eye allows for quick scan without refocusing attention from priority tasking	No number available for alerts; colour saturation can be hard to detect; takes up a lot of bottom screen space	
	Clear; it would be at the forefront of the operator's mind	Takes more space	
		Too wide; won't notice overflow of alerts easily	
		Takes up too much space on RMP screen	
4: Ticker & Fading Bar	This would also keep the operator on the ball	Still has the vertical scale that could be confusing	This could easily be removed
	Ticker for high priority alerts and ability for operator to see information on cause	Recommended fading grey bar in and out (like priority 2 ticker) when priority 3 alert arrives	But this would produce some potential confusion between different alert priorities. In addition, priority 3 alerts are not defined as events that should immediately capture attention.
	Decreasing intrusiveness; wide area only used for incoming alerts	Don't like ticker; fading bar should be option; some operators will like and some won't	
	Allows immediate connection with track in RMP; less steps to view	Fade bar quite distracting; no real info contained	However, this is no different from having a flashing indicator, as in the cumulative counter design.
	With information in the bar, the operator does not have to change what they are doing		This is not really the case, as the operator will have to shift attention momentarily to process the information in the bar.
	Most prominent; easy to distinguish levels		Prominence may become a negative factor in a high frequency alert context.

As shown in Table 19, some of the dislikes were implementation issues and the designs could be easily changed or modified to accommodate the suggestions. There was a comment for the Vertical Cumulative Indicator that needs further explanation. The participant who said, “This is not good for operators that sit for hours in front of this system” and noted “.... the design is not stimulating enough for the mind”. The participant believed that the operator needs to be “stimulated” and their mind “needs to be active”, and believed that with Design 2, this would not happen.

Overall, the Cumulative Total Indicator was evaluated as being non-intrusive and very simple to use and interpret. However, some participants felt that it was too small and could therefore be easily ignored by operators. It appears that there needs to be a compromise relating to the size of the alert such that it is large and salient enough to be noticed yet not too salient as to distract the operator from his/her primary task or become an annoyance.

The Vertical Cumulative Indicator was also rated as non-intrusive yet participants found the scale more confusing to interpret than the digital indicator in the Cumulative Total Indicator.

Only three participants liked some aspects of the Horizontal Indicator Bar, while most participants felt the display obscured too much of the screen. Although the Ticker and Fading Bar used up as much, if not more space than the Horizontal Indicator Bar, participants did not mention this issue for the former. It is clear that such inconsistencies may have biased or influenced the results. Hence, further research is required to explain these inconsistencies.

There were two components to the Ticker and Fading Bar design that did not exist with the other designs. First, the ticker and fading bar itself alerted operators to individual incoming alerts. Second, a counter similar to that of the Vertical Cumulative Indicator was used to depict the total number of active alerts in the system (i.e., alerts that hadn't been addressed). It is not surprising then that participants generally did not like the scale (which is consistent with the comments on the Vertical Cumulative Indicator). A number of participants recommended that the ticker or fading bar be used for both priority 1 and 2 alerts (i.e., there was no need to have the ticker for only priority 1 alerts and the fading bar for priority 2 alerts). Most participants preferred the Ticker and Fading Bar because of the intrusiveness (i.e., it was easily noticed) and the information contained in the display bar. This result may be different, of course, if there are frequent alerts. Further research in an environment with a representative number of alerts should be conducted to validate these findings.

After participants completed the questionnaires, they were asked some additional follow-up questions. These questions related generally to alerting parameters, information presentation in the RMP and potential challenges of an alerting system in general and of our visual designs.

### **6.3.4 General discussion with participants**

The following points were discussed with participants following the design walkthrough and administration of the questionnaire.

#### **6.3.4.1 Alert parameters**

For the purpose of this study, we assumed that the alert parameters operators would want to set included area (co-ordinates), vessel type (e.g., fishing, warship, merchant, etc), speed, and alert priority (1, 2 or 3). Participants stated that they would also like to set alert parameters according to the activity of the vessel, vessel name, threat level (e.g., friendly, neutral, suspect), age of alert, type of anomaly (e.g., not heading to port), flag (i.e., country), course direction, estimated time of arrival, AIS number<sup>14</sup>, and next port of call. They emphasized that changing alert parameters should be done quickly and easily, and they should have the ability to change these parameters geographically depending on their area of interest at a given time. The example given was that if you were monitoring Europe's coast, operators would not want alerts relating to all vessels in that area. Thus, the operators require the ability to quickly and easily set these alerts according to their current area of interest.

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<sup>14</sup> AIS number is used to identify ship transponder to radio receiving station while MMSI number does the same for satellite receiving stations

#### **6.3.4.2 Intrusiveness and priority**

Participants agreed that the level of intrusiveness of an alert must vary according to the priority of the alert. For the purpose of this study, we assumed three priority levels would be appropriate and for the most part, participants agreed. A few participants suggested having 4 or 2 alert priorities instead of 3. Furthermore, several participants added the caveat that priority 3 alerts will be ignored 90% of the time.

#### **6.3.4.3 Inability to see visual alerts**

When asked how often operators could be away from their desks and the RMP, in turn, unable to be notified of alerts, participants reported that there are manning issues on a regular basis and therefore operators are needed elsewhere. Despite this challenge, participants did not like the idea of an auditory or tactile alert (e.g., vibrating pager) because, although the operator would be notified of the alert, he or she would not be able to get back to their workstation to deal with the alert. Furthermore, most participants felt that operators would elect not to use such a pager-type device. Rather, they felt that the visual alert should continue to be displayed on the RMP until the operator acknowledges it (as is the case with the design concepts presented)

#### **6.3.4.4 Workload**

In terms of workload, participants admitted that this type of alert design would increase the operator's workload; however, all believed the anomaly alerting system would be worthwhile because currently most such anomalies are missed.

#### **6.3.4.5 Colour coding**

All the participants liked the colour scheme that was used to depict priority levels in the alert designs (i.e., red for priority 1, gold for priority 2 and grey for priority 3). In the current RMP, red, yellow and green are used, but participants felt that green would be inappropriate for priority 3 alerts. As one participant stated, "Green doesn't communicate the right message. Green means go."

#### **6.3.4.6 Readability**

Participants felt that the size of the displays and fonts were generally acceptable, with the exception of two participants who felt that the numbers in the Cumulative Indicator were too small. Furthermore, one participant suggested that the font in the pop-up windows should be slightly larger.

#### **6.3.4.7 Location on the screen**

All participants also liked the idea of having the ability to click and drag the anomaly alert display anywhere on the screen. The alert designs presented to the participants in the trial had the alert display either in the bottom right hand corner or covering the entire width of the bottom of the screen. Participants thought this may impair their situation awareness if they had to focus on the bottom of the RMP for any length of time. Similarly, the current RMP has the ability to centre around a vessel of interest or area of interest. Participants indicated that they would like this to be an option for the non-intrusive design as well. That is, they would like the ability to centre the picture on a contact for which there is anomalous information. This would allow an operator to understand the immediate area and then the surroundings around the contact of interest. One participant mentioned that the option to centre the RMP on the contact of interest could be

implemented as a button in the AIW. For example, clicking on the name of the ship could centre the RMP on the vessel of interest.

#### **6.3.4.8 Retrieving information on alert**

As previously described, participants were shown two options to retrieve information about an alert. In one case, the RMP had a pop up box coming from the vessel of interest which included the name of the vessel, reason for alert (e.g., grab and dash fishing), the time of the alert, and action buttons (i.e., Clear or Leave). While most of the participants thought the RMP pop up box included enough information, one participant recommended that it include course, speed, latitude, longitude, Maritime Mobile Service Identity (MMSI) number (or the AIS #). The second way to get information about an alert was to go to the AIW which was on a separate screen. As designed, the AIW also functions as a tool to manage all alerts as it shows all the alerts in the system according to priority level, total number of alerts by priority, track number, name of vessel, reason for alert, time of alert, and action buttons (i.e., Clear, Done and RMP, which is a button that takes you back to the RMP). Participants recommended that the AIW also include who reported the alert (i.e., source), vessel type, flag, age of alert (instead of time of alert), time of last report (as well as the ability to go to that report), age of track, course, speed, and the history of the alert (e.g., if the vessel has had other alerts before such as speeding up when it should not). Participants mentioned that track number is not useful and should be exchanged for AIS number. It was also recommended that a smaller version of the AIW pop up in the RMP (similar to the pop-up box) rather than taking the operator to a separate screen as navigating away from the RMP can adversely impact their situation awareness.

Additionally, the alert designs included a flashing circle around the contact of interest, but only in the designs using the AIW (the pop-up window points to the contact of interest so there is no need for a circle). The circle was red for priority 1 alerts, gold for priority 2 alerts and grey for priority 3 alerts. Two options for this design were shown to participants. First, the circle appeared around the contact of interest as soon as the operator clicked on an incoming alert (i.e., before going to the AIW). The other option was to navigate to the AIW first then click on the RMP button to come back to the RMP on which the flashing circle would appear around the contact. All participants preferred when this circle appeared as soon as the alert was clicked (i.e., before going to the AIW). However, participants indicated that they generally preferred the pop-up window over the AIW as the source for anomaly information which means that the flashing circle would not be required.

In summary, for the seven participants there were eleven overall favourite designs, due to participants preferring two of the designs equally. Five of the seven participants preferred the Ticker and Fading Bar, four participants preferred the Cumulative Total Indicator, and one participant preferred the Horizontal Indicator Bar. There was only one participant who favoured the Vertical Cumulative Indicator; however, with the caveat that it had to be in conjunction with the Ticker and Fading Bar.

Thus, overall the Ticker and Fading Bar was favoured because it was the most prominent and participants liked the information provided in the ticker. The participants who favoured the Cumulative Total Indicator did so because it was the least intrusive and they could see the exact number of alerts in the system. The Vertical Cumulative Indicator was disliked because of the scale and the fact that it was difficult to see the exact number of alerts in the system. Further, they were concerned about the amount of space it would take up on the screen if there were a lot of alerts and the scale needed to be increased (a 0-10 scale was used for the design). The Horizontal Indicator Bar was disliked because it was difficult to determine the actual number of alerts and the colour



saturation would be difficult to learn. However, one participant believed that this design requires some cognitive effort to interpret which could be positive in that it would “keep the operator’s mind busy” (i.e., maintaining or improving attention and vigilance). On the other hand, this participant felt that the Cumulative Total Indicator and the Vertical Cumulative Indicator could be easily ignored as they do not require as much mental effort to interpret. These comments suggest that the appropriate level of intrusiveness for a maritime alert system for RJOC operators is not established and must be further researched and determined experimentally, particularly under operational contexts of medium to high alert frequency.

## 6.4 Conclusions and recommendations based on evaluation

This section presents conclusions and a number of recommendations for future anomaly alert system designs based on the SME review and evaluation.

### 6.4.1 Conclusions

In terms of *presentation of incoming alerts*, participants favoured both the Ticker and Fading Bar, which was rated as fairly intrusive and the Cumulative Total Indicator, which was rated as relatively non-intrusive. Further research is therefore required to determine the appropriate level of intrusiveness especially once the potential number alerts that may be present in the system is better understood.

In terms of presentation of the number of active alerts in a system, participants favoured a numerical display rather than a scale as it was easier to interpret at a quick glance.

With regards to getting information about an incoming alert, participants preferred the pop up window in the RMP compared to the AIW. This was primarily because the way in which the AIW was implemented in the prototype; it required the user to navigate to a separate window. Participants felt that this adversely impacted their situation awareness as a result. This suggests that *managing alerts* should be implemented in such a way that operators do not have to leave the RMP. For example, a separate window or sidebar could pop up in the RMP thereby allowing the operators to still have the RMP in view while managing alerts.

Finally, participants felt that the AIW would be appropriate for managing alerts, although they suggested a number of additional pieces of information that it should include.

Although the SME feedback from the design review was valuable, the results must be interpreted with caution given the small sample size and inconsistency in the comments. Further research is required to understand these inconsistencies that may have biased or influenced the results.

Although beyond the scope of the current project, it should be noted that an anomaly alerting system will undoubtedly require revision of the current Standard Operating Procedures (SOPs). For example, information relating to anomalies will have to be passed on to incoming watch keepers during watch handover. That is, operators will at least be required to pass on the current alert parameter preferences (i.e., the alert trip points) as well as a summary of the number and types of alerts that have emerged over the course of the shift. Also, the operator may be required to brief the Watch Officer on any Priority 1 alerts immediately and perhaps keep a log of all priority 2 and 3 alerts. Furthermore, which alerts have been briefed to the Watch Officer and the time of the briefing may be an additional piece of information that should be included in the AIW.

## 6.4.2 Limitations

There are three primary issues concerning the validity of the data obtained from the study.

- (i) *Reliability*: the small sample size means that the data obtained should be treated with caution and should be used to indicate *trends* in attitudes towards a non-intrusive alert system. A more extensive evaluation should be conducted in the future to verify these trends (particularly as they pertain to specific design elements). This evaluation should also involve operators from the West Coast.
- (ii) *Context validity*: the evaluation was limited in scope by showing designs as single event representations. However, in considering a future operational environment, there could be potentially a continuing volume of alerts that occur during a watch. Therefore, the validity of the judgments obtained in the walkthrough concerning the appropriate level of intrusiveness of the design alternatives must be treated with caution. A design option that appears to offer the right level of intrusiveness in alerting the operator, when viewed in isolation, may, over time and with a high frequency of alerts, become too distracting.
- (iii) *Halo effects*: it is possible that if a trial participant favoured a particular design, then all detailed evaluation questions concerning the design could be tainted by this bias. For example, if the design were seen as being insufficiently intrusive to “keep operators on their toes”, then its usefulness and utility may also have been judged lower.

## 6.4.3 Design recommendations for anomaly alert system

Considering the participant feedback, the results suggest that an anomaly alert design which combines the counter from the Cumulative Total Indicator, to indicate the number of active alerts in the system, with the Ticker and Fading Bar, to notify the operator of incoming alerts (with an option for either one), would be the next logical iteration of a non-intrusive anomaly alerting system design.

While participant feedback from the design walkthroughs can be used to point the way toward future iterations of an alert system design, caution must be used in interpreting this feedback especially given the small sample size and inconsistency in the comments. Hence, design guidelines must also be based on human factors principles and further experimentation in a realistic context (i.e., in the RJOC using the RMP). Table 20 shows a number of recommendations for future alert system designs based on participant feedback as well as human factors principles.

**Table 20: Design recommendations for future iterations of alert system interface**

Design feature	Recommendations based on participant feedback	Recommendations considering HF principles
<i>Alert</i>	Alert indicator should be visual	Alert indicator should be visual
	Alert indicator should only disappear after acknowledgement	Alert indicator should only disappear after acknowledgement
	Ability to click and drag the alert display to a different location on the RMP	Ability to click and drag the alert display to a different location on the RMP so as not to obscure the RMP (i.e. primary task)
	Font in the pop-up boxes should be a bit	Font in the pop-up boxes should be

Design feature	Recommendations based on participant feedback	Recommendations considering HF principles
	bigger	appropriate for distance that operator is sitting from screen and size of fonts used in primary task and ambient illumination
	Time should be in Zulu time	Time should be consistent with that used for current tasks
	Ticker and fading bar should also include the vessel name	The required level of information content to be contained within alert indicator should be further investigated
	Option to centre the screen around a vessel of interest or area of interest	Option to centre the screen around a vessel of interest or area of interest to support SA
	Priority <ul style="list-style-type: none"> <li>• Priority 1 alerts will be highlighted in red</li> <li>• Priority 2 alerts will be highlighted gold</li> <li>• Priority 3 alerts will be highlighted in grey</li> </ul>	Priority <ul style="list-style-type: none"> <li>• Priority 1 alerts will be highlighted in red.</li> <li>• Priority 2 alerts will be highlighted gold.</li> <li>• Priority 3 alerts will be highlighted in grey.</li> </ul>
	Incoming vs. Active Alerts <ul style="list-style-type: none"> <li>• Incoming alerts should be indicated in a ticker or fading bar (priority 1 and 2) and/ or as a cumulative number in the count box (priority 1, 2 and 3)</li> <li>• Active alerts left in the system will only be indicated as a cumulative number in the count box (priority 1, 2 and 3)</li> </ul>	Incoming vs. Active Alerts <ul style="list-style-type: none"> <li>• Presentation of incoming alerts should be further investigated in a context that is representative of RJOC operator's actual work environment.</li> <li>• Active alerts left in the system will be indicated as a cumulative number in the count box (priority 1, 2 and 3)</li> </ul>
<i>Retrieving Information</i>	The RMP pop up box, rather than the AIW, should be used to retrieve information related to an anomaly	This solution represents a trade-off between the amount of space required for the appropriate information content concerning the anomaly (which has a potential for obscuring the RMP) and obtaining the information from a separate window, taking the operator's attention away from the RMP. The appropriate design option will require further investigation before this recommendation can be stated definitively.
	The RMP pop up box will show AIS number, name of the vessel, reason for alert, age of alert, and action buttons	The anomaly information content of the RMP pop up box should be further investigated
<i>Managing Alerts</i>	The AIW should be used to manage alerts	The AIW should be used to manage alerts
	The AIW will show priority level, a button to return to the RMP, number of alerts, age of alerts, AIS number, name of vessel, reason for alert, action buttons, source of alert,	The content and functionality of the AIW should be further investigated by determining the specific operational requirements.

Design feature	Recommendations based on participant feedback	Recommendations considering HF principles
	vessel type, flag, age of alert, course, speed, alert history and age of track	
	The operator should not have to navigate to a different screen to see the AIW	This cannot be supported without further investigation. For example, by the end of the watch, and during a high frequency alerting context, there may be numerous alerts in the system. These would either have to be represented in a small window on the RMP, though which the operator would have to continually screen (i.e., not functionally efficient, or usable) or a large window, which would then obscure a significant portion of the RMP.
	The AIW may appear as a pop up window over the RMP that can be increased or decreased in size as desired	The AIW may appear as a pop up window over the RMP that can be appropriately sized for the information content up to a certain maximum.
<i>Acknowledging Alerts</i>	Acknowledgment of an alert will come in the form of LEAVE or CLEAR	The most appropriate terms for acknowledging an alert should be intuitive to all users and be consistent with similar functions in the current system, and should therefore be further investigated
	Ability to action alerts through the RMP pop up box	Ability to action alerts through the RMP pop up box
	Ability to action alerts through the AIW	Ability to action alerts through the AIW

## 7. Overall conclusions and recommendations

This section presents a number of overall conclusions based on the literature review, design development process and SME review and evaluation of the alert system design concepts.

### 7.1 Conclusions

Our general assessment of the literature relating to non-intrusive alert system design is that it is a somewhat piecemeal and haphazard collection of principles and guidelines from various application environments and serving a number of different goals. Clearly, there is a lack of a unified design approach and associated recommendations that would be applicable for non-intrusive alerting contexts. However, the detailed guidelines found in Shorrock et al (2002) and Han et al (2007) provide a good starting point for an integrated guidance document, which would then need to be extended and made more context relevant to the RJOCs. In addition, there would be a need to make this guidance more specific than statements such as “alarms should signal the need for action”, “alarms should be detected rapidly...”, “alarms should not annoy, startle or distract unnecessarily” etc. Thus, while these recommendations are sound, there is a lack of information on how they are to be implemented as specific design guidelines.

The review of the literature gave rise to some general principles for four alert system design concepts that were presented to and evaluated by SMEs. The actual translation of these principles into specific designs was very much based on Humansystems’ prior experience with HF design implementation, rather than specific recommendations from the literature reviewed. The design evaluation, combined with consideration of general human factors principles, resulted in a list of design requirements for the best way to:

- Alert RMP operator to a new incoming alert
- Provide operator with awareness of the number of active alerts in the system
- Provide operator with information specific to an incoming alert
- Provide operator with information on all active alerts in the system
- Provide operator with a means to acknowledge the occurrence of an alert
- Enable operator to manage (i.e., action) any active alerts in the system

Further research, however, is needed to better clarify design options that would support these design requirements, particularly under more realistic operational conditions of multiple alerts within a watch.

### 7.2 Future Work

The literature review and SME feedback from the design review were valuable in providing a direction for both future iterations of an anomaly alert system design as well as future research. Specifically, future design efforts should work toward developing an alert system interface design

in accordance with the design principles listed in section 6.3.3 once these design requirements have been validated through further research.

Future research efforts should focus on both experimentally evaluating anomaly alert system designs in the context of the RMP (i.e., representative of user's work environment including the potential number of alerts) as well as broader research relating to intrusiveness and attention. The following list provides a number of research questions that have yet to be resolved:

- What is the appropriate number of alert priorities?
- What is the most appropriate level of intrusiveness for different priorities of alerts and how is this influenced by alert frequency?
- What is the relative intrusiveness of a range of design parameters such as alert size, location and dynamics?
- How are attention and intrusiveness related?
- In an RMP context, what are the trade-offs between implementing the information within the RMP window and/or providing a separate window?
- In the context of the RJOC, what are the information requirements for an alert management system for data anomalies?
- How should the anomaly alert system be integrated within the overall "alert" system currently used in GCCS-M?
- Given the characteristics of the GCCS-M, what are the most appropriate design characteristics (e.g., colour, font size, etc.) for an anomaly alert system?

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# Annex A: Ethics Protocol

## EXECUTIVE SUMMARY

### Protocol # L676

**Title:** Evaluation of Interface Designs for Non-Intrusive Alerts: Pilot Study

**Principal Investigators:** Dr. Michael Matthews, Lora Bruyn Martin, Humansystems<sup>®</sup> Incorporated (HSI<sup>®</sup>), Guelph, Ontario. Tel: 519-836-5911

### Defence Research and Development Canada (DRDC) Co-Investigators:

Ms. Sharon McFadden, DRDC Toronto, Tel (416) 635-2189

Ms. Liesa Lapinski, DRDC Atlantic. Tel: (902) 426-3100 x180

**Thrust:** 11he Maritime Domain Awareness

### Objectives:

The goal of this experiment is to explore, in the context of the Recognized Maritime Picture (RMP), non-intrusive ways of presenting to the operator information concerning anomalous behavior of vessels. Anomalous behavior can take many forms, e.g. a sudden increase in speed, a vessel in transit that suddenly stops, a ship that changes its port of destination or a ship heading into regulated waters without appropriate permissions. Because of the large number of vessels and associated track data, it is not currently possible for operators to readily determine when, or where, such anomalies occur.

### Overview:

Six volunteer participants (no age or gender restrictions) will be required to review a number of different design options for a non-intrusive, anomaly alerting system. The participants will individually do a walk through of the options which will be presented as a PowerPoint mock up of the screen interface. A questionnaire will be administered at the end of each session, to record the volunteers' subjective evaluation of the different design options in terms of their utility and usability. The experiment will be undertaken at the MAPLE laboratory DRDC and will require one walkthrough session. Each session will comprise approximately 15 minutes of background briefing and a 60-90 minute walkthrough session, which will involve interface walkthroughs and the completion of a questionnaire. This work will be conducted by Humansystems<sup>®</sup> Incorporated.

### Participants:

Male or female Navy or ex-Navy operators will be recruited and paid for their participation. There is no restriction on age or gender. The two ex-Navy operators are both males.

### Risks:

This experiment offers minimal risk to the participant's health and well-being. There is a low risk of eye fatigue or eyestrain, as is associated with doing any visually intensive task on a computer display.

### Protocol # L676

**Title:** Evaluation of Interface Designs for Non-Intrusive Alerts: Pilot Study



### **Principal Investigators:**

Dr. Michael Matthews, Lora Bruyn Martin, Humansystems Incorporated® (HSI®), Guelph, Ontario. Tel: 519-836-5911

### **DRDC Co-Investigators:**

Ms. Sharon McFadden, DRDC Toronto, Tel (416) 635-2189

Ms. Liesa Lapinski, DRDC Atlantic, Tel: (902) 426-3100

**Thrust:** 11he Maritime Domain Awareness

### **List of Acronyms:**

DRDC	Defence Research and Development Canada
HSI®	Humansystems Incorporated
MDA	Maritime Domain Awareness
RMP	Recognized Maritime Picture
RJOCs	Regional Joint Operations Centres

### **Background:**

This applied research project in the Maritime Domain Awareness (MDA) Thrust is studying information visualization and management for enhanced domain awareness in maritime security. The DRDC/HSI® team wants to investigate the best way to provide operators with non-intrusive alerts when certain forms of anomalous vessel behavior occur to see if the information provided by way of the alert can help improve understanding of the Recognized Maritime Picture (RMP), decision making based on the RMP and the efficiency of the RMP operators' duties.

The RMP is a product produced by the Regional Joint Operation Centres (RJOCs). In its common form, it is a map of the Canadian coastal waters, with contacts, typically ships, marked on the map. Each contact has a set of metadata associated with it which can include (but is not exclusive to) position, speed, heading, ship name, hull number, threat, flag, destination, origin, type, cargo and a digital image. At worst, the metadata only consist of a position (i.e., there is something out there). At best, the metadata consist of all of the above. The different degrees of metadata are due to the multiple sources of information that feed the RMP. These sources include everything from radar to surveillance flights to self reporting systems to voluntary reports, each providing its own subset of data.

Anomalies in the movement and behavior of vessels may be of many types and include, for example:

- Unexplained high speed: a ship that is claiming to be a normal merchant ship suddenly starts travelling at a high speed more typical of a passenger ship or warship.
- Speed too slow: a Cargo, Passenger, or Ferry is observed going slowly. As these vessels generally go as fast as they safely can, it may be an indicator of a problem.
- Loitering: a cargo ship stops outside of or far from a harbour, or steams very slowly, rather than proceeding directly into port.

- Grab and dash fishing: a foreign fishing boat moves from the international zone to Canadian waters (where it is forbidden from fishing) for a few hours just before leaving for its home port.
- Not heading to port: a vessel is heading in a direction where there is no harbour, or is not heading toward its declared destination. Cargo and Ferry vessels always go from one port to another port, and generally by the shortest available route.

The purpose of the proposed study is to explore the best ways of alerting operators to such anomalies in a non-intrusive manner. Given the potential for many such anomalies during a normal watch, it is imperative that discipline be used in the design of an alerting system to ensure that operators are not hindered in the performance of their primary task by nuisance alerts. Also, it is important that functionality is provided to allow operators to define their own criteria for different alert priorities in different contexts, and that the interface provides good situation awareness of the different alert types. The outcome of this work will serve both the maritime operations communities, as well as the scientific communities in the advancement of new methods for the design of non-intrusive alerting systems. This work will be conducted by Humansystems<sup>®</sup> Incorporated.

### **Objectives:**

The goal of this experiment is to explore, in the context of the RMP, non-intrusive ways of presenting to the operator information concerning anomalous behavior of vessels. Because of the large number of vessel and associated track data, it is not currently possible for operators to readily determine when or where such anomalies occur.

### **Overview:**

Six volunteer participants (no restriction on age or gender) will be recruited to review a number of different design options for a non-intrusive, anomaly alerting system. The participants will individually do a walk through of the options which will be presented as a PowerPoint mock up of the screen interface. A questionnaire will be administered at the end of each session, to record the volunteers' subjective evaluation of the different design options in terms of their utility and usability. The experiment will be undertaken at the MAPLE laboratory DRDC Atlantic and will require one walkthrough session. Each session will comprise approximately 15 minutes of background briefing and a 60-90 minute walkthrough session, which will involve interface walkthroughs and the completion of a questionnaire. This work will be conducted by Humansystems<sup>®</sup> Incorporated.

### **Procedures:**

#### *Background Briefing*

Immediately prior to the walkthrough session, participants will be given an orientation briefing on the overall study, its objectives and what they will be asked to do. At this stage they will be asked to complete a consent form and an information sheet about the study.

#### *Walkthrough session: Review of design options*

The goals of a non-intrusive alerting system will be described to the participant and the major functional components of the system will be described at a high level. Participants will then be guided through a PowerPoint presentation of how a non-intrusive alerting system interface would look and work. For each functional component of the system, participants will interact with an animated PowerPoint slide to simulate the actions of an interface. As participants proceed through

the design they will be engaged in discussion concerning how intuitive and easy the interface is to use, how it serves their information needs, what information requirements are not being met and what additional functions they would like to see. It is anticipated that the participant will be presented with 4-5 design options to review in this manner.

At the completion of the walkthrough the participants will complete a subjective questionnaire documenting their evaluation of the different design options.

### **Participants:**

Approximately six Navy, or ex-Navy operators, will participate Navy operators will be recruited through a formal request through the DRDC Atlantic Navy Liaison Officer. There will be no restriction on age or gender. Ex-Navy participants will be recruited from a list maintained by HSI of ex-Navy personnel who have indicated a prior willingness to be contacted as potential study participants. . The ex-navy operators are males, Participants will be required to self identify that they have normal colour vision.

### **Equipment and Facilities:**

The apparatus comprises a standard “Windows” workstation with 19” colour screen, a mouse and keyboard input, a work surface to record notes, and an ergonomically designed operator’s chair.

### **Data collected:**

The following information will be collected during each walkthrough session:

- Responses to the questionnaires concerning the participant’s evaluation of the design alternatives
- Summary of the participants’ comments during free discussion with the walkthrough facilitator

### **Experimental Design/Statistical Analysis:**

The small sample size (limited by the availability of operational personnel) will likely have insufficient power to warrant the use of analytical statistical procedures for estimation of probabilities. However, it should be noted that the present study is designed to be an exploratory approach to defining a preliminary set of good design alternatives, which, at some future date, could be evaluated more completely in a more rigorous experiment.

### **Risks and Safety Recommendations:**

This experiment offers minimal risk to the participant’s health and well-being. There is a low risk of eye fatigue or eyestrain, as would be associated with doing any visually intensive task (e.g. web searching, word processing) on computer display for the period of time used in the walkthrough sessions. This may manifest itself as eye discomfort, dry or itchy eyes, or mild headache. However, the duration of exposure to the presentation will be short. Participants will be encouraged to inform experimenters if they experience any discomfort or eyestrain, or if they have any problems during the investigation. They may be told to stop their activities until problems or conditions are resolved. The risks from participation in this experiment are generally the same as those associated with the performance of normal monitoring of a visual display that a person might do while word processing, surfing the web or playing video games.

**Benefits of Study:**

Through their involvement in the study participants will be able to contribute to the validation, development and design of new methods for providing information on vessel anomalies, which in turn provides important human factors data for the re-design and automation of future systems to represent the maritime picture.

**Informed Consent:**

Participants will be fully briefed on the relevant aspects of the experimental protocol and will be given a copy of this protocol to review. They will be required to sign a voluntary consent form, indicating their willing informed consent, before being allowed to participate in the experiment. No deception is involved.

**Confidentiality:**

Any personal or performance data collected for each participant will be available only to the experimenters and will be held in the strictest confidence. Participants will not be identified by name in the data records; group statistics will be used in future presentations or publications. Individual participant data will be coded anonymously and maintained in a computer file. The file may be accessed only by the project team.

**Participant Debriefing:**

Participants will be permitted to ask any questions they wish about the study after they have completed the experiment.

**Participant Stress Remuneration:**

Participants will be paid participant pay in the amount of \$26.93. This assumes that the total time required will be no more than 3 hours per participant for participation in this study (in accordance with DRDC guidelines and as authorized by DND policies<sup>15</sup>). The remuneration is calculated as follows:

$$3 \text{ hours} \times 2 \text{ (stress level)} \times \$2.50 + \$11.93 \times 1 \text{ day} = \$26.93$$

**Approximate Time Involvement:**

All participants will be required to participate in one session of approximately 3 hours with a 15 minute break in the middle.

**Medical screening:**

No screening is required for this study

**Physician supervision:**

No physician supervision is required for this study.

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<sup>15</sup> Guide to Stress Compensation for Human Subjects, R. Pigeau. DRDC Toronto.





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## **Voluntary Consent Form**

**Protocol Number: L676**

**Research Project Title: Evaluation of Interface Designs for Non-Intrusive Alerts: Pilot Study**

**Principal Investigators:**

Dr. Michael Matthews, Humansystems Incorporated, Guelph, Ontario.

Lora Bruyn Martin, Humansystems Incorporated, Guelph, Ontario

**DRDC Co-Investigators:**

Ms. Sharon McFadden, DRDC (Toronto)

Ms. Liesa Lapinski. DRDC (Atlantic)

1. I, \_\_\_\_\_  
\_\_\_\_\_

(Name, Address, Phone number) hereby volunteer to participate as a participant in the experiment entitled "Evaluation of Interface Designs for Non-Intrusive Alerts: Pilot Study", the aim of which is to explore the best ways of providing operators with information on anomalous behavior of vessels in a maritime context. I understand that I am required to read the attached protocol in its entirety. I have had the opportunity to study and discuss the attached protocol with the investigators and I have been informed to my satisfaction about the possible discomforts associated with these tests.

2. I am aware that before starting I will receive a briefing on the aims and procedures for the experiment. I will have the opportunity to ask and receive answers to any questions I may have. I understand that I am free to refuse to participate and may withdraw my consent without prejudice or hard feelings at any time. Should I withdraw my consent, my participation as a participant will cease immediately. I understand that the entire session will last no more than 3 hours.

3. I have been told that the principal risks associated with this experiment are the possible development of eyestrain or visual fatigue. This may manifest itself as eye discomfort, dry or itchy eyes, or mild headache. I understand that the limited duration of each experiment and rest periods between experiments will mitigate this risk. I understand and accept this risk. I am aware that there are inherent, unknown and currently unforeseen risks by DRDCs Atlantic and Toronto and the Project Investigators that are associated with any scientific research and that all known risks have been explained to my satisfaction.. I have been given examples of potential minor and remote risks associated with the experiment and consider these risks acceptable as well.

4. I agree to provide responses to questions that are to the best of my knowledge truthful and complete. I have been advised that the experimental data concerning me will be treated as confidential and not revealed to anyone other than the investigators without my consent except as data unidentified as to source. I understand that my name will not be identified or attached in any manner to any publication arising from this study.

5. I understand that for my participation in this research project, I am entitled to stress remuneration in the form of participant payment of \$ 26.93. Stress remuneration is taxable. However, T4A slips are issued only for amounts in excess of \$500.00 remuneration per year.



6. I acknowledge that I have read this form and I understand that my consent is voluntary and has been given under circumstances in which I can exercise free power of choice. I have been informed that I may, at any time, revoke my consent and withdraw from the experiment, and that the investigators may terminate my involvement in the experiment, regardless of my wishes.

7. I understand that by signing this consent form I have not waived any legal rights I may have as a result of any harm to me occasioned by my participation in this research project beyond all risks I have assumed.

8. [For Canadian Forces (CF) members only] – I understand that I am considered to be on duty for disciplinary, administrative and Pension Act purposes during my participation in this study. With that said, this duty status has no effect on my right to withdraw for the experiment at any time I wish and it is clear that no action will be taken against me for exercising this right. As well, in the unlikely event that my participation in this study results in a medical condition rendering me unfit for service, I may be released from the CF and my military benefits apply.

Volunteer's Name: \_\_\_\_\_

Signature: \_\_\_\_\_ Date: \_\_\_\_\_

Name of Witness to Signature: \_\_\_\_\_

Signature: \_\_\_\_\_ Date: \_\_\_\_\_

Family Member or Contact Person (name, address, daytime phone number & relationship): \_\_\_\_\_

Principal Investigator: \_\_\_\_\_

Signature: \_\_\_\_\_ Date: \_\_\_\_\_

**FOR PARTICIPANT ENQUIRY IF REQUIRED:**

Should I have any questions or concerns regarding this project before, during, or after participation, I understand that I am encouraged to contact any of the contacts below by phone or e-mail, to

**Principal Investigators:**

Dr. Michael Matthews, Humansystems<sup>®</sup> Incorporated (HSI<sup>®</sup>), Guelph, Ontario Tel: (519) 836-5911, email: [mmatthews@humansys.com](mailto:mmatthews@humansys.com)

Lora Bruyn Martin, Humansystems<sup>®</sup> Incorporated (HSI<sup>®</sup>), Guelph, Ontario Tel: (519) 836-5911 Ex. 303, email: [lbruyn@humansys.com](mailto:lbruyn@humansys.com)

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Ms. Sharon McFadden, DRDC Toronto, Tel (416-635-2189), email: [sharon.mcfadden@drdc-rddc.gc.ca](mailto:sharon.mcfadden@drdc-rddc.gc.ca)

**Chair, DRDC Human Research Ethics Committee (HREC):** Dr. Jack P. Landolt, phone: 416-635-2120, email: [jack.landolt@drdc-rddc.gc.ca](mailto:jack.landolt@drdc-rddc.gc.ca)

**I understand that I will be given a copy of this consent form so that I may contact any of the above-mentioned individuals at some time in the future should that be required.**

**Secondary Use of Data:** I consent/do not consent (delete as appropriate) to the use of this study's experimental data involving me in unidentified form in future related studies provided review and approval have been given by DRDC HREC.

Volunteer's Signature \_\_\_\_\_ Date \_\_\_\_\_



## **INFORMATION FOR PARTICIPANTS**

**Title:** Evaluation of Interface Designs for Non-Intrusive Alerts

**Protocol #L676**

**Principal Investigators:** Dr. Michael Matthews & Lora Bruyn Martin (HSI<sup>®</sup>), Guelph, Ontario

**Defence Research and Development Canada (DRDC) Co-Investigators:**

Ms. Sharon McFadden (DRDC Toronto) & Ms. Liesa Lapinski (DRDC Atlantic)

### **Background & Purpose of Study:**

This applied research project in the Maritime Domain Awareness Thrust is studying information visualization and management for enhanced domain awareness in maritime security. The DRDC/HSI<sup>®</sup> team wants to investigate the best way to provide operators with non-intrusive alerts when certain forms of anomalous vessel behavior occur to see if the information provided by way of the alert can help improve understanding of the Recognized Maritime Picture (RMP), decision making based on the RMP and the efficiency of the RMP operators' duties. Given the potential for many such anomalies during a normal watch, it is imperative that the design of an alerting system ensures that operators are not hindered in the performance of their primary task by nuisance alerts. Also, it is important that functionality is provided to allow operators to define their own criteria for different alert priorities in different contexts, and that the interface provides good situation awareness of the different alert types. The outcome of this work will serve in the advancement of new methods for the design of non-intrusive alerting systems.

### **Procedure:**

Immediately prior to the walkthrough session, you will be given an orientation briefing on the overall study, its objectives and what you will be asked to do. At this stage you will be asked to complete a consent form.

The goals of a non-intrusive alerting system will be described to you and the major functional components of the system will be described at a high level. You will then be guided through a PowerPoint presentation of how a non-intrusive alerting system interface would look and work. For each functional component of the system, you will interact with an animated PowerPoint slide to simulate the actions of an interface. As you proceed through the design you will be engaged in discussion concerning the interface, how it serves your information needs, what information requirements are not being met and what additional functions you would like to see. You will be presented with 4-5 design options to review in this manner. You will then complete a subjective questionnaire documenting your evaluation of the different design options.

The session will be approximately 2-3 hours with a 15 minute break in the middle.

## Annex B: Questionnaires for SME Evaluation

### Demographic Questionnaire

**Instructions:** Please read each question below and write the appropriate response in the answer section.

Question	Answer
1. Name.	
2. What is your current rank?	
3. What is your current position?	
4. How long have you been in that position?	
5. Please list any other related positions you have had.	



## Usability and Usefulness Questionnaire

**Instructions:** Please read each statement below and circle the response you feel is most appropriate concerning the usefulness of a *general non-intrusive alerting system*.

Statement	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
1. These alerts would enhance our knowledge of anomalies	1	2	3	4	5
2. This alerting system would be used on a daily basis	1	2	3	4	5
3. Tasks can be performed in a straightforward manner using this alerting system	1	2	3	4	5
4. The thinking required to use this alerting system requires significant effort	1	2	3	4	5
5. This alerting system would be difficult to use	1	2	3	4	5
6. This alerting system will improve my situation awareness	1	2	3	4	5
7. This alerting system would make it easier to identify anomalies	1	2	3	4	5
8. I would find this alert system useful	1	2	3	4	5
9. I would not ignore alerts while using this technology	1	2	3	4	5
10. The Alert Information Window (AIW) was confusing	1	2	3	4	5
11. It was easy to learn how the AIW was represented	1	2	3	4	5
12. The AIW had all the necessary information	1	2	3	4	5
13. It was easy navigating between the RMP and the AIW	1	2	3	4	5
14. I prefer clearing and deferring alerts directly from the RMP	1	2	3	4	5
15. I prefer using the AIW to clear or defer alerts	1	2	3	4	5



## Alert Design Questionnaire

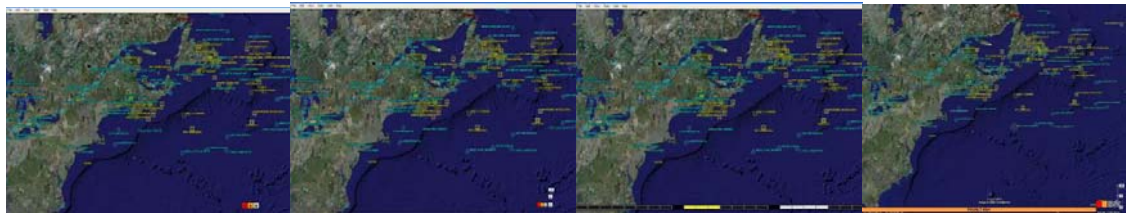
**Instructions:** Please read each statement below and circle the response you feel is most appropriate concerning the usability of *each non intrusive alert design*.

Statement & Design	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
<b>16. The number of alerts were easy to comprehend</b>					
Design 1: Cumulative Total Indicator	1	2	3	4	5
Design 2: Vertical Cumulative Indicator	1	2	3	4	5
Design 3: Horizontal Indicator Bar	1	2	3	4	5
Design 4: Ticker & Fading Bar	1	2	3	4	5
<b>17. The presence of an alert was easy to recognize</b>					
Design 1: Cumulative Total Indicator	1	2	3	4	5
Design 2: Vertical Cumulative Indicator	1	2	3	4	5
Design 3: Horizontal Indicator Bar	1	2	3	4	5
Design 4: Ticker & Fading Bar	1	2	3	4	5
<b>18. The priorities of the alerts were easy to comprehend</b>					
Design 1: Cumulative Total Indicator	1	2	3	4	5
Design 2: Vertical Cumulative Indicator	1	2	3	4	5
Design 3: Horizontal Indicator Bar	1	2	3	4	5
Design 4: Ticker & Fading Bar	1	2	3	4	5
<b>19. It was easy to find the relevant anomaly</b>					
Design 1: Cumulative Total Indicator	1	2	3	4	5
Design 2: Vertical Cumulative Indicator	1	2	3	4	5
Design 3: Horizontal Indicator Bar	1	2	3	4	5
Design 4: Ticker & Fading Bar	1	2	3	4	5
<b>20. It was easy to find information on anomalies</b>					
Design 1: Cumulative Total Indicator	1	2	3	4	5
Design 2: Vertical Cumulative Indicator	1	2	3	4	5
Design 3: Horizontal Indicator Bar	1	2	3	4	5
Design 4: Ticker & Fading Bar	1	2	3	4	5
<b>21. The alerting design enhanced my situation awareness of maritime anomalies</b>					
Design 1: Cumulative Total Indicator	1	2	3	4	5
Design 2: Vertical Cumulative Indicator	1	2	3	4	5

Statement & Design	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Design 3: Horizontal Indicator Bar	1	2	3	4	5
Design 4: Ticker & Fading Bar	1	2	3	4	5
<b>22. The appearance of the alerts is compatible with my current interface</b>					
Design 1: Cumulative Total Indicator	1	2	3	4	5
Design 2: Vertical Cumulative Indicator	1	2	3	4	5
Design 3: Horizontal Indicator Bar	1	2	3	4	5
Design 4: Ticker & Fading Bar	1	2	3	4	5

## Ranking Questionnaire

**Instructions:** For the following questions, please rank each of the alert designs in order of preference (where 1 = most preferred, 4 = least preferred).



Cumulative Total Indicator

Vertical Cumulative  
Indicator

Horizontal Indicator Bar

Ticker and Fading Bar

### 23. In terms of overall effectiveness in bringing alerts to my attention

Design 1: Cumulative Total Indicator

\_\_\_\_\_

Design 2: Vertical Cumulative Indicator

\_\_\_\_\_

Design 3: Horizontal Indicator Bar

\_\_\_\_\_

Design 4: Ticker & Fading Bar

\_\_\_\_\_

### 24. In comparing the methods for representing the different alert priorities

Design 1: Cumulative Total Indicator

\_\_\_\_\_

Design 2: Vertical Cumulative Indicator

\_\_\_\_\_

Design 3: Horizontal Indicator Bar

\_\_\_\_\_

Design 4: Ticker & Fading Bar

\_\_\_\_\_

### 25. In terms of providing all of the required information about alerts, without distracting me from my primary task

Design 1: Cumulative Total Indicator

\_\_\_\_\_

Design 2: Vertical Cumulative Indicator

\_\_\_\_\_

Design 3: Horizontal Indicator Bar

\_\_\_\_\_

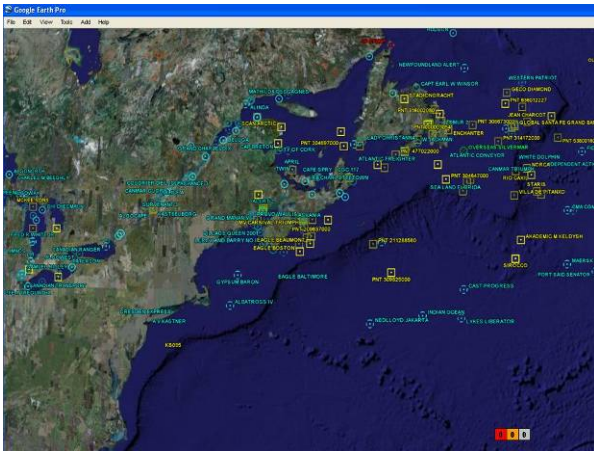
Design 4: Ticker & Fading Bar

\_\_\_\_\_

## Likes and Dislikes Questionnaire

**Instructions:** Please respond to each alert design below by indicating whether or not the design should be implemented, your likes and dislikes, and the design's intrusiveness.

26. Should Design 1: Cumulative Total Indicator be implemented?      Yes      No



Likes: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Dislikes: \_\_\_\_\_

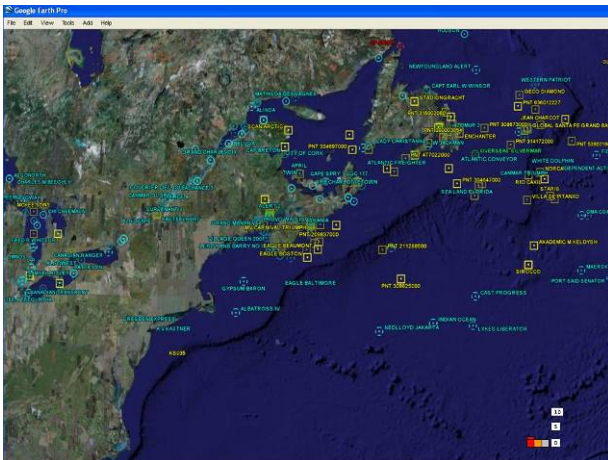
\_\_\_\_\_

\_\_\_\_\_

1                      2                      3                      4                      5                      6                      7

Not at all intrusive                      Somewhat intrusive                      Extremely intrusive

27. Should Design 2: Vertical Cumulative Indicator be implemented?      Yes      No



Likes: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Dislikes: \_\_\_\_\_

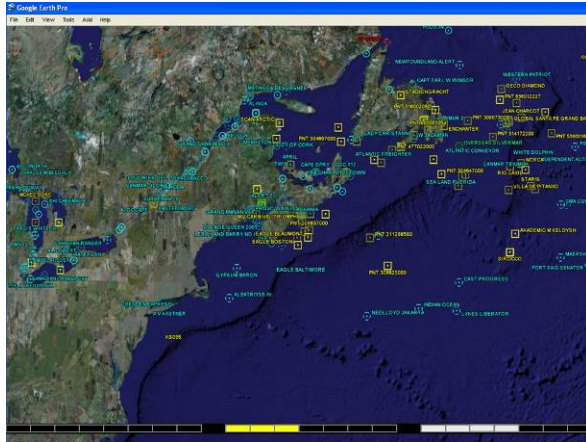
\_\_\_\_\_

\_\_\_\_\_

1                      2                      3                      4                      5                      6                      7

Not at all intrusive                      Somewhat intrusive                      Extremely intrusive

28. Should Design 3: Horizontal Indicator Bar be implemented?      Yes      No



Likes: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Dislikes: \_\_\_\_\_

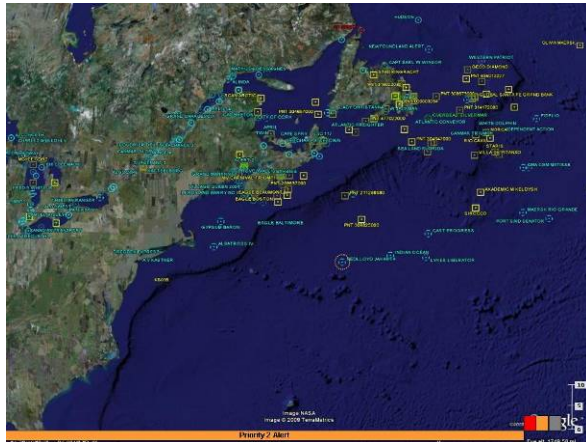
\_\_\_\_\_

\_\_\_\_\_

1                      2                      3                      4                      5                      6                      7

Not at all intrusive                      Somewhat intrusive                      Extremely intrusive

29. Should Design 4: Ticker & Fading Bar be implemented?      Yes      No



Likes: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Dislikes: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

1                      2                      3                      4                      5                      6                      7

Not at all intrusive                      Somewhat intrusive                      Extremely intrusive



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## **Annex C: General Discussion Interview Questions**

### **SME Interview Questions: Evaluating Interface Designs for Non-Intrusive Alerts**

#### **Things to emphasize:**

- Operators will define priorities and select rules
- Show 3 priority levels Rory created
- Show rule selection window

#### **General:**

- At desk vs. away from desk
- Looking at screen vs. not looking at screen
- Frequency of alerts (by priority)
- Should priority 1 alerts be intrusive?
- Ignoring alerts
- Did you like the way the priorities were indicated?

#### **Interface design:**

- Alert colour scheme (e.g., red, orange, yellow, grey)
- Font (e.g., size, colour)
- Was the terminology used familiar, clear and understandable?
- Alert Information Window – useful and comprehensiveness?
- Navigation – can you find the relevant information?
- Intuitive versus not intuitive
- Intrusiveness of alerts
- Should there be auditory/tactile alerts in tandem or separately?
- Flexibility in the location of ticker and horizontal indicator bar
- Would operators want RMP centred on contact?
- Would you want more information in the pop up box in the RMP?

#### **Context of use:**

- Ability to return to primary task
- Potential problems from using the non-intrusive alert designs in practice?
  - During an increased workload?
  - When you are not at your computer screen?
  - At shift change over? Beginning or end of shift





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## Acronyms

AB AIS	Affect and Belief Adaptive Interface System
ACT	Alarm Cleanup Toolbox
AIS	Automatic Identification System
AIW	Alert Information Window
ANOVA	Analysis of Variance
ARO	Assistant Reactor Operator
ATCS	Air Traffic Control Specialists
ATM	Air Traffic Management
AVMS	AIS Vessel Monitoring System
CAPTA	Cognitive, Affective, Personality Task Analysis
CCS	Combat Control System
CDTI	Cockpit Displays of Traffic Information
CHDB	Contact History Database
CHEX	Change History Explicit
CISTI	Canada Institute for Scientific and Technical Information
CONOPS	Concept of Operations
COTS	Commercial-Off-The-Shelf
CS	Combat System
DCS	Distributed Control System
DRDC	Defence Research and Development Canada
DSS	Decision Support System
ELINT	Electronic Intelligence
ETA	Estimated Time of Arrival
FCR	Fire-Control Radar
FFC	Bio-Fuelled District Heating Plant
GCCS-M	Global Command and Control System-Maritime
GSFC	Goddard Space Flight Center
GUI	Graphic User Interface
HAIL	Human Alerting and Interruption Logistics
HCI	Human Computer Interaction
HF	Human Factors
HFSWR	High Frequency Surface Wave Radar
HMIAS	Hazard Monitor and Intelligent Alerting System
IAMS	Intelligent Alarm Management System
ID	Identification



IDS	Intrusion Detection Systems
IOP	Input Open
IP	Internet Protocol
IRC	Interruption, Reaction and Comprehension
IS	Identification Supervisor
LCCI	Large Complex Critical Infrastructure
LCL	Lower Control Limits
MARLANT	Maritime Forces Atlantic
MISR	Maritime Intelligence, Surveillance, and Reconnaissance
MMI	Man-Machine Interface
MMSI	Maritime Mobile Service Identity
MPA	Maritime Patrol Aircraft
MSOCC	Multisatellite Operations Control Center
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NRC	Nuclear Regulatory Commission
OFMspert	Operator Function Model Expert System
PAL	Provincial Airlines
PDA	Personal Digital Assistant
PL	Platoon Leaders
R&D	Research and Development
RJOC	Regional Joint Operations Center
RMP	Recognized Maritime Picture
RO	Reactor Operator
RSVP	Rapid Serial Visual Presentation
SHIELD	System to Help Identify and Empower Leader Decisions
SME	Subject Matter Expert
SOP	Standard Operating Procedure
TA	Technical Authority
VDU	Visual Display Unit
VOI	Vessel of Interest
UAV	Unmanned Aerial Vehicle
UCL	Upper Control Limits

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This project involves the investigation of best practices for the development of design concepts for a visualization aid, specifically an alerting system, which would increase the RMP operators' awareness and understanding of maritime anomalies in the RMP (e.g. vessel not heading to port, grab and dash fishing, etc.). Such an alerting system, however, must make operators aware of anomalies that may be present without impacting on the performance of their primary tasks.

The objectives of this project were (i) to identify and analyse available literature relevant to non-intrusive alert systems, (ii) develop design concepts for a non-intrusive alerting interface to be used in GCCS-M and (iii) obtain feedback from Navy Subject Matter Experts (SMEs) on the suitability of the design options.

The results of the literature review suggest that there is a lack of a unified design approach and associated recommendations for non-intrusive alerting contexts. Furthermore, there was no single paper that definitively addressed the issue of how to design a non-intrusive alerting system. However, we were able to extract relevant concepts from the literature relating to alert/alarm design in general. These concepts, combined with general human factors principles, provided direction for a number of design concepts which were then reviewed and evaluated by subject matter experts.

Future design efforts should work toward developing an alert system interface design in accordance with the design principles listed above, once these design requirements have been validated.

Le projet comprend l'étude des meilleures pratiques applicables à la définition de concepts pour un système d'aide à la visualisation, en l'occurrence un système d'alerte, qui aiderait les opérateurs du TSM à mieux connaître et comprendre les anomalies maritimes indiquées dans le TSM (déroutement d'un navire, braconnage maritime, etc.). Un tel système d'alerte doit toutefois permettre aux opérateurs d'être informés des anomalies éventuelles sans pour autant entraver l'exécution de leurs tâches principales. Le projet visait les objectifs suivants : (i) identifier et analyser la documentation disponible sur les systèmes d'alerte non intrusive, (ii) élaborer des concepts pour une interface d'alerte non intrusive à utiliser dans le GCCS-M et (iii) obtenir la rétroaction des experts de la Marine sur la valeur des options de conception.

L'examen de la documentation a révélé l'absence d'une approche de conception unifiée et de recommandations associées dans le contexte d'alertes non intrusives. En outre, aucun document n'offrait de solution définitive au problème de la conception d'un système d'alerte non intrusive. Toutefois, on a pu extraire de la documentation des concepts pertinents pour la conception de systèmes d'alerte et d'alarme en général. Ces concepts, associés à des principes généraux touchant les facteurs humains, ont fourni des orientations pour la définition d'un certain nombre de concepts qui ont ensuite été examinés et évalués.

Les recherches futures devraient viser à définir une conception d'interface de système d'alerte conformément aux principes de conception présentés ci-dessus, une fois que ces exigences de conception auront été validées.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (Technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

anomalies; visualization; alerts; non-intrusive; recognized maritime picture