Copy No. _____

Defence Research and Development Canada
Recherche et développement pour la défense Canada

DEFENCE R&D DÉFENSE

11he Final Report

Information Visualization and Management for Enhanced Domain Awareness in Maritime Security

Anna-Liesa S. Lapinski

Defence R&D Canada – Atlantic

Technical Memorandum
DRDC Atlantic TM 2009-265
June 2010

Canada

This page intentionally left blank.

11he Final Report

Information Visualization and Management for Enhanced Domain Awareness in Maritime Security

Anna-Liesa S. Lapinski

Defence R&D Canada – Atlantic

Technical Memorandum

DRDC Atlantic TM 2009-265

June 2010

Principal Author

Original signed by Anna-Liesa S. Lapinski

Anna-Liesa S. Lapinski

Defence Scientist

Approved by

Original signed by Francine Desharnais

Francine Desharnais

Head, Maritime Information and Combat Systems Section

Approved for release by

Original signed by Ron Kuwahara fort

Calvin Hyatt

Chair, Document Review and Library Committee

This report and the research described therein were completed under the 11h Maritime Domain Awareness Thrust, under project 11he, Information Visualization and Management for Enhanced Domain Awareness in Maritime Security.

In conducting the research described in this report, the investigators adhered to the policies and procedures set out in the Tri-Council Policy Statement: Ethical conduct for research involving humans, National Council on Ethics in Human Research, Ottawa, 1998 as issued jointly by the Canadian Institutes of Health Research, the Natural Sciences and Engineering Research Council of Canada and the Social Sciences and Humanities Research Council of Canada.

Abstract

On April 1, 2005, Defence Research and Development Canada (DRDC) started a new applied research project (ARP) in the Maritime Domain Awareness (MDA) thrust: Information visualization and management for enhanced domain awareness in maritime security (11he). This is the final report on the project. 11he was a 4-year 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 project was focused on visualization design and experimentation as well as creating a visualization testbed. This work included doing a study on the "Future Recognized Maritime Picture", a state-of-the-art-study on Information Visualization from a Maritime Intelligence, Surveillance and Reconnaissance (MISR) point of view, work on developing visualization to represent the uncertainty inherent in the information populating the Recognized Maritime Picture (RMP), work on developing non-intrusive alerts to be used in the RMP when anomalies are detected, and a MISR-Vis testbed to help in the generation of effective MISR related visualizations. This report gives some background on the 11he project, documents what was achieved, and points the reader to the reports generated by the work.

Résumé

Dans le cadre de l'élan de la connaissance de la situation dans le secteur maritime, Recherche et développement pour la défense Canada (RDDC) a mis en œuvre, le 1er avril 2005, un nouveau projet de recherches appliquées (PRA) : visualisation et gestion de l'information pour une meilleure connaissance du domaine en sécurité maritime (11he). Le présent rapport constitue le dernier rapport sur ce projet R & D de 4 ans, dont le but était de faire progresser la « situation maritime » au moyen d'une qualité améliorée de l'information et de nouvelles façons adaptatives de visualiser cette information. Le projet portait sur la conception visuelle et l'expérimentation visuelle, ainsi que sur la création d'un banc d'essai visuel. Plusieurs recherches ont été menées au cours de ce projet, notamment une étude sur le « tableau de la situation maritime futur », et une étude de pointe de la visualisation de l'information selon un point de vue MISR (renseignement maritime, reconnaissance maritime, surveillance maritime). Des travaux ont également était faits sur l'élaboration d'une représentation visuelle de l'incertitude inhérente à l'information contenue dans le tableau de la situation maritime (TSM) et sur la création d'alarmes non intrusives qui se déclenche lorsque des anomalies sont détectées dans le TSM. Enfin, un banc d'essai visuel MISR a été créé pour aider à la production de visualisations relatives au MISR. Le projet 11he et les résultats obtenus sont précisés dans le présent rapport, qui indique au lecteur les rapports découlant de ces recherches.

This page intentionally left blank.

Executive summary

11he Final Report: Information Visualization and Management for Enhanced Domain Awareness in Maritime Security

A.-L. S. Lapinski; DRDC Atlantic TM 2009-265; Defence R&D Canada – Atlantic; June 2010.

Background: The Recognized Maritime Picture (RMP) is a key tool used by Canadian military operation centres to help develop Maritime Domain Awareness. Created and maintained by the Regional Joint Operation Centres (RJOCs), it primarily contains position and identity information that is relevant to operational commanders. In its common form, it is represented as a map, with contacts, which are any discrete airborne, surface or subsurface object detected by electronic, acoustic, and/or visual sensors, marked on the map. This map representation of the maritime situation allows various maritime organizations (e.g., RJOCs, Marine Security Operation Centres (MSOCs)) to develop an understanding of current maritime activities in their area of interest or Area of Responsibility (AOR). On April 1, 2005, Defence Research and Development Canada (DRDC) started a new applied research project (ARP) in the Maritime Domain Awareness (MDA) thrust: Information visualization and management for enhanced domain awareness in maritime security (11he). This was a 4-year 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 project was focused on visualization design and experimentation as well as creating a visualization testbed. This report is the final report for 11he.

Results: The results of this work included development of a MISR related visualization testbed, visualization designs for visualizing uncertainty and non-intrusive alerts for anomalies, and valuable documents summarizing requirements and state-of-the-art visualization technologies.

Significance: The results of this work can be of use to the RJOCs for enhanced domain awareness and maritime security. Many findings highlighted in the various literature reviews produced for this ARP as well as the experimental results will be available to support improvements to the RMP. Though centered on the RJOCs, findings would be equally useful to future iterations of the MSOC displays.

Future plans: The future plans may include continuing to progress the uncertainty visualization research to the point that it can be integrated and used by the RJOCs; focussing more on research on how to visualize sensor coverage; continuing to research non-intrusive alerting systems so that an appropriate design for anomaly alerts can be discovered; continuing to develop and improving the MISR Vis testbed; initiating research into optimizing the user interface to the RMP; and researching the visualizing of both position and movement of ships to establish behaviour.

Sommaire

11he Final Report: Information Visualization and Management for Enhanced Domain Awareness in Maritime Security

A.-L. S. Lapinski; DRDC Atlantic TM 2009-265; R & D pour la défense Canada – Atlantique; Juin 2010.

Introduction : Le tableau de la situation maritime joue un rôle important dans le développement de la connaissance de la situation dans le secteur maritime par les centres d'opérations militaires canadiens. Conçu et maintenu par les centres d'opérations interarmées de la région (COIR), il contient principalement de l'information sur la position et sur l'identité pertinente pour les commandants des opérations. Le format standard consiste en une carte sur laquelle sont indiqués les contacts, qui sont les objets discrets en vol, sur la surface ou sous la surface détectés par des capteurs électroniques, acoustiques ou visuels. Cette représentation cartographique de la situation maritime permet à diverses organisations maritimes (p. ex. les COIR et les centres des opérations de la sécurité maritime (COSM)) de mieux comprendre les activités maritimes actuelles de leur secteur d'intérêt ou de leur zone de responsabilité (ZResp). Dans le cadre de l'élan de la connaissance de la situation dans le secteur maritime, Recherche et développement pour la défense Canada (RDDC) a mis en œuvre, le 1er avril 2005, un nouveau projet de recherches appliquées (PRA) : visualisation et gestion de l'information pour une meilleure connaissance du domaine en sécurité maritime (11he). Le présent rapport constitue le dernier rapport sur ce projet R & D de 4 ans, qui visait à faire progresser la « situation maritime » au moyen d'une qualité améliorée de l'information et de nouvelles façons adaptatives de visualiser cette information. Le projet portait sur la conception visuelle et l'expérimentation visuelle, et consistait en la création d'un banc d'essai visuel.

Résultats : Le projet a permis la création d'un banc d'essai de visualisation MISR, la mise en œuvre de conceptions visuelles représentant l'incertitude et les alarmes non intrusives qui signalent les anomalies, la production de documents importants qui décrivent les besoins et le développement de technologies de visualisation de pointe.

Portée : Les COIR peuvent tirer parti des résultats de ces recherches pour améliorer leur connaissance de la situation et de la sécurité maritime. Les nombreuses conclusions mises en relief dans la documentation diverse produite pour ce PRA et les résultats des expériences seront disponibles en vue de l'amélioration du TSM. Les découvertes, quoique centrées sur les COIR, seraient également utiles aux itérations futures des affichages des COSM.

Recherches futures : Plusieurs possibilités sont considérées pour les recherches futures. On pourrait notamment poursuivre des recherches sur la visualisation de l'incertitude en vue de sa mise en œuvre pour les COIR, mettre l'accent sur la façon de visualiser la portée des capteurs, continuer l'étude des systèmes d'alarme non intrusifs en vue de trouver un modèle approprié pour signaler les alertes d'anomalies, procéder au développement et à l'amélioration du banc d'essai de visualisation MISR, lancer des recherches portant sur l'optimisation de l'interface utilisateur avec le TSM et procéder à des recherches portant sur la visualisation de la position et du mouvement des navires pour en cerner le comportement.

Table of contents

List of figures

List of tables

Acknowledgements

The author and the original Project Manager, Alain Bouchard, would like to thank the Regional Joint Operation Centres (RJOCs) on the east and west coast for their valuable help with this research, in particular Lt(N) Jay Warwick and Lt(N) Phil Hagell. The author and Bouchard would also like to thank Neil Carson, Andrew Wind and Steven Horn for their assistance.

The author and Bouchard would like to acknowledge David MF Chapman, Sharon McFadden, Jérôme Lavoie, Denis Gouin, Richard Brown, Chris Helleur and Ron Kessel for their varied contributions to this project.

The author and Bouchard would also like to acknowledge that parts of this work were accomplished using standing offer No. W7701-054996/002/QCL which supported the Joint Command Decision Support for the 21st Century (JCDS 21) TD and standing offer No. W7714-040900/001/SV which supported the MUlti-Sensor Integration within a COE (MUSIC) TD.

This page intentionally left blank.

1 Introduction

The Recognized Maritime Picture (RMP) is a key tool used by Canadian military operation centres to help develop Maritime Domain Awareness. Created and maintained by the Regional Joint Operation Centres (RJOCs), it primarily contains position and identity information that is relevant to operational commanders. In its common form, it is represented as a map, with contacts, which are any discrete airborne, surface or subsurface object detected by electronic, acoustic, and/or visual sensors [1], marked on the map. This map representation of the maritime situation, commonly referred to as the Current Plot, allows various maritime organizations (e.g., RJOCs, Marine Security Operation Centres (MSOCs)) to develop an understanding of current maritime activities in their area of interest or Area of Responsibility (AOR). This traditional way of representing the RMP has worked relatively well for years in the symmetric warfare environment where almost exclusively military agencies were involved and positional and identity information were all that were required. With the rise of terrorism and asymmetric threats, multiple agencies must now collaborate to ensure the security of Canada. Additionally, new sources and types of information are becoming available from both the collaborating agencies and developing technologies. The traditional way of representing the RMP does not fully utilize the information now available and likely will not always meet the needs of the multiple agencies. Alternate methods of visualizing maritime data are required to achieve a higher level of Maritime Domain Awareness (MDA).

A report on the security of Canada's coastlines [2] published in October 2003, mentions that a key element to Canada's security includes an increased emphasis on both intelligence and other sources of information such as High Frequency Surface Wave Radar (HFSWR), Automated Identification System (AIS), transponders, drones, aircraft passenger information, and so forth. In that context, the Current Plot, the present way of maintaining domain awareness, needs to evolve to include all these new sources of information. Contacts from some of these new sources are already being added to the RMP (e.g., AIS). However, the amount of information now available can be overwhelming. The number of contacts is quite large and each one of those contacts has its own set of metadata. As the amount of information increases, the method of presenting and representing all the information available (which is more than just the information traditionally fed into the map-based RMP) needs to be revisited. In addition, representing information not associated with a contact also needs to be revisited. A more efficient method of presenting/representing the RMP information of value would likely aid the decision makers and generally improve understanding of the picture.

On April 1, 2005, Defence Research and Development Canada (DRDC) started a new applied research project (ARP) in the current MDA thrust: Information visualization and management for enhanced domain awareness in maritime security (11he). This was a 4-year 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 project was focused on visualization design and experimentation as well as creating a visualization testbed.

Section 1.1 gives further detail on 11he. The remainder of this final report includes descriptions of the project's work breakdown elements (WBE) 11he01 to 11he04 (listed in Section 1.1.2), followed by a section describing conclusions and recommendations based on the completed research. Annex A is a bibliography of the documents produced in this ARP organized by WBE.

1.1 The Project

The aim of 11he was to demonstrate, design, and prototype novel information visualization techniques to represent aspects of the RMP as well as evaluate the tools and techniques developed under the project for their effectiveness to support the activities under the RJOCs.

1.1.1 Outputs

To achieve the above aim, the outputs and deliverables of the project were

- Reports on: the future RMP; Information Visualization; experimentation outcomes
- Maritime ISR visualization experimental environment (MISR-Vis) also known as the testbed
- Human factors research on novel visualization techniques, with prototypes

1.1.2 Work Plan

The work plan for 11he was as follows:

WBE 11he01: Formulate Vision for Future Maritime Picture

WBE 11he02: Conduct SOTA study on InfoVis applied to MISR

WBE 11he03: Development of Demonstration Environment for Visualization

WBE 11he04: Visualization Design & Experiment

WBE 11he05: Generate Final Report

WBE11he03 encompassed the planning and building of the MISR-Vis testbed and WBE11he04 encompassed investigating novel information visualization concepts for RMP representation. Sections 2 to 5 describe the work done under the first four WBEs. This report satisfies WBE 11he05.

1.1.3 Milestones

The milestones of the project were as follows (including the dates they were completed):

- Apr 06 – Report on vision of future RMP
- Jun 06 – Report on State-of-the-art study on Information Visualisation techniques applied to MISR
- Sep 07 – Prototype Experimental Environment Operational
- Sept 07 – Deliver plans for experimental environment implementation
- Mar 08 – Submit experimentation plan for remainder of project

- Aug 08 – Final Experimental Environment Operational
- Mar 09 – Demonstrate implementation of information and knowledge management and visualization techniques
- – Deliver project summary report.

With the completion of this final report, all milestones have been reached.

1.1.4 Technology

The project built on current research in visualization, ontologies, Imago [3], prototyping and technology transitioning, and human-machine interaction. It was focused especially on maritime security and maritime domain awareness issues, which are different than the more traditional battle-space C4ISR issues, where targeting and force protection are paramount.

The technology for the testbed and visualization research already existed for this ARP. For the testbed, the technological issue was to implement the components of MISR-Vis after the ontology was defined. The testbed research followed on research that was being done at DSTO in Australia [3]. For the visualization design research the only technological issues encountered had to do with the technical challenges of setting up the desired experiments in the computer environments that were to be used.

1.1.5 Personnel and Leveraging

The project was conducted by staff from DRDC Valcartier, DRDC Atlantic and DRDC Toronto. Personnel from DRDC Ottawa and DRDC CORA also contributed at times during the project. The project leveraged, where appropriate, on other initiatives in the R&D program and on international initiatives, where mutual benefits could be gained; e.g., the JCDS21 TD, MUSIC TD, the COP 21 Situational Awareness Portal, and TTCP (TTCP C3I TP2, TTCP C3I AG3).

Of note, the position of Project Manager was somewhat unstable through the course of the project. While Alain Bouchard was officially Project Manager for most of the project, he was on exchange, out of the country, for most of the first 2 fiscal years. Denis Gouin acted as Project Manager for the first fiscal year and 11he was put in hibernation with no acting Project Manager for the second fiscal year. Alain Bouchard was back as Project Manager during the third fiscal year. During the fourth fiscal year, in July 2008, Alain Bouchard took a leave of absence which ended with his resignation from DRDC. Anna-Liesa Lapinski was named Project Manager for the final 8 months of the project, starting in July 2008.

The work capitalized on the familiarity and links already established by DRDC Atlantic with the RJOCs through previous collaboration in the ALIX trials (the Canadian Forces Experimentation Centre (CFEC) undertook a large-scale experiment known as the Atlantic Littoral ISR Experiment (ALIX) in 2004, during which DRDC collected RMP data), through the MUSIC TDP, and through regular meetings, ensuring access to real data, understanding of intent, and user orientation. The work also helped establish familiarity and links between DRDC Valcartier and the RJOCs. The work itself leveraged on previous work done on Information Visualization (e.g., Link Analysis tools) and work previously initiated on visualization of uncertainty and alerts. The testbed heavily leveraged on work done by DSTO on Imago [3].

1.1.6 Evolution

There was a certain amount of evolution of project goals and ideas after the project started.

Canada has adopted a new stance toward maritime security, for example, standing up the new Maritime Security Operations Centers (MSOCs). These centers were stood up to facilitate communication between several government departments that share a mandate for maritime security. Information gathering and sharing are central to the operations of these centers. The RMP produced by the RJOCs is an important contribution to the MSOCs. The original intent was for 11he to support the MSOCs; however, during the course of 11he we were instructed that this could no longer be the case, as the MSOC ConOps were still in development at the early stages of the ARP. The ARP switched its support to TRINITY (east coast) and JTFP (west coast) under which the RJOCs are housed. The focus of the research was to support the RJOCs.

Another evolution is in regards to the MISR-Vis testbed. One of the key products of 11he, from the conception of the project, was to build a testbed. Originally, the plan was to build a flexible testbed to emulate the essential elements of the future RMP, so as to facilitate experimentation to advance and validate 1) applied elements of information fusion, data-mining, and human-machine interaction, and 2) novel techniques for visualizing information. The focus of the testbed, however, evolved during the course of the project. The testbed was not, in the end, designed to emulate the future RMP but rather to act as a tool where visualization applications may be deployed and experimented with, in the context of MISR. This is discussed further in Section 4 and [4]. The testbed was designed to be of use to those working with data in the MISR domain, such as those working at the RJOCs.

2 WBE 11he01: Formulate Vision for Future Maritime Picture

WBE lead: David M.F. Chapman, DRDC Atlantic

2.1 Background

One of the goals of 11he was to work on demonstrating, designing, and prototyping novel information visualization techniques to represent aspects of the Recognized Maritime Picture (RMP), a product produced by the Regional Joint Operations Centres (RJOCs). Prior to commencing this research, it was important to establish the perception of how the RMP would evolve in the coming years. By postulating its assumed evolution, it would help isolate research areas of value, which, in turn, would help guide the research areas of this project.

Three studies were commissioned by DRDC Atlantic. The goal was to explore the realm of possible futures for Maritime Intelligence, Surveillance, and Reconnaissance (MISR), looking as far ahead as 2020. This was an opportunity, for those doing the study, to express educated opinions, predict future trends, and promote a vision of what could be achieved. The term "Future Maritime Picture" (FMP) was used to distinguish the future RMP from the current and evolving RMP.

The main deliverable for each of the three contracts was a contract report, one for each commissioned study [5-7] detailing the respective visions. In addition, at the conclusion of the contracts, a mini-symposium was held at DRDC Atlantic during which the authors of each study presented their visions to employees of DRDC and members of the Canadian Forces.

2.2 Associated Contracts

W7707-053074/001/HAL; MacDonald Dettwiler and Associates Ltd. (MDA)

W7707-053074/002/HAL; Ultra Electronics Maritime Systems (Ultra)

W7707-053074/003/HAL; CarteNav Solutions Ltd. (CarteNav)

2.3 Discussion

While each company, MDA, Ultra and CarteNav, approached the project from their own unique perspectives, there were certain themes that reoccurred in the reports. The following are some examples. The need for sharing and combining of information between government departments to produce a better RMP as well as the expectation of the need to share the RMP with other government departments was recognized and discussed in more than one report. The changes in the information sources feeding the RMP were discussed in all reports. Two of the reports proposed new system architectures for the FMP. Improved fusion of data feeding the RMP was recognized by all reports as something needed. An appropriate user interface was discussed from each company's perspective. These common topics indirectly showed the most obvious areas that would be worthwhile to focus research on. In addition, some ideas presented in the reports were, if not similar then complementary as seen in Table 1. Table 1 is a cursory comparison of ideas written in the reports organized by company and theme. (The comparison should not be considered comprehensive in any way or considered to be a complete summary of what is in the reports.) For those planning and working towards the FMP, comparing the reports side by side in a similar way would likely give a strong indication of the direction research should likely take as well as a plethora of ideas of where to start the research.

Table 1: A cursory comparison of ideas in the contract reports, organized by company and theme.

MDA	Ultra	CarteNav
The FMP will potentially be		
able to visualize abstract and geographically referenced information in an improved manner.	able "to draw together data in real-time from many different types of sensor systems, and place this data in a geographic, historical and behavioural context that will help operators of the FMP analyze and understand what is happening in Canadian waters on many levels".	"able to provide clarity as to the identity, position and movement of every contact in the Canadian maritime areas".
both visual and interpretative.		
Interdepartmental Sharing		
"the traditional 'Current Plot' must be thoroughly inter-linked with intelligence information to form a 'Maritime Intelligence Nexus.' That nexus will be built by the whole MISR community, using a new generation of internet tools and rules that enable people to self-organize around shared knowledge."	"It is envisioned that in the future a single governmental agency will oversee security and surveillance of the waters surrounding Canada."	The FMP will have interdepartmental users.

MDA	Ultra	CarteNav
The FMP will interweave intelligence, surveillance and reconnaissance information	The FMP may be used for "civilian security and interdiction, search and rescue, CBRN or pollution incident response, navigation and shipping traffic control, support for marine biological field work, and tracking climate and environmental trends"	The FMP "must also have the capability to attach relevant security-related information to each of those contacts, and then alert operators when this collated information indicates that a vessel has become a Vessel of Interest (VOI)".
The FMP will be one element of the Canadian Common Operating Picture. The FMP will be a service provider for the COP.		The FMP "must then be able to support interdepartmental operations with appropriate decision-making aids".
		The FMP must have a strict operational information structure/standardization.
		The FMP must be "more supportive of security information sharing"
		The FMP must support being added to other pictures (help form joint picture, coalition partner pictures)
Sources and Information		
Satellite AIS coverage will be key to automated data fusion of benign traffic.	Sources: Underwater Sensors, Radar, Imagery, Global Navigation Satellite System (GNSS), AIS, Specialized and Satellite Sensor Systems, METOC, Field Reports, Data Feeds From Other	Expect:

MDA	Ultra	CarteNav
	Agencies, and the internet.	
Canadian sensors must be increased		"increased environmental data and information;
Supplemental active radar coverage will be key to detect threats		increased Canada-US cooperation concerning the transfer of information and knowledge related to security threats and natural disasters;
		more input from commercial sources;
		the development of Arctic sensors;
		a need for better Intelligence, Surveillance and Reconnaissance (ISR) of disputed maritime areas."
System Architecture		
"A service-oriented architecture (SOA) will help make the FMP robust to direct attacks, including the loss of whole facilities. The SOA will also make the FMP robust to continual changes in technology and operational expectations, by allowing segments to be added and removed without re-engineering all the other components."	a "model used by commercial computing rather than traditional military networking" is proposed	

MDA	Ultra	CarteNav
	a modular system architecture	
Fusion		
The FMP will use automated data fusion to process data to help the operator focus on what is unknown about the picture rather than what is known.	"The most difficult process in this Data Fusion will likely be attaining interoperability, technically and legally."	It is expected that fusion will remain greatest challenge.
Use and acceptance of new generation fully-automated fusion tools is needed.		If fusion is not greatly improved then there will likely be “diminishing value in gathering ever-increasing amounts of information.”
The FMP will be “a linked collaboration of autonomous service-providers maintained by member agencies.”		It is expected that “data fusion will occur before data is displayed or sent as information.”
		The FMP “must fuse a large amount of structured and unstructured information using semantic technologies and knowledge management”.

MDA	Ultra	CarteNav
User interface and visualization		
New user interface tools will include workflow software and visualization tools that allow exploration of the FMP and its associated data spaces.	"The interface will, by necessity, be easy to understand and work with, allow some customization, look much like applications the user may already be familiar with from prior computer use, and be brief and clear on what the operator is expected to do."	It is expected that computer interfaces will optimize human factors engineering.
		"The FMP will treat uncertainty in a systematic fashion and creatively display the level of uncertainty to support more effective decision-making, without having to drill down to supporting details."
		"the FMP will be able to display real-time data in complex combinations from multiple layers assembled to suit the requirements of a particular role or situation."
		"The FMP will facilitate ad hoc or scheduled virtual and face-to-face discussions in support of decision making rather than the education of decision-makers."

MDA	Ultra	CarteNav
		"Computers will be sophisticated enough to understand an individual user's requirements and situational context, making for a more sophisticated interaction."

2.4 Assessment

Requisitioning for three contractors to each write a speculative report on the FMP in the time around 2020 was a good idea. It ensured 3 different points of view as well as allowed for comparing and contrasting the ideas contained within. The reports themselves were each quite different; each attacking the topic from a different bias depending on the authors' background. The Ultra report was not as extensive as the other two.

2.5 Significance

This work provided a foundation for the work done in this ARP. The visions presented helped illuminate how the FMP could potentially develop as well as cumulatively pointed to the important areas of change the current RMP will likely go through (or must go through).

The reports guided and confirmed the research planned for this ARP. For example, CarteNav's report states, "The FMP will treat uncertainty in a systematic fashion and creatively display the level of uncertainty to support more effective decision-making, without having to drill down to supporting details." (p. v) Independent of this report, it had been decided that researching appropriate methods to visualize the uncertainty in the RMP might be worthwhile. CarteNav's report supported that idea. That visualization work is discussed in Section 5 of this report. CarteNav's report also states, "Computers will be sophisticated enough to understand an individual user's requirements and situational context, making for a more sophisticated interaction," which was essentially the goal for building the Maritime ISR Visualization testbed, discussed later in this report (Section 4).

3 WBE 11he02: Conduct SOTA study on InfoVis applied to MISR

WBE lead: Anna-Liesa S. Lapinski, DRDC Atlantic

3.1 Background

As a foundation for developing innovative and effective ways to visualize information in the maritime security context, the state-of-the-art of the field of Information Visualization needed to be established. To accomplish this, a literature survey and a product review were undertaken on Information Visualization, with an emphasis on MDA and MISR applicable matter. The literature survey and product review were carried out under a contract issued from DRDC Atlantic. The main deliverables of the contract were a contract report [8] containing the literature survey and product review results and an Endnote® database containing useful documents with comments from the contractors, quality assessments of some documents, keywords, and links.

3.2 Associated Contracts

W7707-053019/001/HAL; MacDonald Dettwiler and Associates Ltd. (MDA)

3.3 Summary

The literature survey in the contract report [8] identifies foundational documents and sorts them into eight categories: Human Factors, Computer Visualization, Defence Applications, The Art and the Craft, Electronic Displays, Measures of Effectiveness, documents to give Inspiration, and Journals and Conference Streams. The last category does not point to foundational documents but rather points towards reputable journals and conferences that might be of interest. The literature survey also identifies and gives brief biographies on the leaders in Information Visualization related research. In addition, the pressing questions in the research are identified.

For MISR, the topics of interest identified for the literature survey were space-time visualization, visualizing attribute information, visualizing what is unknown, defence applications of information visualization, visualizing uncertainty, information visualization as pertains to domain awareness and information overload, the human factors aspect of information visualization, measures of effectiveness for information visualization, and literature on display technologies. The contract report provides references for documents on these topics as well as on some less prioritized topics of interest.

For the product review, the report contains one-page descriptions of sixty eight MISR-related visualization products. The products range from public-domain code for a specific visualization task to commercial multipurpose toolkits. Twenty of the products were reviewed in great detail, using available literature, demonstrations, reviews, in-house experience or any other available resources that could support the assessment. The product reviews are separated into two large categories: hardware and software products. Within the hardware section, 2-D displays, 3-D displays, and interactive displays were reviewed. The software section includes reviews on general purpose toolkits, time series display tools, tools for visualizing the web and web searches, knowledge visualization tools, treemap tools, network visualization tools, enterprise knowledge visualization tools, tools for visualizing context and depth, tools for linking knowledge to spatial data, OLAP and data mining tools as well as other potential tools of interest.

In addition to the report, an Endnote® database was provided. A copy of the database content is placed in the Annotated Bibliography section of the contract report. There are about 240 references to texts, conferences, journals, and institutional websites in the Annotated Bibliography.

In Section 4 of the report, the authors discuss four pertinent visualization research areas for MISR and marine security with reference to research and products. These include, visualizing where and when sensors have been deployed; visualization of both position and movement of ships to establish behaviour; detecting anomalous behaviour through the help of visualization; and to generate awareness through visualization of attributes of vessels, such as ship owner, cargo, etc.

3.4 Contractor Conclusions

The report concluded that there exists literature and products that can be drawn upon to help further develop MISR visualization, though they may not be directly related to MISR. MISR visualization still requires research to get to the ambitious vision of what can be achieved with MISR visualizations and to generate visualizations in an automatic fashion. The specific MISR visualization problems discussed in Section 4 are unsolved and therefore require research.

3.5 Assessment

The literature survey and product review are both very comprehensive, as is the Endnote® database. The contract report is an excellent reference for those looking for literature on Information Visualization, whether their focus is on MISR and maritime security or not. The product review is extensive. Unfortunately, due to the ever changing nature of technology, the usefulness of the product review is continually waning; more so than the literature review. However, the objective of the contract report was not to create a report with longevity but rather to establish a base of knowledge from which the follow-on research could grow. The report accomplished that objective. In addition, Sections 4 and 5 gave good suggestions for further research and development within the field of MISR visualization.

3.6 Significance

This work provided a foundation for the work done in this ARP. For example, the product review provided potential visualization aids that could be used in the visualization testbed (Section 4 in this report). The literature review gave a foundation of work in, or applicable to, the field for all aspects of the ARP. The report also pointed out some gaps in the existing research. The work done under this ARP has touched upon, either directly or indirectly, most of the MISR visualization problems listed in the contract report's Section 4 & 5. These direct or indirect touches include: visualizing surveillance coverage and its uncertainty, visualizing uncertainty in attribute data of interest, creating visualizations to alert to anomalous behaviour and setting up a partially automatic method of choosing appropriate visualizations. The contract report was also found useful by some people outside the ARP, such as at the RJOCs and others in DRDC.

4 WBE 11he03: Development of Demonstration Environment for Visualization

WBE lead: Alain Bouchard, DRDC Valcartier

Significant contribution: Jérôme Lavoie, B.Sc. student, École des Technologies Supérieures (ÉTS)

4.1 Background

After doing the foundational work in the previous WBEs, the project began developing a prototype of a tool to help pick appropriate visualizations for visualizing maritime domain related data given a particular task. The tool or testbed is called the MISR-Vis testbed (MISR testbed for visualization) and is based on previous work Alain Bouchard did on a tool called Imago. Vernik et al. [3] introduced Imago, an environment being developed jointly by Defence Science and Technology Organisation (DSTO) and Defence Research and Development Canada (DRDC) to support the prototyping, evaluation, and transitioning of information visualization approaches for military Command and Control (C2). Imago is the main component of the testbed. The goal of the MISR-Vis testbed was to further the research on Imago while giving it a decidedly MISR slant.

The MISR-Vis testbed, like Imago, was developed to automatically suggest appropriate visualizations given the data to be visualized, the task and who is performing the task. In order to achieve this, the testbed also allows a person to feed the testbed by uploading a visualization technique, characterizing it and recording an evaluation of it for particular tasks. The aspects that make up the MISR-Vis testbed are:

- Imago: an application which is used to prototype and evaluate visualization techniques.
- MISR-Vis knowledge base: a maritime ISR domain knowledge base based on the RM-Vis (Reference Model for Visualization) structure.
- Maritime Datasets
- The ability to integrate instrumentation.
- The ability to provide simulation functionalities through integration of existing tools.

The work was done under two contracts with MDA and Thales. The deliverables for this WBE included the MISR-Vis testbed, the MISR-Vis knowledge base and five contract reports [9-13]. For further details on the MISR-Vis testbed not covered in this WBE synopsis, an in-depth treatise on Design and Development of an MISR-Vis Testbed, Requirements for a MISR-Vis Testbed and a Showcase of Visualizations for MISR related to this WBE, please see [4], authored by the WBE lead, Alain Bouchard. (Note that the first author of this 11he final report did not get a chance to see the MISR-Vis testbed in action before Alain Bouchard took a leave of absence, shortly after its completion. This section is based on the contract reports.)

4.2 Associated Contracts

W7701-065113/001/QCL, MacDonald Dettwiler and Associates Ltd

W7701-071670/A, Thales Systems Canada

4.3 Summary

MDA designed and developed a MISR-Vis knowledge base [9] rooted in a previously established reference model for visualization (RM-Vis) [14]. The goal of the knowledge base was to incorporate it into the MISR-Vis testbed. The knowledge base was developed to support the discovery, showcasing, and evaluations of visualization technologies. The knowledge base consists of two ontologies: MISR domain ontology and MISR-Visualization (MISR-Vis) ontology. The MISR-Vis knowledge base describes the domain that is observed by Maritime ISR operations, and describes how various tools could be used to visualize the MISR domain. The domain ontology includes tangible concepts such as ships, ports, and cargos, as well as intangibles, such as objectives, capabilities, and allegiance. The MISR domain ontology's high-level structure follows JC3IEDM (Joint Consultation, Command and Control, Information Exchange Data Model).

Thales designed and developed the MISR-Vis testbed. The primary contract report documenting this work is the MISR Visualization Experimental Environment: System Architecture Document (SAD) [11]. The report gives a summary on the Imago objectives and scope; the RM-Vis concepts in which the MISR-Vis knowledge base is rooted; use cases; system architecture; system implementation and recommendations. Thales' objectives under the contract were to 1) provide a testbed to demonstrate, prototype and evaluate visualization techniques for RMP (Recognized Maritime Picture) related data; 2) ensure the testbed is generic enough to support the MISR-Vis knowledge base; 3) make extensive use of the DSTO Livespace distributed environment; and 4) provide an ergonomically designed user interface.

At the time of the report, Thales had identified several issues with the MISR-Vis testbed: the ontology model must conform to the RM-Vis format which means other ontology formats cannot be easily used; the knowledge base size could cause a performance problem in the future if it gets too big; the system is completely configured on current software releases which could cause problems when updates are released in the future; and an appropriate user interface was still needed.

One of the goals of the Imago application, and therefore MISR-Vis testbed, is to have dynamic previews of the visualization tools available to the user so that the user can preview and try out different visualizations tools as they decide how to visualize the data in question. Imago is designed to be used to prototype and evaluate visualization techniques. The user needs to have access to visualization tools (commercial or otherwise) in order to create the visualizations. Ideally, there should be the capacity to upload data into the available visualization tools through Imago. This requirement produces problems that were addressed in one of the contract reports [10]. Paying for the license of the commercial visualization tools to be integrated into each copy of Imago presents a fundamental complication (who pays for the licence(s), where do the licences reside, etc.), as does ensuring that none of the licenses are violated, because this could have legal ramifications. If the licensing complication can be solved, then the next problem is that the viewer for each visualization tool will need to be installed with the Imago client on every user's computer.

In the course of this work, a study was done [12] on the possible approaches for the Imago search engine. The contract report [12] lists realistic example queries and then summarizes the two most probable types of searches: full text index search and custom query builder. The document describes the pros and cons of several technology solutions such as SPARQL, the DataO Query builder, and JENA rules and derivation logging. The report also documents suggestions on a simple approach for integrating a query tool.

A short product review of AGI's Satellite Toolkit (STK) was performed under this WBE [13]. The STK can be used to perform complex simulations of land, sea, air, and space assets, and has the ability to share results. The product was investigated for its potential to be used in Canadian MISR activities and research activities that require modeling of environments containing assets. The reviewer's general finding was that it is a complex tool. The reviewer was only able to fully accomplish one of the four tasks set out to be performed: "Integration of the CHDB Format". The task "STK integration in Imago" was described in text rather than physically done. The tasks "Integration of the WPG format" and "OTH-GOLD Integration in RT3" could not be accomplished by the reviewer.

By August 2008, the testbed was operational and in September 2008, the MISR-Vis knowledge base and the testbed were transferred to DSTO Edinburgh as a TTCP contribution.

4.4 Contractor Recommendations

Thales detailed recommended improvements to the query tool, editing screens, simulation tools and dataset integration for the testbed [11].

Regarding the dynamic preview issues [10], it is recommended that 1) the possibility of using mock-ups instead of the real visualization tools, 2) the possibility of giving the user a remote desktop connection to a machine that holds the visualization products (tools) rather than deploying and integrating the tools directly into Imago, and 3) the development costs of the dynamic preview idea, all be evaluated.

Regarding the Imago search engine [12], it is recommended that further investigation, prototyping applicable approaches, and picking an approach and submitting it to a developers list for comments, be the way to proceed.

Regarding the STK product review [13], the recommendations that came out of the brief investigation, within the context of the testbed that was being designed and built, were to verify the need for such a complex simulation environment, keep investigation of the AGI line of products separate from Imago because they have very little in common and if the STK is needed, make sure there is an expert on hand to run it.

4.5 Assessment

Based on the reports, the work done under this WBE was able to push forward the research on an environment to support the prototyping, evaluation, and transitioning of information visualization approaches for military C2. Its success is evident from the MISR-Vis knowledge base and the testbed being transferred to DSTO Edinburgh as a TTCP contribution.

4.6 Significance

The significance of this work is that the MISR-Vis testbed helped further the research on semi-automated information visualization for C2 particularly in the MISR domain. The work has the potential to improve the ease of creating visualizations that are effective in the MISR domain.

5 WBE 11he04: Visualization Design & Experiment

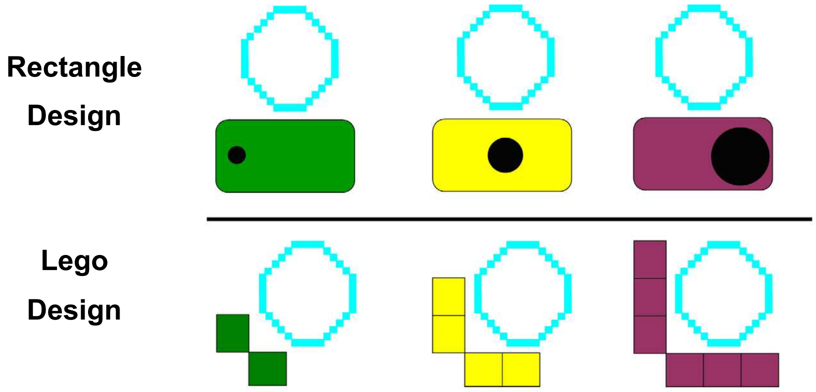
WBE lead: Anna-Liesa S. Lapinski, DRDC Atlantic

Significant Contribution: Sharon McFadden, DRDC Toronto

5.1 Background

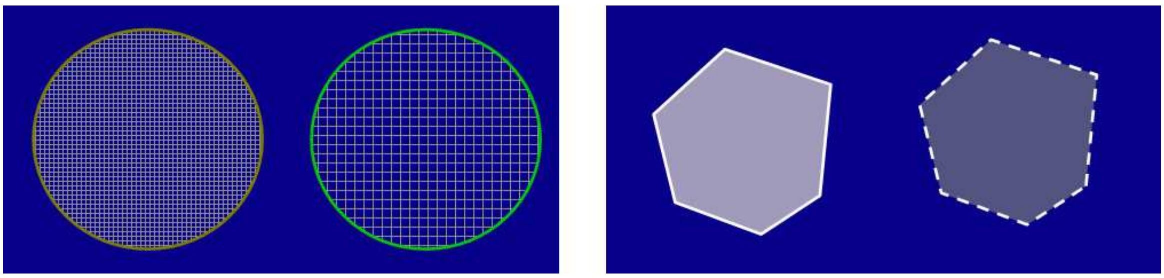
This WBE focussed on researching the best way to visualize certain aspects of the contact data in the RMP. The work focused on two issues: visualizing uncertainty in the RMP (which was the bulk of the work) and designing non-intrusive alerts for alerting operators to anomalies present in the RMP.

Uncertainty Visualization. The uncertainty visualization work was focused on identifying a pertinent set of uncertainty visualizations to represent uncertainty in the identity, uncertainty in the spatial position and uncertainty due to the passage of time for the contacts, as well as identifying a pertinent set of uncertainty visualizations to represent uncertainty associated with the RMP data source and uncertainty in the source due to the passage of time since it last reported data. The research was done under contract with Human*systems* Inc. (HSI®). The work was split into two phases. The objective of the first phase was to identify promising uncertainty visualization designs for the RMP, through human-in-the-loop experimentation. Through a literature review and discussions with the WBE lead and Sharon McFadden of DRDC Toronto, two icons (Rectangle design and "Lego" design Figure 1) were developed and selected to display uncertainty related to the contacts. In addition, background swaths with two features (fill and border) were developed to display sensor coverage uncertainty (Figure 2). The designs were assessed using computer-based experiments at the HSI® Test Lab, augmented by a questionnaire evaluation.



good identity	poor identity	no identity
precise position	approximate position	unknown position
current time	old time	out of date time

Figure 1: Sample of design concepts for contact uncertainty, phase one. Colour = identity uncertainty, spatial uncertainty = size of the black dot (Rectangle) or number of squares in the horizontal bar (Lego); uncertainty due to the passage of time = position of black dot (Rectangle) or number of squares in the vertical bar (Lego).



Sensor quality: strong	Sensor quality: weak	Sensor quality: strong	Sensor quality: weak
Time information: Out of data.	Time information: current	Time information: current	Time information: out of date

Figure 2: Sample of design concepts for sensor uncertainty, phase one. Sensor quality: Good quality was represented by either light grey or a fine hash; poor quality by a dark grey or coarse hash. Sensor time lateness was indicated by either the type of the swath border (current=solid/out of date=broken) or the border color (current=green/out of date=gold).

The designs tested in the first phase were carried over into the second phase. The objective of the second phase was to evaluate the effectiveness with which the uncertainty visualization techniques from the first phase enhance the information presented in the RMP. Important enhancements were considered to be improving understanding of the RMP for users (e.g., operators, supervisors at RJOCs), improving decision making based on the RMP by users and improving the effectiveness of the RMP operators/supervisors' duties. To achieve this, Canadian Forces Naval subject matter experts (SMEs) conducted a series of operationally relevant tasks on a simulated RMP created with archival RMP data and Google™ Earth (Figure 3). The performances of the visualization aids were assessed (i) in terms of task completion times in comparison with SME estimates of the typical time it would take in current operational practice, and (ii) by questionnaire evaluation of the usability, usefulness and potential operational effectiveness of the concepts. The main deliverables of the contract call-ups were two contract reports [15-16], each documenting a phase of the research in addition to the designs.

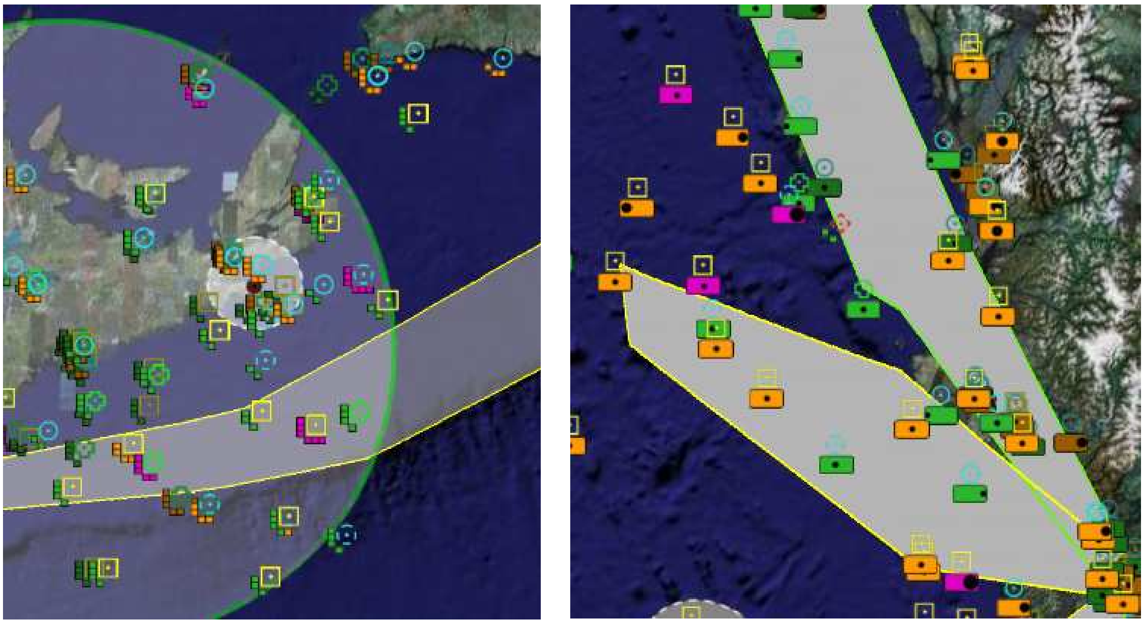


Figure 3: Example of phase two mapping of the uncertainty representations into Google™ Earth (icons in the figure are reproduced smaller than would be seen on a computer monitor).

Non-intrusive alerts. There is considerable research being carried out on anomaly detection in the RMP. Under this ARP and WBE there was work done on designing an alerting system for when anomalies are detected such that it would make operators aware of anomalies, without affecting the operator's performance of their primary tasks (i.e., non-intrusive alert). This work was lead by Sharon McFadden at DRDC Toronto. This non-intrusive alert work included identifying and analyzing available literature relevant to nonintrusive alert systems; developing design concepts for a non-intrusive alerting interface, designed to be used in GCCS-M; and obtaining feedback from Navy Subject Matter Experts (SMEs) on the suitability of the design options. The alerts that were tested were visual, though the literature review did cover other types of alerts, such as auditory. Much of the research was done under contract with HSI®. The main deliverable of the contract was a contract report documenting the work [17], in addition to the designs (e.g., Figure 4 and Figure 5).

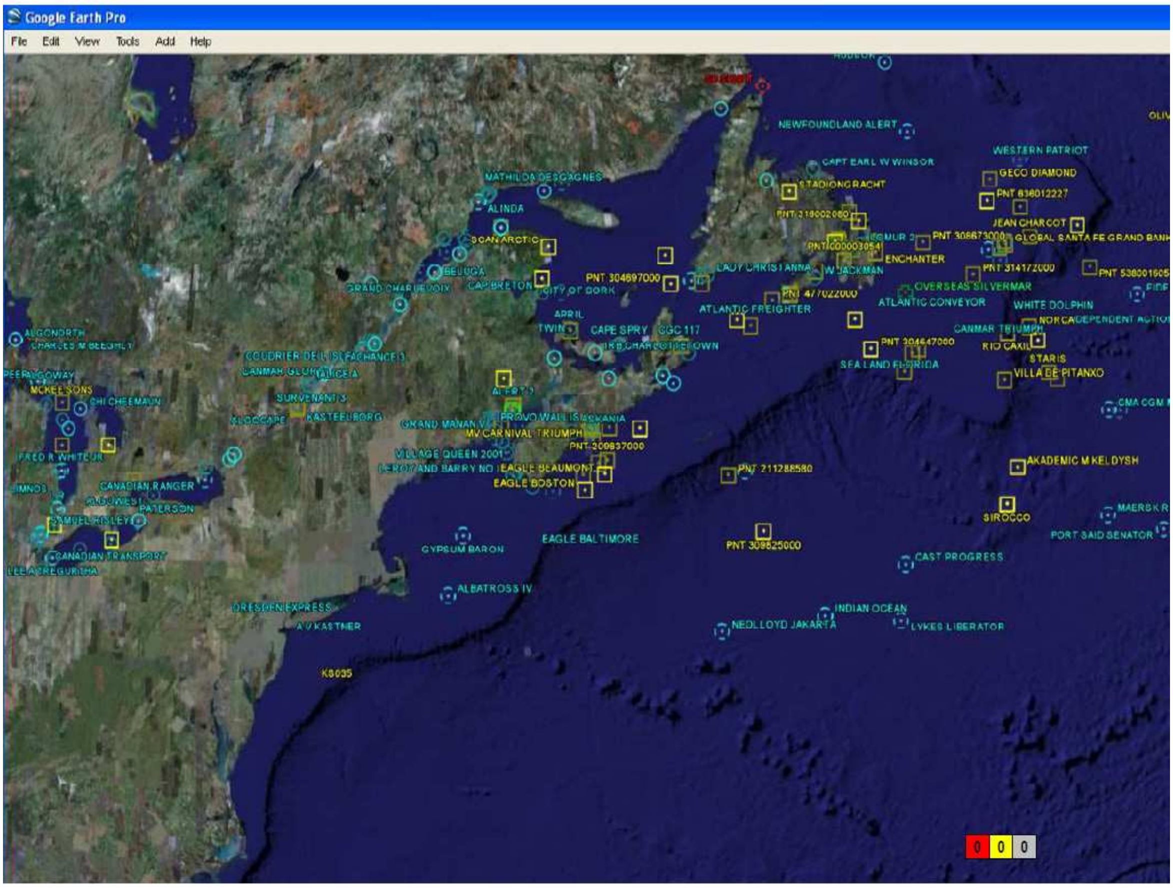


Figure 4: Cumulative total indicator. The alert category is indicated by colour. For priority 1 alerts, the number in the red box increments and the box blinks at rate of 2 Hz. The flashing continues until the operator acknowledges the alert by clicking on it. For priority 2 alerts, the number in the 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. On a new priority 3 alert, the number in the grey box simply increments. [17]

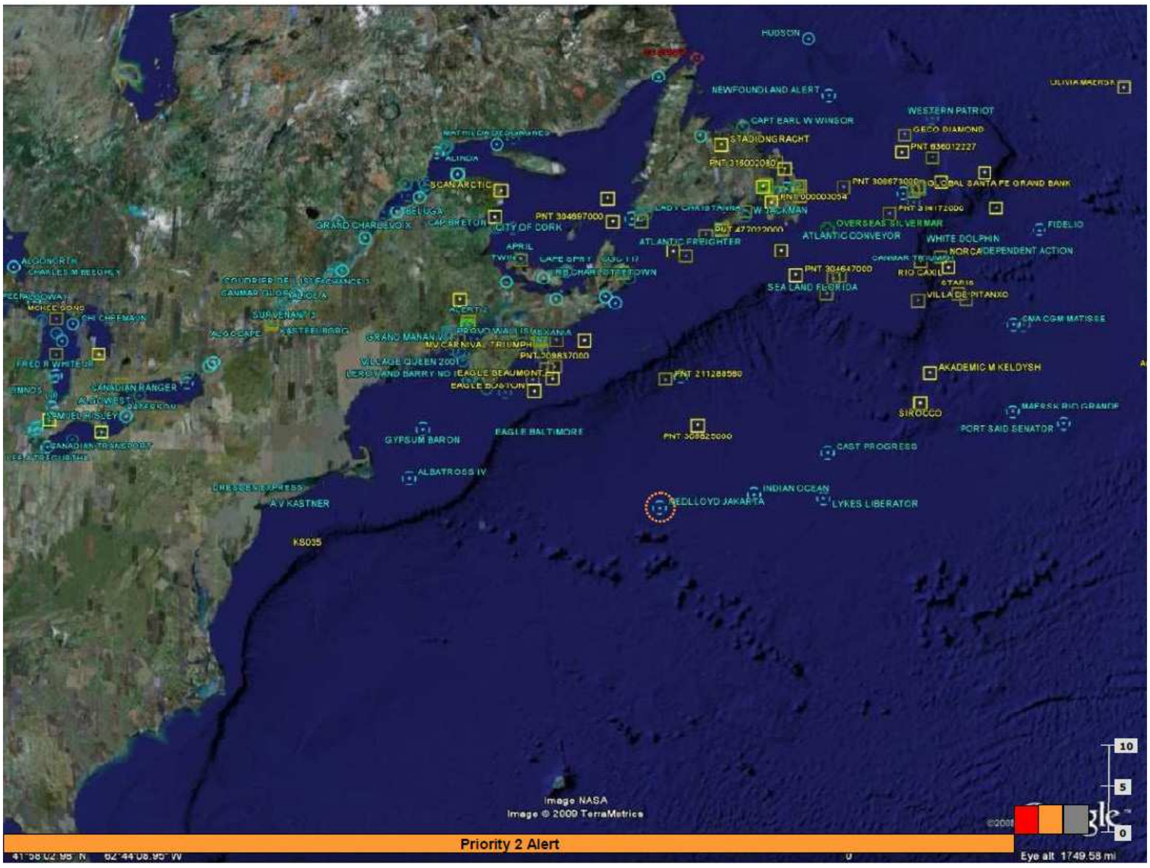


Figure 5: Ticker and Fading Bar. On a new priority 1 alert, a red bar appears across the bottom of the screen with a message scrolling from right to left indicating that there is a new priority 1 alert. A brief description of the type of anomaly is also provided (e.g., contact veering off-course). An unacknowledged priority 1 alert would also increment the height of the red bar in the counter on the bottom right of the screen, showing an increase in the number of active priority 1 alerts in the system. The red bar is present and the scrolling continues until the operator acknowledges the alert by clicking it. On a new priority 2 alert, an orange bar with text indicating that there is a priority 2 alert fades in and out of the bottom of the screen at a rate of 5 Hz. The bar and message remain on the screen for approximately 2 seconds before fading away and then returning again until the alert is acknowledged by the operator (by clicking on it). On a new priority 3 alert, the height of the grey bar in the counter at the bottom right of the screen would increment by one indicating an increase in the number of active priority 3 alerts. The operator would only notice this increment if he/she was looking directly at the counter at moment it increments.[17]

5.2 Associated Contracts

W7707-054996/002/QCL; Call-up No.: W7707-078067; Human*systems*® Incorporated (HSI)

W7714-040900/001/SV; Task No. 2008-201; Human*systems*® Incorporated (HSI)

W7711-088124/001/TOR; Human*systems*® Incorporated (HSI)

5.3 Summary

Uncertainty Visualization. In the first phase of the uncertainty visualization research, non-expert participants were given search tasks to perform using the developed uncertainty representations in an RMP-like computer environment. They also completed a questionnaire at the end of their sessions. Search times and accuracy were investigated using eleven participants and six experimentation sessions. The object of the research was to 1) determine the best uncertainty representations being tested; 2) gauge how fast the searches could be performed given varying number of criteria the participants must search for and 3) to note any (recurring) inaccuracies when the participants performed the tasks. If the search times were consistently prohibitively slow or a significant number of participants did poorly in the searches, this would be a sign that the uncertainty representations were inadequate for RMP applications.

For the Lego design, the search times were somewhat uninfluenced by the number of search criteria while search times for the Rectangle design were fastest when doing searches for all three criteria (i.e., searching for a specific uncertainty due to the passage of time, a specific uncertainty in position and specific uncertainty in identity, at once). This latter observation could be the result of subjects having more difficulty in ignoring the irrelevant dimensions of the uncertainty icon; i.e., when the search task asked them to focus on only one or two dimensions of the uncertainty they had trouble ignoring the dimensions of the uncertainty icon that were immaterial. This could be a sign that they had learned the overall gestalt for that design.

A small search time benefit was recorded for the Rectangle design and small performance differences were observed among the different designs for sensor coverage. While the performance difference between the Rectangle and Lego designs was statistically significant, there is a question of whether a .25 to .5 second advantage in locating a contact that meets a specific set of conditions is of operational consequence. Accuracy was high for all visualization techniques, with no significant differences between the different uncertainty visualization designs. Participants rated the workload associated with using the designs as low. All of the design options evaluated were considered to be suitable candidates for evaluation by the operational community in the next phase.

In the second phase, again there were tasks to complete and a questionnaire to fill out as part of the testing of the designs. The performance of the visualization aids was assessed using the relative task completion times and the questionnaire. The task completion times were compared to SME estimates of the typical time it would take in current operational practice. The questionnaire evaluated the usability, usefulness and potential operational effectiveness of the concepts.

Some of the results from this study included a general agreement that visualizations would add to operational capability in terms of situation awareness (e.g., improved overall awareness of weaknesses in the RMP), decision making (e.g., determining areas where to send assets for investigation) and RMP management (e.g., better management and exploitation of all available data in the picture compilation process). It was predicted that the information provided by the sensor coverage swaths would be particularly useful in determining potential sensor problems, RMP areas needing better coverage, planning of future sensor deployment and monitoring vessels of interest. The design concepts received positive evaluations for both usability and usefulness from the subject matter experts. It was thought that the design concepts had the potential to improve operational performance, if coupled to an appropriate underlying technology. Further, these studies have shown that the visualization aids can be easily learned. The study, however, was unsuccessful at determining whether the aids would result in faster execution times for the tasks. This would require more rigorous and controlled testing during any future phase of this work.

Non-intrusive alerts. The literature review for the non-intrusive alerts work could not find a unified design approach for designing a non-intrusive alert system, recommendations for non-intrusive alerting, nor a paper that definitively addressed the issue of how to design a non-intrusive alerting system. The literature review did find relevant general concepts in the literature relating to alert/alarm design. These general concepts, in addition to general human factors principles, helped guide the prototype designs for the non-intrusive alerting interfaces.

The seven subject matter experts evaluated four non-intrusive alerting interface designs. The validity of the experimental data is effected by the small sample size, by not asking them to use the designs in a realistic environment, and when an operator biases their evaluation of some designs based on a preference for one design. Despite this, valuable insights were obtained during the evaluation. No one design was clearly favoured within the small number of participants. To keep track of alerts, displaying the number of alerts using numerals rather than a scale was preferred. Based on feedback from participants, “an anomaly alert design which combines the counter from the Cumulative Total Indicator [Figure 4], to indicate the number of active alerts in the system, with the Ticker [Figure 5] and Fading Bar [Figure 5], 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” p. 94. Table 20 of the report summarizes the design recommendations for future work based on participant feedback and human factor principles.

5.4 Contractor Conclusions

Uncertainty Visualization. With regards to uncertainty visualization, in the first phase of the investigation, HSI found that the Rectangle design (for the icon design) and grey swath fill with solid/broken border (for the senor coverage uncertainty) had observable advantages over the other comparable designs. It was questioned whether these observable advantages were significant enough to warrant dismissing the other designs; therefore, HSI suggested that all designs be considered candidates for the follow-on investigation.

In the second phase of the investigation, the uncertainty designs all received positive results but no optimal designs could be isolated based on the results. HSI, therefore, made recommendations based upon an extrapolation from basic principles and research findings concerning human visual and cognitive information processing. For the contact uncertainty icon they recommended the Lego design be adopted. One example of their reasoning was that the Lego design could be further reduced in size while maintaining clear discriminability of the coding levels and dimensions, unlike the Rectangle design. Regarding the source coverage uncertainty, HSI recommended the white broken/solid border. For example, they reason that a solid fill would be preferred over hashing because of the potential of the latter to reduce the discriminability of symbology and text superimposed upon it. HSI also recommended that the sensor information needs to be represented only in terms of area of coverage. Uncertainty in the source itself was not perceived as immediately useful. In other conclusions, HSI was unable to state whether or not the visualization would improve performance times for the tasks the subjects performed. They also state that further research is required to determine the optimal number of levels of uncertainty the symbology must represent as well as give the local managers the ability to alter or assign the extent of the uncertainty each level represents.

Non-intrusive alerts. Regarding the non-intrusive alerting designs, HSI concluded that the subject matter expert review and evaluation did not narrow down an optimal prototype but it did provide guidance for future research and development. It was identified that there is a need to scale the intrusiveness of alerts such that high priority alerts are more intrusive than low priority. It was concluded that further research is needed to better identify optimal design option(s) that would support the design requirements of those working with or monitoring the RMP. Through this work, HSI was able to identify the design requirements for a non-intrusive alerting system for the RMP as being:

- "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" p. 97 [17]

HSI recommended that future research efforts should focus on testing new anomaly alert system designs, through human-in-the-loop experimentation, in the context of the daily RMP work environment; as well as, broader research into intrusiveness and attention.

5.5 Assessment

All the research done under this WBE went well and produced usable results. The uncertainty visualization research can be used in the future to help design a way to visualize uncertainty in the RMP, once a systematic method to calculate that uncertainty can be determined. It is likely that once the calculation method and visualization method are combined, the local managers will need the ability to easily alter the mapping rules to suit their local context. The non-intrusive alerts work has highlighted an area of study that requires further research. While it did not isolate a particular alerting design that could be implemented, it did point towards what kind of design would be the next logical iteration. The next iteration of SME evaluation should probably include hands on testing by the SMEs to get a better sense of its usability.

5.6 Significance

The significance of the uncertainty visualization research is that it showed that by using simplistic visual cues, general uncertainty in the RMP data could be shown for multiple dimensions of that data. The results were very promising for incorporating such functionality into the RMP. The significance of the non-intrusive alert research was that it furthered a field with very little research and helped direct the research to come up with a usable design.

6 Recommendations & Conclusions

6.1 Concluding Remarks

The work elements of this ARP were successfully completed:

WBE 11he01: The work guided and confirmed the research planned for this ARP. The visions presented in the three reports helped illuminate how the FMP could potentially develop as well as cumulatively pointed to the important areas of change the current RMP will likely go through (or must go through).

WBE 11he02: The work provided a foundation for the work done in this ARP. The product review provided potential visualization aids that could be used in the visualization testbed. The literature review gave a foundation of work in, or applicable to, the field for all aspects of the ARP.

WBE 11he03: The MISR-Vis testbed helped further the research on semi-automated information visualization for C2 particularly in the MISR domain.

WBE 11he04: The uncertainty visualization research showed that by using simplistic visual cues, general uncertainty in the RMP data could be shown for multiple dimensions of that data. The results were very promising. The work on nonintrusive alerting showed the direction further research must go in.

The output of this ARP has been ample. Several valuable documents were developed early on in the ARP that have been of use to not only those working on the ARP but also those working outside the ARP on other MISR or MDA topics. The testbed that was developed and the research and experimentation results were all satisfactory and in line with expectations of the applied research project. The opinion of the author and the MDA Thrust Leader is that this was a successfully completed ARP.

6.2 General Recommendations

- Continue progressing the uncertainty visualization research to the point that it can be integrated and used by the RJOCs.
- More focussed research on how to visualize sensor coverage.
- Continue researching non-intrusive alerting systems so that an appropriate design for anomaly alerts can be discovered.
- Continue developing and improving the MISR Vis testbed.
- Initiate research into optimizing the user interface to the RMP. An optimized user interface using cutting edge user interface technology seemed to be a unanimous predicted aspect of the Future RMP (Table 1).
- Research visualizing of both position and movement of ships to establish behaviour, as recommended by the SOTA study on Information Visualization as applied to MISR (WBE 11he02).
- Research the detection of anomalous behaviour through the help of visualization as recommended by the SOTA study on Information Visualization as applied to MISR (WBE 11he02).

References

[1] NATO Standardization Agency (NSA) (2007), AAP-6(2007) NATO Glossary of Terms and Definitions (English and French), NATO.

[2] Standing Senate Committee on National Security and Defence (2003), Canada's Coastlines: The Longest Under-Defended Borders in the World, Report No. 17, Vol. 1, 183 pages.http://www.parl.gc.ca/37/2/parlbus/commbus/senate/com-e/defe-e/rep-e/rep17Vol1-e.htm

[3] Vernik, R., Itzstein, G.S.V. and Bouchard, A. (2007), Imago: An integrated prototyping, evaluation and transitioning environment for information visualisation, From the Proceedings of the 11th International Conference Information Visualization, IEEE Computer Society, Zurich, Switzerland.

[4] Bouchard, A. and Lapinski, A.-L.S. (2010), MISR Visualization Testbed: Requirements, Design, and Development, Defence R&D Canada - Atlantic, Dartmouth NS (CAN) *in review*.

[5] Aikins, G., Davies, H., Mason, L., Lechmann, M. and Petolas, B. (2006), Visions of a Future Maritime Picture: Study 3 of 3 (Corporate Author CarteNav) (Limited Distribution), (DRDC Atlantic CR 2006-040) Defence R&D Canada - Atlantic, Dartmouth NS (CAN); Cartenav Solutions Inc, Halifax NS (CAN).

[6] Crawford, J. (2006), Visions of a Future Maritime Picture: Study 2 of 3 (Corporate Author Ultra) (Limited Distribution), (DRDC Atlantic CR 2006-039) Defence R&D Canada - Atlantic, Dartmouth NS (CAN); Ultra Electronics Maritime Systems, Dartmouth NS (CAN).

[7] Davenport, M. and Franklin, S. (2006), Visions of a Future Maritime Picture: Study 1 of 3 (Corporate Author MDA) (Limited Distribution), (DRDC Atlantic CR 2006-038) Defence R&D Canada - Atlantic, Dartmouth NS (CAN); MacDonald Dettwiler and Associates Ltd, Richmond BC (CAN); MacDonald Dettwiler and Associates Ltd, Dartmouth NS (CAN).

[8] Davenport, M. and Risley, C. (2006), Information Visualization: The State of the Art for Maritime Domain Awareness, (DRDC Atlantic CR 2006-122; MDA-RX-RP-52-4186) Defence R&D Canada - Atlantic, Dartmouth NS (CAN); MDA (Halifax), Dartmouth NS (CAN).

[9] Davenport, M. (2008), MISR-Vis: Maritime Intelligence, Surveillance, and Reconnaissance Knowledge Base, (DRDC Valcartier CR 2007-543) Defence R&D Canada - Valcartier, Valcartier QUE (CAN); MacDonald Dettwiler and Associates Ltd, Richmond BC (CAN).

[10] Blanchette, R. (2008), MISR Visualization Experimental Environment: Visualization Tool Preview and Dataset Integration, (DRDC Valcartier CR 2008-129) Defence R&D Canada - Valcartier, Valcartier QUE (CAN); Thales Systems Canada (CAN).

[11] Dubé, P.-S., Hébert, C., Pellerin, É. and Tardif, M. (2008), MISR Visualization Experimental Environment: System Architecture Document (SAD) (DRDC Valcartier CR 2008-126) Defence R&D Canada - Valcartier, Valcartier QUE (CAN); Thales Systems Canada (CAN).

[12] Hébert, C. and Blanchette, R. (2008), MISR Visualization Experimental Environment: Search Engine Study, (DRDC Valcartier CR 2008-127) Defence R&D Canada - Valcartier, Valcartier QUE (CAN); Thales Systems Canada (CAN).

[13] Blanchette, R. and Hébert, C. (2008), MISR Visualization Experimental Environment: MISR STK Study, (DRDC Valcartier CR 2008-128) Defence R&D Canada - Valcartier, Valcartier QUE (CAN); Thales Systems Canada (CAN).

[14] Gouin, D., Vernik, R.J., Evdokiou, P., Houghton, P., Barnes, M., Monk, D. and Rosenblum, L. (2002), Information Visualization in C3I: Final Report of TTCP C3I AG-3, (DOC-C3I-AG3-1-2002) TTCP C3I AG-3.

[15] Matthews, M. and Rehak, L. (2009), Assessing the Potential Operational Effectiveness of Visualization Aids for Representing Uncertainty in the Recognized Maritime Picture, (DRDC Atlantic CR 2009-030) Defence R&D Canada - Atlantic, Dartmouth NS (CAN); Humansystems Inc., Guelph ON (CAN) *In Press*.

[16] Matthews, M., Rehak, L., Famewo, J., Taylor, T. and Robson, J. (2008), Evaluation of New Visualization Approaches for Representing Uncertainty in the Recognized Maritime Picture, (DRDC Atlantic CR 2008-177) Defence R&D Canada - Atlantic, Dartmouth NS (CAN); Humansystems Inc., Guelph ON (CAN).

[17] Matthews, M., Martin, L.B., Tario, C.D. and Brown, A.L. (2009), A non-intrusive alert system for maritime anomalies: Literature Review and the development and assessment of prototype design concepts, (DRDC Toronto CR 2009-042) Defence R&D Canada - Toronto, Toronto ON (CAN); Humansystems Inc., Guelph ON (CAN).

This page intentionally left blank.

Annex A Documents 11he Produced, Categorized by WBE

Documents are sorted by work breakdown element (WBE) and publication date.

A.1 WBE 11he01: Formulate Vision for Future Maritime Picture

WBE lead: David M.F. Chapman, DRDC Atlantic

TITLE: Visions of a Future Maritime Picture: Study 1 of 3 (Corporate Author MDA) (Limited Distribution)
AUTHOR(S): M. Davenport and S. Franklin
DRDC DOCUMENT NUMBER: DRDC Atlantic CR 2006-038
PUBLISHER & AUTHOR AFFILIATION: Defence R&D Canada - Atlantic, Dartmouth NS (CAN); MacDonald Dettwiler and Associates Ltd, Richmond BC (CAN); MacDonald Dettwiler and Associates Ltd, Dartmouth NS (CAN)
DATE: May 2006
PAGES: 134

TITLE: Visions of a Future Maritime Picture: Study 2 of 3 (Corporate Author Ultra) (Limited Distribution)
AUTHOR(S): J. Crawford
DRDC DOCUMENT NUMBER: DRDC Atlantic CR 2006-039
PUBLISHER & AUTHOR AFFILIATION: Defence R&D Canada - Atlantic, Dartmouth NS (CAN); Ultra Electronics Maritime Systems, Dartmouth NS (CAN)
DATE: May 2006
PAGES: 76

TITLE: Visions of a Future Maritime Picture: Study 3 of 3 (Corporate Author CarteNav) (Limited Distribution)
AUTHOR(S): G. Aikins, H. Davies, L. Mason, M. Lechmann and B. Petolas
DRDC DOCUMENT NUMBER: DRDC Atlantic CR 2006-040
PUBLISHER & AUTHOR AFFILIATION: Defence R&D Canada - Atlantic, Dartmouth NS (CAN); Cartenav Solutions Inc, Halifax NS (CAN)
DATE: May 2006
PAGES: 160

A.2 WBE 11he02: Conduct SOTA study on InfoVis applied to MISR

WBE lead: Anna-Liesa S. Lapinski, DRDC Atlantic

TITLE: Information Visualization: The State of the Art for Maritime Domain Awareness
AUTHOR(S): M. Davenport and C. Risley
DRDC DOCUMENT NUMBER: DRDC Atlantic CR 2006-122

PUBLISHER & AUTHOR AFFILIATION: Defence R&D Canada - Atlantic, Dartmouth NS (CAN); MDA (Halifax), Dartmouth NS (CAN)
DATE: August 2006
PAGES: 180

A.3 WBE 11he03: Development of Demonstration Environment for Visualization

WBE lead: Alain Bouchard, DRDC Valcartier

TITLE: MISR-Vis: Maritime Intelligence, Surveillance, and Reconnaissance Knowledge Base
AUTHOR(S): M. Davenport
DRDC DOCUMENT NUMBER: DRDC Valcartier CR 2007-543
PUBLISHER & AUTHOR AFFILIATION: Defence R&D Canada - Valcartier, Valcartier QUE (CAN); MacDonald Dettwiler and Associates Ltd, Richmond BC (CAN)
DATE: January 2008
PAGES: 71

TITLE: MISR Visualization Experimental Environment: System Architecture Document (SAD)
AUTHOR(S): P.-S. Dubé, C. Hébert, É. Pellerin and M. Tardif
DRDC DOCUMENT NUMBER: DRDC Valcartier CR 2008-126
PUBLISHER & AUTHOR AFFILIATION: Defence R&D Canada - Valcartier, Valcartier QUE (CAN); Thales Systems Canada (CAN)
DATE: July 2008
PAGES: 44

TITLE: MISR Visualization Experimental Environment: Search Engine Study
AUTHOR(S): C. Hébert and R. Blanchette
DRDC DOCUMENT NUMBER: DRDC Valcartier CR 2008-127
PUBLISHER & AUTHOR AFFILIATION: Defence R&D Canada - Valcartier, Valcartier QUE (CAN); Thales Systems Canada (CAN)
DATE: March 2008
PAGES: 21

TITLE: MISR Visualization Experimental Environment: MISR STK Study
AUTHOR(S): R. Blanchette and C. Hébert
DRDC DOCUMENT NUMBER: DRDC Valcartier CR 2008-128
PUBLISHER & AUTHOR AFFILIATION: Defence R&D Canada - Valcartier, Valcartier QUE (CAN); Thales Systems Canada (CAN)
DATE: March 2008
PAGES: 25

TITLE: MISR Visualization Experimental Environment: Visualization Tool Preview and Dataset Integration
AUTHOR(S): R. Blanchette
DRDC DOCUMENT NUMBER: DRDC Valcartier CR 2008-129
PUBLISHER & AUTHOR AFFILIATION: Defence R&D Canada - Valcartier, Valcartier QUE (CAN); Thales Systems Canada (CAN)
DATE: March 2008

PAGES: 15

TITLE: Evaluation of information visualization approaches within the MISR-Vis experimental environment (Limited Distribution)
AUTHOR(S): A. Bouchard and J. Lavoie
Personal Communication
DATE: December 2008
PAGES: 44

A.4 WBE 11he04: Visualization Design & Experiment

WBE lead: Anna-Liesa S. Lapinski, DRDC Atlantic

TITLE: Evaluation of New Visualization Approaches for Representing Uncertainty in the Recognized Maritime Picture
AUTHOR(S): M. Matthews, L. Rehak, J. Famewo, T. Taylor and J. Robson
DRDC DOCUMENT NUMBER: DRDC Atlantic CR 2008-177
PUBLISHER & AUTHOR AFFILIATION: Defence R&D Canada - Atlantic, Dartmouth NS (CAN); Humansystems Inc., Guelph ON (CAN)
DATE: October 2008
PAGES: 110

TITLE: A non-intrusive alert system for maritime anomalies: Literature Review and the development and assessment of prototype design concepts
AUTHOR(S): M. Matthews, L. B. Martin, C. D. Tario and A. L. Brown
DRDC DOCUMENT NUMBER: DRDC Toronto CR 2009-042
PUBLISHER & AUTHOR AFFILIATION: Defence R&D Canada - Toronto, Toronto ON (CAN); Humansystems Inc., Guelph ON (CAN).
DATE: March 2009
PAGES: 140

TITLE: Assessing the Potential Operational Effectiveness of Visualization Aids for Representing Uncertainty in the Recognized Maritime Picture
AUTHOR(S): M. Mathews and L. Rehak
DRDC DOCUMENT NUMBER: DRDC Atlantic CR 2009-030
PUBLISHER & AUTHOR AFFILIATION: Defence R&D Canada - Atlantic, Dartmouth NS (CAN); Humansystems Inc., Guelph ON (CAN)
DATE: In Press
PAGES: 96

A.5 Miscellaneous

TITLE: Evaluation of information visualization approaches for an enhanced recognized maritime picture
AUTHOR(S): A. Bouchard, A.-L. S. Lapinski, J. Lavoie and J. Roy
CONFERENCE: SPIE Defense+Security: Optics and Photonics in Global Homeland Security IV
PUBLISHER: SPIE
DATE: March 17-20, 2008

PAGES: 694510-694521

List of symbols/abbreviations/acronyms/initialisms

11he	Information visualization and management for enhanced domain awareness in maritime security ARP project
AIS	Automatic Identification System
AOR	Area of Responsibility
API	Application Programming Interface
ARP	Applied Research Project
C2	Command and Control
C2NetVis	Command and Control Network Visualization
C3I-Vis	visualization for Command, Control, Communications, and Intelligence
CHDB	Contact History Database
CoALA	Collation And Link Analysis
COP	Common Operational Picture
COTS	Commercial off-the-shelf
DA	Descriptive Aspects
DC	Domain Context
DIR	Defence Industrial Research (program)
DRDC	Defence Research and Development Canada
DSTO	Defence Science and Technology Organization
FMP	Future Maritime Picture
FOSS	Free and Open Source Software
GCCS	Global Command and Control System
GEOLAP	Geospatial On-Line Analytical Processing
GIS	geographic information system
GNSS	Global Navigation Satellite System
GOTS	Government off-the-shelf
GPW	Global Position Warehouse
G-Vis	general visualization
HFSWR	High Frequency Surface Wave Radar
HITS	Historical Temporal Shipping (database)
HSI	Humansystems Incorporated
ISR	Intelligence Surveillance and Reconnaissance

JC3IEDM	Joint Consultation, Command and Control Information Exchange Data Model
JSP	Java Server Pages
JTFP	Joint Task Force (Pacific)
MDA	MacDonald Dettwiler and Associates Ltd.
MDA	Maritime Domain Awareness
MetOc	meteorology and oceanography
MIKM	Maritime Information and Knowledge Management
Mil-Vis	military visualization
MISR	Maritime Intelligence Surveillance and Reconnaissance
MISR-Vis	Maritime Intelligence Surveillance and Reconnaissance Visualization
MISR-Vis KB	MISR-Vis Knowledge Base
MOE	Measures of Effectiveness
MOP	Measures of Performance
MSOC	Maritime Security Operation Centre
PNNL	Pacific Northwest National Laboratory
R&D	Research and Development
RCP	Rich Client Platform
RJOC	Regional Joint Operations Centre
RMP	Recognized Maritime Picture
RM-Vis	Reference Model for Visualization
SAD	System Architecture Document
SME	Subject Matter Expert
SNA	social network analysis
SOA	service-oriented architecture
SOM	self-organizing map
STK	Satellite Toolkit
SVG	Scalable Vector Graphics
TD	Technology Demonstration
TDP	Technology Demonstration Project
TTCP	The Technical Cooperation Program
VA	Visualization Approach
VGS	Visualization and Geospatial Systems

VOI	Vessel of Interest
WBE	Work breakdown element

This page intentionally left blank.

Distribution list

Document No.: DRDC Atlantic TM 2009-265

Copies	LIST PART 1: Internal Distribution by Centre
3	DRDC ATLANTIC LIBRARY (1 hard copy, 2 CDs)
1	M. MCINTYRE
1	T. HAMMOND
1	A.W. ISENOR
1	S. WEBB
1	A. MACINNIS
1	F. DESHARNAIS
1	J. CREBOLDER
1	B. CHALMERS
1	D. COADY
1	M. HAZEN
1	L. LAPINSKI
1	G. FRANCK
1	D. PETERS
1	S. PECKNOLD
1	J. OSLER
18	TOTAL LIST PART 1

	LIST PART 2: External Distribution by DRDKIM
1	Library and Archives Canada, Attn: Military Archivist, Government Records Branch
1	DRDKIM
3	DRDC Valcartier 2459 Pie-XI Blvd North, Québec, QC G3J 1X5 Attn: Valerie Lavigne Dennis Gouin Stephane Paradis
1	DRDC Toronto 1133 Sheppard Avenue West, P.O. Box 2000, Toronto, ON M3M 3B9 Attn: Sharon McFadden
1	DRDC Ottawa 3701 Carling Avenue, Ottawa, ON K1A 0Z4 Attn: Chris Helleur
1	Andrew Wind, DRDC CORA MARLANT HQ 3rd Floor, Room 311 PO Box 99000 Stn Forces, Halifax, NS B3K 5X5

1	Steven Horn, DRDC CORA JTFP J02 OR-1, PO Box 17000 Station Forces, Victoria, BC B9A 7N2
3	Human*systems*® Incorporated 111 Farquhar St., 2nd floor, Guelph, ON N1H 3N4 Attn: Michael Matthews Lisa Rehak Ron Boothby
1	Commanding Officer TRINITY JOSIC, PO Box 99000 Stn Forces, Halifax, NS B3K 5X5
1	Capt(N) K. Greenwood J3, Canada COM HQ, NDHQ - 101 Col. By Dr., Ottawa, ON K1A 0K2
1	LCdr A. Gyorkos OIC Maritime Operations Centre, JTFP HQ, MARPAC/JTFP, PO Box 17000 Station Forces, Victoria, BC B9A 7N2
1	Cdr James Day Co-Chair 1h Thrust LSTL, 555 blvd de la Carriere, 5 EG03, NDHQ – 101 Colonel By Dr., Ottawa, ON K1A 0K2
1	DRDC CORA NDHQ - 101 Colonel By Drive, Ottawa, ON K1A 0K2 Attn: Roy Mitchell
1	Paul Therrien CFMWC, S32, RM 351 PO Box 99000, Stn Forces, Halifax, NS B3K 5X5
18	TOTAL LIST PART 2
36	**TOTAL COPIES REQUIRED**

DOCUMENT CONTROL DATA

(Security classification of the title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (The name and address of the organization preparing the document, Organizations for whom the document was prepared, e.g. Centre sponsoring a contractor's document, or tasking agency, are entered in section 8.) Publishing: DRDC Atlantic Performing: DRDC Atlantic DRDC Valcartier DRDC Toronto Monitoring: Contracting:	2. SECURITY CLASSIFICATION (Overall security classification of the document including special warning terms if applicable.) UNCLASSIFIED

3. TITLE (The complete document title as indicated on the title page. Its classification is indicated by the appropriate abbreviation (S, C, R, or U) in parenthesis at the end of the title)

11he Final Report: Information Visualization and Management for Enhanced Domain Awareness in Maritime Security (U)

4. AUTHORS (First name, middle initial and last name. If military, show rank, e.g. Maj. John E. Doe.)

Anna−Liesa S. Lapinski

5. DATE OF PUBLICATION (Month and year of publication of document.) June 2010	6a NO. OF PAGES (Total containing information, including Annexes, Appendices, etc.) 56	6b. NO. OF REFS (Total cited in document.) 17

7. DESCRIPTIVE NOTES (The category of the document, e.g. technical document, technical note or memorandum. If appropriate, enter the type of document, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

Technical Memorandum

8. SPONSORING ACTIVITY (The names of the department project office or laboratory sponsoring the research and development − include address.)

Sponsoring:

Tasking:

9a. PROJECT OR GRANT NO. (If appropriate, the applicable research and development project or grant under which the document was written. Please specify whether project or grant.) 11he	9b. CONTRACT NO. (If appropriate, the applicable number under which the document was written.)
10a. ORIGINATOR'S DOCUMENT NUMBER (The official document number by which the document is identified by the originating activity. This number must be unique to this document) DRDC Atlantic TM 2009−265	10b. OTHER DOCUMENT NO(s). (Any other numbers under which may be assigned this document either by the originator or by the sponsor.)

11. DOCUMENT AVAILABILITY (Any limitations on the dissemination of the document, other than those imposed by security classification.)

Unlimited distribution

12. DOCUMENT ANNOUNCEMENT (Any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availability (11), However, when further distribution (beyond the audience specified in (11) is possible, a wider announcement audience may be selected.))

Unlimited announcement

UNCLASSIFIED

DOCUMENT CONTROL DATA
(Security classification of the title, body of abstract and indexing annotation must be entered when the overall document is classified)

13. ABSTRACT (A brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), (R), or (U). It is not necessary to include here abstracts in both official languages unless the text is bilingual.)

(U) On April 1, 2005, Defence Research and Development Canada (DRDC) started a new applied research project (ARP) in the Maritime Domain Awareness (MDA) thrust: Information visualization and management for enhanced domain awareness in maritime security (11he). This is the final report on the project. 11he was a 4−year 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 project was focused on visualization design and experimentation as well as creating a visualization testbed. This work included doing a study on the “Future Recognized Maritime Picture”, a state−of−the−art−study on Information Visualization from a Maritime Intelligence, Surveillance and Reconnaissance (MISR) point of view, work on developing visualization to represent the uncertainty inherent in the information populating the Recognized Maritime Picture (RMP), work on developing non−intrusive alerts to be used in the RMP when anomalies are detected, and a MISR−Vis testbed to help in the generation of effective MISR related visualizations. This report gives some background on the 11he project, documents what was achieved, and points the reader to the reports generated by the work.

(U) Dans le cadre de l’élan de la connaissance de la situation dans le secteur maritime, Recherche et développement pour la défense Canada (RDDC) a mis en œuvre, le 1er avril 2005, un nouveau projet de recherches appliquées (PRA) : visualisation et gestion de l’information pour une meilleure connaissance du domaine en sécurité maritime (11he). Le présent rapport constitue le dernier rapport sur ce projet R & D de 4 ans, dont le but était de faire progresser la « situation maritime » au moyen d’une qualité améliorée de l’information et de nouvelles façons adaptatives de visualiser cette information. Le projet portait sur la conception visuelle et l’expérimentation visuelle, ainsi que sur la création d’un banc d’essai visuel. Plusieurs recherches ont été menées au cours de ce projet, notamment une étude sur le « tableau de la situation maritime futur », et une étude de pointe de la visualisation de l’information selon un point de vue MISR (renseignement maritime, reconnaissance maritime, surveillance maritime). Des travaux ont également était faits sur l’élaboration d’une représentation visuelle de l’incertitude inhérente à l’information contenue dans le tableau de la situation maritime (TSM) et sur la création d’alarmes non intrusives qui se déclenche lorsque des anomalies sont détectées dans le TSM. Enfin, un banc d’essai visuel MISR a été créé pour aider à la production de visualisations relatives au MISR. Le projet 11he et les résultats obtenus sont précisés dans le présent rapport, qui indique au lecteur les rapports découlant de ces recherches.

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.)

(U) Visualization; Visualisation; Information Visualization; Information Visualisation; testbed; MISR; Maritime Intelligence Surveillance and Reconnaissance; ISR; Intelligence Surveillance and Reconnaissance; MISR−Vis; Maritime Intelligence Surveillance and Reconnaissance Visualization; alert; uncertainty; anomaly; MDA; Maritime Domain Awareness; final report; 11he

UNCLASSIFIED

This page intentionally left blank.

Defence R&D Canada

Canada's leader in defence
and National Security
Science and Technology

R & D pour la défense Canada

Chef de file au Canada en matière
de science et de technologie pour
la défense et la sécurité nationale

DEFENCE DÉFENSE

www.drdc-rddc.gc.ca