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Final Report 11HL: Technologies for Trusted Maritime Situational Awareness

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Defence R&D Canada – Atlantic

Technical Report

DRDC Atlantic TR 2011-093

October 2011

Canada

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Technical Report
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Abstract

The Applied Research Project (ARP) titled *Technologies for Trusted Maritime Situational Awareness* and denoted 11HL, was initiated under the 1H thrust *Maritime Domain Awareness* in April 2008. The following is the final report for this three year project. The project focused on technologies that provide data and information in support of Maritime Situational Awareness (MSA). The technologies were considered relative to their contribution to the creation of trust. Some of the activities included the utilization of a vessel's Automatic Identification System (AIS) messages for camera cuing and vessel imagery collection; investigations involving AIS utilization for visualizing surveillance regions, consistency checking as it relates to trust enhancement, and defining probabilistic vessel tracks between AIS messages; investigations into architectures relevant to the trusted distribution of MSA data; and investigations into the trust implications of evolving data sources and system architectures. This report provides an overview of the 11HL project using previously reported results, and listings of reports and papers that resulted from 11HL.

Résumé

Le projet de recherche appliquée (PRA) intitulé *Technologies assurant la fiabilité de la connaissance de la situation maritime* et désigné par les caractères 11HL a été lancé dans le cadre de la *Connaissance du domaine maritime*, 1H, en avril 2008. Le document suivant est le rapport final pour ce projet de trois ans. Le projet portait surtout sur les technologies qui fournissent des données et des renseignements en appui à la connaissance de la situation maritime. Ces technologies ont été évaluées en fonction de leur contribution à la création de la fiabilité. Certaines des activités comprenaient l'utilisation des messages du système d'identification automatique (SIA) d'un navire pour le repérage des caméras et la collecte d'images du navire, des enquêtes nécessitant l'utilisation du SIA afin de visualiser les régions de surveillance, des vérifications de l'uniformité puisqu'elle est en lien direct avec l'amélioration de la fiabilité et la définition des trajectoires probabilistes des navires entre les messages du SIA, des enquêtes portant sur des architectures pertinentes à la distribution fiable des données de connaissance de la situation maritime, ainsi que des enquêtes portant sur les incidences de la fiabilité des sources de données évolutives et des architectures du système. Le présent rapport fournit un aperçu du projet 11HL à l'aide des résultats obtenus précédemment et des listes de rapports et de documents produits dans le cadre du projet 11HL.

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Executive summary

Final Report 11HL: Technologies for Trusted Maritime Situational Awareness

A.W. Isenor; A. MacInnis; A-L. S. Lapinski; T.R. Hammond; M. McIntyre; S.P. Webb; D.J. Peters; M.A. Stoddard; DRDC Atlantic TR 2011-093; Defence R&D Canada – Atlantic; October 2011.

Background: The Applied Research Project (ARP) 11HL titled *Technologies for Trusted Maritime Situational Awareness* was conducted by the Maritime Information and Combat Systems section at DRDC Atlantic. The project was of 3 year duration with a contracting budget of $1,015k and a full time equivalent (FTE) effort of 10.5 years. The 11HL project built upon the efforts of ARP 11HF, titled *Self-Reporting Systems in Maritime ISR*.

The 11HL project focused on technologies that provide data and information in support of Maritime Situational Awareness (MSA), and in particular how the technologies may contribute to the creation of trust for defence and security decision makers.

Results: The results of this work included an extensive examination of land and space-based Automatic Identification System (AIS) data and novel uses of these data. In some respects, the culmination of this was the deployment of the Automated Ship Image Acquisition (ASIA) system to the Vancouver 2010 Olympics and Paralympics in support of the security and defence decision makers. As well, 11HL resulted in the first Canadian contribution to the Maritime Safety & Security Information System (MSSIS), an understanding of the components of trust and how trust might relate to system components, and an understanding of how the global community is developing infrastructures for the sharing and utilization of data relevant to the formation of situational awareness (SA).

Significance: The CF needs to recognize how the development of SA has radically changed over the past five years. Historically, the development of SA was the niche of those with the budget and the sensors to provide the necessary surveillance. Now, commercially or freely available data relevant to SA are becoming increasingly important and widely available. The introduction of information from entity (i.e., vessel or aircraft) self-reports, combined with inexpensive receiving equipment has changed the SA information paradigm. This project helped elucidate this change.

Future plans: The data sources, algorithms, and techniques investigated under 11HL will be combined with other data sources and applied to the Arctic under 11HO, an ARP on *Situational Information for Enabling Development of Northern Awareness (SEDNA).* SEDNA also has elements dealing with trust and partnering with other government departments.

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Final Report 11HL: Technologies for Trusted Maritime Situational Awareness

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Contexte : Le projet de recherche appliquée (PRA) 11HL intitulé *Technologies assurant la fiabilité de la connaissance de la situation maritime* a été réalisé par la section Information maritime et systèmes de combat à RDDC Atlantique. Le projet, d'une durée de 3 ans, présentait un budget de 1 015 000 $ et un équivalent temps plein de 10,5 ans. Le projet 11HL a été mis sur pied grâce aux résultats du PRA 11HF, intitulé *Systèmes d'auto-signalisation existants dans le domaine du RSR maritime*.

Le projet 11HL portait surtout sur les technologies qui fournissent des données et des renseignements en appui à la connaissance de la situation maritime et en particulier sur la manière dont ces technologies peuvent contribuer à la création de la fiabilité pour les responsables de la prise de décisions relativement à la défense et à la sécurité.

Résultats : Les résultats du présent projet comprenaient un examen exhaustif des données provenant d'un système d'identification automatique spacial ou terrestre, ainsi que des nouvelles utilisations de ces données. À certains égards, le point culminant de ce projet a été le déploiement du système d'acquisition automatisée d'images de navires (AAIN) lors des Jeux olympiques et paralympiques de Vancouver 2010 en appui au responsable de la prise de décisions relativement à la sécurité et à la défense. De plus, le projet 11HL a occasionné la première contribution canadienne au Système d'information sur la sécurité et la sûreté maritimes (MSSIS), une compréhension des composants de la fiabilité et de la manière dont la fiabilité est associée aux composants du système, ainsi qu'une compréhension de la manière dont la communauté globale met au point des infrastructures en vue du partage et de l'utilisation des données pertinentes à la formation de la connaissance de la situation.

Importance : Les Forces canadiennes doivent reconnaître que la connaissance de la situation a changé de façon radicale au cours des cinq dernières années. Par le passé, la mise au point de la connaissance de la situation était le créneau de ceux qui possèdent le budget et les capteurs nécessaires pour fournir la surveillance requise. Désormais, les données disponibles sur le marché ou gratuitement qui sont pertinentes pour la connaissance de la situation deviennent de plus en plus importantes et sont de plus en plus accessibles. L'introduction de renseignements provenant d'autoévaluations d'entité (c.-à-d. un navire ou un aéronef) combinés à de l'équipement de réception peu coûteux a changé le paradigme des renseignements de connaissance de la situation. Le présent projet a aidé à élucider ce changement.

Perspectives : Les sources de données, les algorithmes et les techniques évalués dans le cadre du projet 11HL seront combinés à d'autres sources de données et seront appliqués à l'Arctique dans le cadre du projet 11HO, qui est un PRA qui porte sur les *Renseignements sur la situation en vue de développer la connaissance de la situation dans le Nord*. Ce projet comprend également des

éléments relatifs à la fiabilité et à l'association avec d'autres ministères et organismes gouvernementaux.

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Acknowledgements

The success of the 11HL project was enhanced by significant partnerships with non-DND partners. External funding was used to enhance the research into areas relevant not only to DND, but to the Canadian government as a whole. We would therefore like to acknowledge the funding from the DRDC Centre for Security Science, Public Security Technical Program and from Transport Canada. This leveraged funding allowed the expansion of project scope into research topics involving the use of technologies for close coastal and northern awareness. We also acknowledge the support from DRDC Ottawa, who made contributions to a field trial and utilization of space-based radar systems.

1 Introduction

In recent years, the information that supports Maritime Situational Awareness (MSA) has undergone considerable evolution. New technologies, specifically those related to vessel self-reporting, provide much potential for vessel monitoring. However, the large data volumes and a lack of understanding regarding the best utilization methods, often leads to the data being used to simply place more symbols on a geospatial display.

The increased usage of data from self-reporting systems has in turn identified the issue of how much faith or trust can be placed on the information from these systems. The trust placed on the information can in turn influence the products created from the information. Understanding the implications of these new technologies on the development of trusted MSA, is a critical component to proper information utilization.

As a means of progressing towards solutions to the trusted awareness issue, an Applied Research Project (ARP) was initiated. The aim of the project was an improved understanding of how new and evolving technologies influence trust within the MSA domain. The project had a major focus on trust, the result being a considerable initial effort on understanding trust, and how trust relates to systems and data that support MSA.

1.1 The Project

The 11HL ARP was funded under the 1H thrust *Maritime Domain Awareness*. The ARP began in April 2008 and was initially scheduled to last four years. However, funding reallocations combined with evolving Thrust priorities resulted in the early termination of the ARP in March 2011.

The work conducted under 11HL was the responsibility of the Maritime Information and Knowledge Management (MIKM) group at DRDC Atlantic. As the managing group, MIKM was responsible for the organization, execution, and reporting associated with the project. However, the project delivery was in collaboration with many other groups both inside and outside the DRDC agency.

Internal to the Agency, collaborations spawned from 11HL included work with the DRDC Centre for Security Science (CSS) and DRDC Ottawa. Links to CSS were formed in those 11HL research areas related to security. In particular, investigations involving sensing and self-reporting systems applicable to remote Canadian areas and to 11HL activities associated with close coastal and port awareness. 11HL successfully leveraged the Public Security Technical Program (PSTP) (managed by CSS) to complement several research activities. DRDC Ottawa made contributions to field trials involving radar data collection, space-based radar and more generally the utilization of space-based platforms. In return, 11HL strengthened DRDC Ottawa led projects by providing expertise on the utilization of data from self-reporting systems for future DND satellite missions.

The project also had strong ties to other government departments. Transport Canada's (TC) Marine Security Policy Section funded research activities in the areas related to distribution of MSA information, which built on the 11HL research area of trust management for defence, security and safety applications in maritime domains. As well, TC contributed to investigations to understand and enhance MSA capabilities in Canada's northern regions.

The collaborative efforts, and resulting leveraging that took place as part of 11HL, must be emphasized. 11HL considered technologies relevant to both defence and security. Unlike the defence domain, the security domain consists of many departmental mandates. The personal networking required to build the collaborative relationships in such a domain is extremely time consuming. Although these collaborations represent challenges to the successful execution of security-related research activities, having successfully developed such collaborations represents a considerable accomplishment in itself.

Finally, international collaborations should be recognized. The trusted MSA theme of 11HL was directly applicable to The Technical Cooperation Panel (TTCP) Action Group (AG) 8, named *Maritime Domain Awareness (MDA)*. This group was tasked with identifying critical science and technology gaps to producing trusted surveillance and reconnaissance information. The AG 8 Canadian National Lead was Group Leader MIKM. As well, 11HL supported Canadian involvement in the NATO Information Systems Technology (IST) 075 group, named *Semantic Interoperability*. This group researched methods for enhancing semantic clarity and thereby providing unambiguous information exchange between systems. The 11HL Project Manager was a member of IST-075.

1.1.1 Work Plan

The Work Breakdown elements (WBE) for 11HL are shown in Table 1.

Table 1: The Work Breakdown elements of 11HL.

WBE No.	Description
WBE 11HL01	Concepts and technologies to support trust in open-source information
WBE 11HL02	Static[1] anomaly detection from self-reported information
WBE 11HL03	Architectures, infrastructures and models for trusted sharing of maritime situational information
WBE 11HL04	Fundamental investigations of trust management for defence, security and safety applications in maritime domains
WBE 11HL05	Definition of a trusted MSA demonstration project
WBE 11HL06	Automatic Identification System (AIS) Snapshots
WBE 11HL010	MacDonald, Dettwiler and Associates Ltd.; Defence Industrial Research (DIR) - Coastal Surveillance
WBE 11HL11	ICAN DIR

The sections that follow describe WBEs 01-04. These WBEs were the focal point of the 11HL project and contain the majority of the deliverables.

Regarding the other WBEs:

- WBE05 was an effort to develop a proposal for submission to the Technology Demonstration (TD) program. The proposal was completed and entered into the TD competitive process, but was not funded by the TD program.
- WBE06 was an element established for the purpose of tracking purchases of space-based Automatic Identification System (S-AIS) data.
- WBE10 was an additional WBE placed in 11HL out of convenience for management tracking. This activity was not managed as part of 11HL.
- WBE11 was a proposal submission to the Defence Industrial Research (DIR) Program. This activity began only months before 11HL ended and is now being tracked under ARP 11HO.

No further reference will be made to WBEs 05-11.

[1] Static refers to data or information that typically varies on a long time scale. e.g., vessel name

1.1.2 Milestones

The milestones of the project are shown in Table 2.

Table 2: The Milestones of 11HL.

Date	Milestone Description
November 2008	Demonstrate trusted sharing of near-real-time data with the Regional Joint Operations Centre Atlantic (RJOCA)
December 2008	Proposal for a concept and technology demonstration project in trusted maritime situational awareness
February 2009	Demonstrate trusted sharing of near-real-time data with Maritime Safety and Security Information System
February 2009	Demonstrate trusted sharing of near-real-time data with NATO Baseline for Rapid Iterative Transformational Experimentation (BRITE)
June 2009	Demonstrate trusted sharing of near-real-time data with US MDA Data Sharing Community-of-Interest
September 2009	Participate in MSA workshop, organized by NATO Systems Concepts and Integration group 211
January 2011	Government/industry/university workshop on MSA in support of security, safety and efficiency in the North
March 2011	Demonstrate application of shared data for visualizing AIS receptions
March 2011	Identify information available from applicable sensors for northern application
March 2011	Demonstration of integration of self-report information with sensor data
March 2011	Report on architectures for trusted sharing of trusted MSA information
March 2011	Report on integration options for sensor and self-reports

1.1.3 Outputs

Predominate outputs from the project can be summarized as including:

- reports in the form of DRDC Technical Memoranda,
- conference and journal papers,

- development of unique data collection technologies,
- contributions to and an understanding of, international MSA data distribution systems, and
- presentations on any of the above.

All project output is noted in the Work Breakdown element sections that follow.

1.2 Outline

This report provides a summary of 11HL activities that were reported on separately. The topic of trust is broad, and its connection to maritime situational awareness offers the opportunity for many diverse research topics. Only a subset of potential topics was considered during 11HL.

Section 2 describes WBE01 and includes work that examined the components of trust as determined from a literature review. The components of an automated system were also considered, along with the relationship between the trust and system components. WBE01 also explored the utilization of AIS messages in the further development of the Automated Ship Image Acquisition (ASIA) system. Applications of the ASIA system at the 2010 Vancouver Olympics and in an international field trial are also described.

WBE02 (Section 3) continues the utilization of AIS message content. Messages received through a global aggregation and distribution system are used to visualize AIS receptions over large areas, such as Halifax Harbour. The internal consistency of information in the AIS messages is also examined. Consistency is then extended to include multiple open sources, providing a means to combine and visualize the consistency of the information from these sources. Finally, an interpolation approach using probabilities is used to determine potential vessel tracks between AIS reported positions.

WBE03 (Section 4) describes activities related to the sharing of maritime situational information. An AIS repository built at DRDC Atlantic is first described. Next, global data aggregation and distribution systems like the Maritime Safety and Security Information System (MSSIS) and the Data Sharing Community of Interest are described. On the air side, a system similar to AIS but for aircraft, is also highlighted.

WBE04 (Section 5) concludes the report with a review of an activity related to information management systems for the CF that could promote the idea of operational clarity. Space-based AIS (S-AIS) is also described, and it is noted that 11HL was the leader in recognizing the importance of and purchasing of S-AIS. Activities on understanding the differences between centralized and decentralized data systems is then described, followed by activities related to MSA in the Canadian north.

Section 6 provides outcomes and concluding remarks. In this section the results of 11HL are linked to the broad Science & Technology outcomes of DRDC.

2 WBE 11HL01: Concepts and technologies to support trust in open-source information

Work under this breakdown element was focused on forming a cursory understanding of trust, and the trust implications when incorporating new technologies into existing capabilities. This WBE also extended the application of the ASIA system, deploying it for the 2010 Vancouver Olympics and an international field trial.

2.1 11HL01 activities

2.1.1 Trust Components

The concept of trust was a major influence on 11HL. As part of the trust investigation, this work activity examined the concept of trust, and how trust might relate to the components of a system. The investigation, conducted by Isenor *et al.* [1], included an explanation of trust components as determined from a literature review. The review considered trust from a human perspective, and also from the human-system perspective. The latter field drew on work conducted in the field of human-system automation, and in particular in the field of air traffic control.

One aspect of the literature review focused on the constituents or components of trust. This review identified 12 components of trust, those being:

- Predictability
- Dependability
- Faith
- Reliability
- Robustness
- Familiarity
- Understandability
- Explication of intention
- Usefulness
- Competence
- Self-confidence
- Reputation

Next, the components of a computer data system were described, in an extremely coarse manner, as being source, data, delivery, and processing. These components essentially identify the acquisition of data, the data, a mechanism for transferring the data, and the processing of those data. The trust components were then linked to the system components, identifying if a particular system component was capable of demonstrating the particular trust component.

As an example of these concepts, the work also conducted a detailed examination of timing issues in AIS messages. Particular emphasis was placed on the time stamping present in such messages, and how errors in the time stamping could influence trust in the information content.

2.1.2 Automated Ship Image Acquisition System

Vessel self-reporting systems (SRS), such as AIS, played an important role in 11HL. Such systems typically provide a vessel's positional information as part of the SRS message content. Other vessel attribute information is also included in the message (e.g., vessel name, vessel type, etc.). To investigate the reliability of this attribute information, 11HL continued the refinement of the Automated Ship Image Acquisition (ASIA) system (note; ASIA was started under 11HF, see [2]).

ASIA represents a combination of AIS technology with digital photography. The ASIA system collects vessel photographs with minimal human intervention, utilizing vessel self-reports from AIS to direct a high-resolution digital camera towards a vessel target, compose the shot automatically, and then store the resulting photograph on a personal computer (PC). In addition to position, AIS provides a rich assortment of data fields that include the name, heading, dimensions, destination, hazardous cargo type, call sign, Maritime Mobile Service Identity (MMSI) number and International Maritime Organization (IMO) number of the vessel. These fields can then be linked to the photograph of the vessel taken by ASIA.

ASIA was designed to provide its users with high-resolution images of vessels-of-interest for a variety of security and safety-related applications. It attempts to photograph every vessel fitted with AIS that comes in range from a wide variety of viewing angles.

ASIA was originally fixed to a DRDC lab, collecting photographs from the Narrows in Halifax Harbour. However, during the 2010 Olympics held in Vancouver, ASIA was deployed to a remote site on Vancouver Island. This involved considerable modifications to both the hardware and software, including incorporating a tripod and remote operator control over the photographs. The Vancouver Island deployment is shown in Figure 1.

Work conducted under contract by A.U.G. Signals Ltd. [3] was also directed towards the extraction of information from the ASIA photographs, to assess the reliability of vessel attribute information in the AIS message. This work attempted to detect and classify vessels in the ASIA photographs.

Figure 1: ASIA deployment during the 2010 Vancouver Olympics. The AIS antenna can be seen on the wooden pole to the right. The ASIA camera is contained within the Pelco enclosure (i.e., white case) on top of the tripod.

An Image Processing Library with several image processing tools was implemented and applied to ASIA images in order to extract specific information. The delivered software attempted to detect and recognize vessel type, extract vessel information (e.g., size), recognize text printed on the vessel, etc.

Although initial results appeared promising (Figure 2), more detailed inspection showed biases in the validation component. Also, alterations to the camera setup that resulted in changes to the image size had a significant impact on results (e.g., inability to detect the vessel), possibly indicating a lack of robustness in the detection algorithm.

2.1.3 Canada-The Netherlands- Sweden Project Arrangement

11HL provided DRDC Atlantic with an opportunity to develop extensive knowledge on SRS and the utilization of the information provided by such technologies. In turn, this expertise provided the foundation for developing international partnerships with others interested in these technologies. A Project Arrangement (PA) grew out of this international interest, involving Canada, The Netherlands and Sweden.

The development of the Canada-The Netherlands-Sweden PA provided the three nations with a collaborative opportunity that became known as SICCPA (for Sensor Integration for Close-Coastal and Port Awareness). The focus of the PA was on the enhanced understanding of the impact of technologies like AIS and Long-Range Identification and Tracking (LRIT) on close-coastal and port awareness. Participants were interested in ways by which these new technologies might be integrated with traditional sensors. A particular focus of this collaboration was on the improvement that comes from the integration and data sharing between sensor systems.

While the objective of the PA was to improve sensor integration, a large portion of the focus was driven by AIS and LRIT. Also, while the port awareness element of the PA title might suggest a tactical focus, the emphasis was actually more strategic. Thus, little consideration was given to interdiction or first response; instead, the aim was improvement of the recognized maritime picture (RMP) near ports and along national coasts, especially at choke points. As a result, the PA considered topics such as the use of above-water sensors to improve the underwater picture; the use of underwater sensors to improve the above-water picture; verification of self-reported data using data from more traditional sensors; and the use of self-reported data to enhance the output of more traditional sensors.

Figure 2: Top panel shows CFAV QUEST in the Narrows of Halifax Harbour, during the winter. Lower panel shows the estimated hull outline.

2.1.4 Sensor Integration for Close Coastal and Port Awareness trial

As a means of pushing forward the PA objectives, Canada and Sweden agreed to contribute above-water and underwater sensor systems to a joint trial to be held in the approaches to Halifax Harbour. The idea was to use data collected during the trial to showcase some new capabilities afforded by interaction between individual systems. In order for this to be possible, the contributed sensor systems had to be deployed in such a way that a region of overlapping sensor coverage would exist for every pair of contributed systems.

The trial was conducted in 29 September – 5 October 2010 (Figure 3) [4]. The trial goal was to test the capability of a suite of underwater and above-water sensors to detect, classify and identify vessels (especially small ones) at various ranges and aspect angles. This required the deployment of a suite of underwater and above-water sensors (radar, acoustic, electro-magnetic and optical) in the approaches to Halifax Harbour. Participants collected data relevant to both the tracking and identification of vessels in this area, as well as data for a number of task-able reference targets.

The collected data are being investigated in two focus areas: the first seeks ways in which above-water and underwater pictures might interact to enhance each other; the second seeks ways in which self-reporting systems, like AIS, and sensors that do not require the cooperation of the vessels might interact to enhance each other. These investigations are being conducted with support from the PSTP.

2.2 11HL01 associated reports

Reports associated with this breakdown element include:

– trust components and relationship to system components, and AIS timing issues by Isenor *et al.* [1],

– a summary of the SICCPA trail, by Hammond and Leadbetter [4],

– descriptions of ASIA by Hammond [5] and Hammond *et al.* [6], and

– contract reports detailing ASIA development, installation, and processing [3], [7], [8], [9], [10].

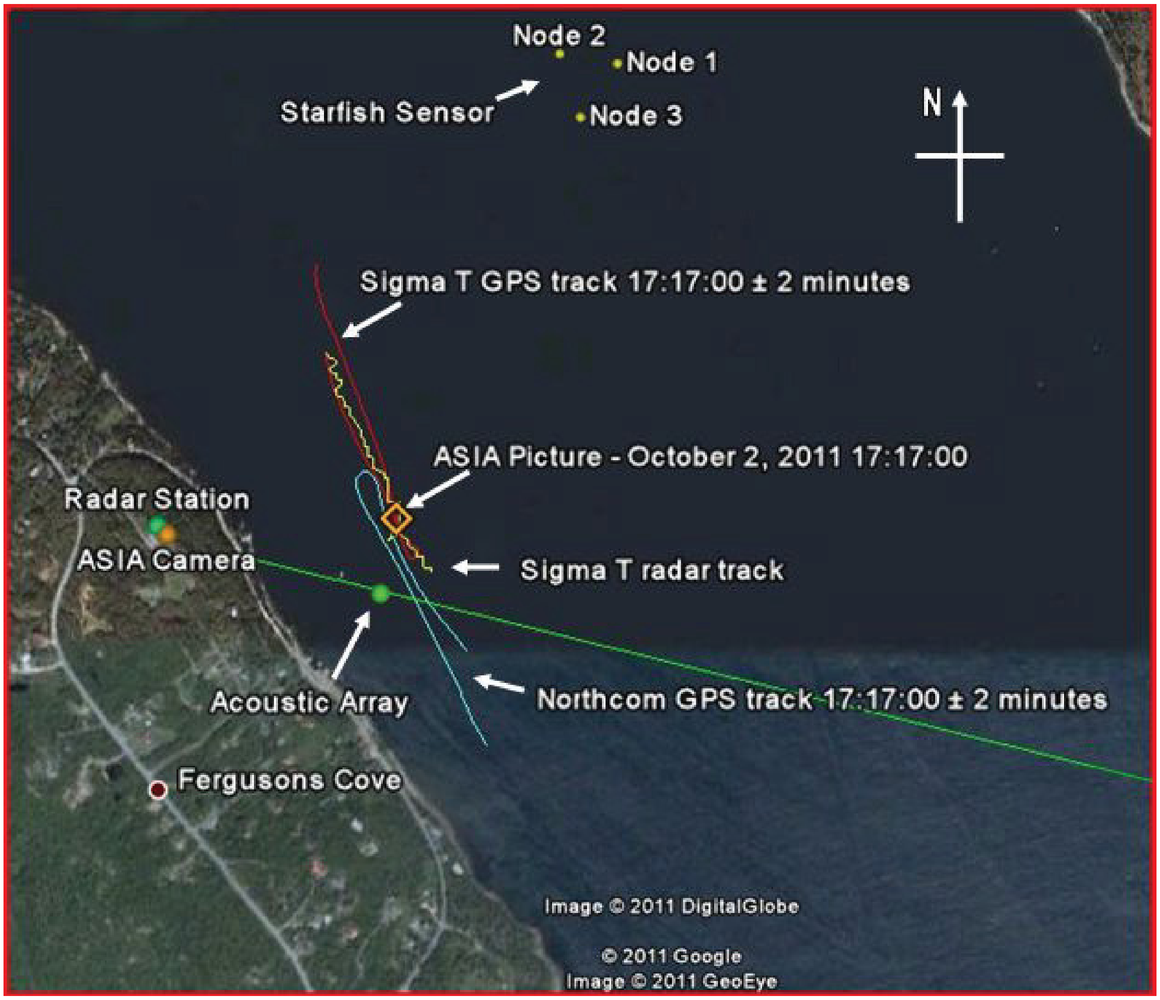

Figure 3: The SICCPA trial vessel tracks based on GPS and radar. The physical deployment of ASIA, radar and the acoustic array are also shown.

3 WBE 11HL02: Static anomaly detection from self reported information

Work under this breakdown element was focused on understanding and utilizing self-report information, such as AIS, to ascertain or extract additional information from the self-report. Irregularities in the static information, defined as information content that typically changes infrequently (e.g., vessel name, vessel type, vessel identifying number, etc.), was the primary focus of the WBE.

3.1 11HL02 activities

3.1.1 Visualizing AIS receptions for surveillance

The AIS was designed to be a collision avoidance system. However, from a surveillance perspective, a sequence of frequent AIS messages (e.g., messages separated by 10s interval) may be redundant, given that a vessel travelling at 14 knots will only progress 70m in a 10s interval. Not every AIS message sent from the vessel may be required. The possibility of AIS messages with larger than normal temporal gaps being useful for surveillance, indicates that the robustness and reliability of the delivery mechanism could be degraded (i.e., it becomes less trusted), while still providing data that would be considered useful (i.e., trusted) to the surveillance task.

Under WBE02, a technique was investigated by Lapinski and Isenor [11] and [12] to assess spatial-temporal vessel reporting characteristics using AIS messages that have unknown and variable temporal spacing. The technique creates a visual representation of the spatial-temporal AIS reception characteristics that can then be used to assess surveillance capabilities.

The algorithm utilizes AIS messages acquired for a given domain and time period. The domain is spatially divided into geographic cells. Then, the positional data in the AIS message is used to associate each message with a specific geographic cell. A temporal analysis of the AIS messages then determines the first time the vessel was detected, the last time the vessel was detected, and the time between AIS message receptions from that vessel.

Based on time and space criteria applied to the receptions, an empirical-based index is computed and then used in generating a color coded map of the spatial area being considered. An example of the results is shown in Figure 4. The colour coded squares of the figure allude to the spatial division of the domain into geographic cells. A beige coloured cell indicates that vessels are not prone to appear or disappear within that cell, within the time defined in the algorithm. A red coloured cell indicates areas where vessels are prone to appear or disappear; this suggests that the frequency of AIS messages is not sufficient for persistent surveillance (where in this case persistent is defined as a 6 minute time window). A black cell means there is an absence of any

AIS messages from that cell, either due to lack of reception or the lack of vessel traffic in that cell.

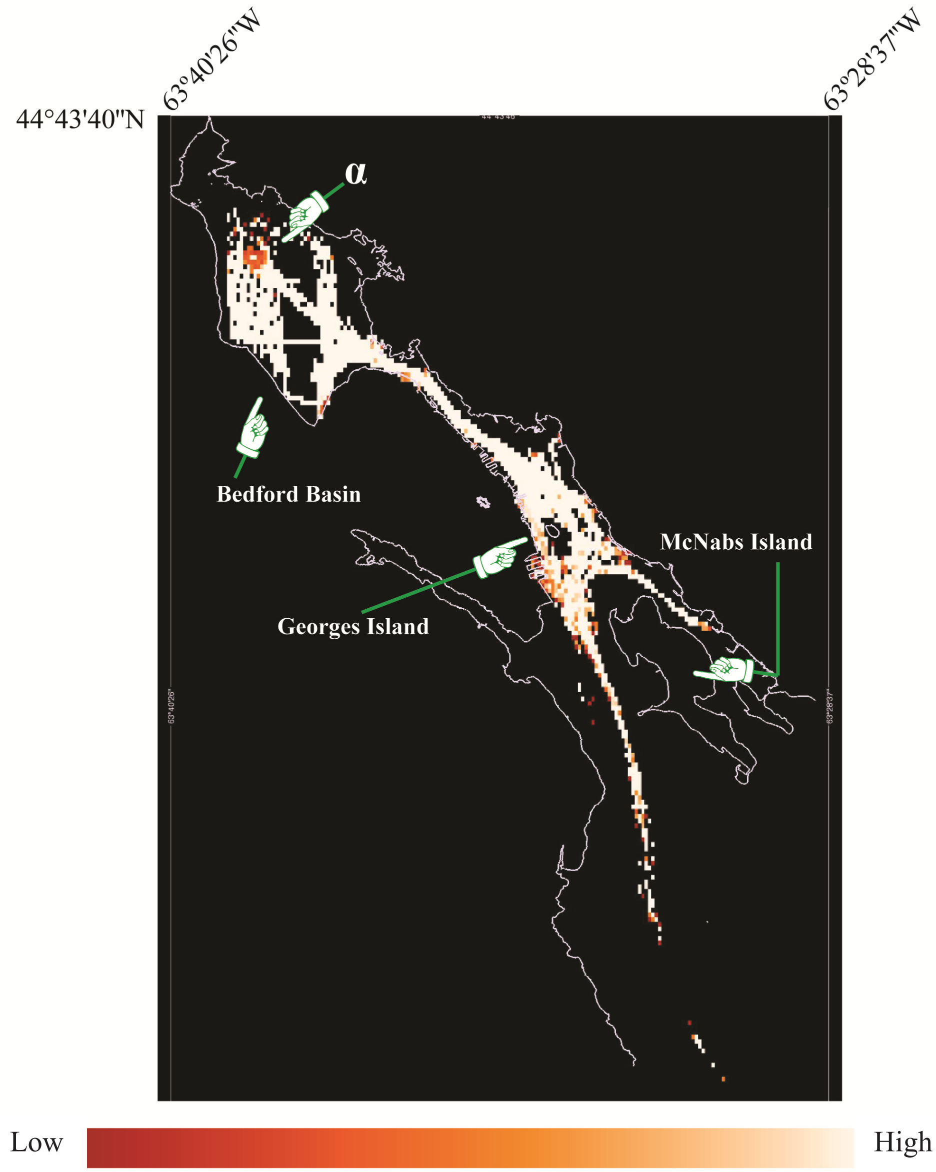

Figure 4: The visualization of algorithm results using AIS receptions from Halifax Harbour. The red-orange color indicates areas where the AIS reception is primarily births and deaths, while white indicate areas where vessel AIS reports are received at rates sufficient for persistent surveillance.

The technique provides a visual indication of the temporal consistency in AIS reporting. This consistency does not refer to the anticipated AIS reporting rate, but rather takes into account degradation that reduces AIS message frequency while not necessarily impacting surveillance capabilities.

3.1.2 Consistency of AIS information

Both the understandability and usefulness components of trust are related to the data (see Isenor *et al.* [1]). In a single data set, usefulness could be indicated by the reporting of consistent results. Within the AIS message structure, there exists information that should be consistent.

In WBE02, AIS messages were examined from the perspective of the consistency of information within the message. Some AIS messages have fields that contain data that should be duplicated in other parts of the same message. For example, the MMSI number in an AIS message contains within it, a Maritime Identification Digit (MID) number. This MID number is issued based on the country where the vessel is registered. However, the country flag is also contained within the AIS message. Thus, the flag and MID number should be in agreement for any particular vessel.

This type of duplicated information was utilized to determine the inconsistencies in AIS message content by Isenor *et al.* [13]. Using data obtained from the MSSIS, an analysis was conducted to determine the inconsistencies, grouped by the country indicated in the MID number.

Results (Figure 5) indicate that Sweden has the most consistent MID and call sign designation, with about 0.5% inconsistency. Norway is next with a percentage of 1.4% inconsistency. The figure indicates a levelling off near the 5% level, and has a median of 5.0%. Starting at Spain (ES), Saint Vincent and the Grenadines (VC), and France (FR), there is an upward trend in the inconsistency. Note that Canada (CA) has inconsistent reporting at 29% for the 1 hour data sample (see the red bar in the figure). The largest inconsistency is from Turkey, at 59%.

The inconsistency noted in the Canadian AIS messages was investigated further by identifying the spatial location of the Canadian vessels in the data sample. Figure 6 shows the locations of the 177 vessels in this sample, with the three reporting regions indicated in a mosaic. The green symbols indicate a Canadian vessel reporting consistent information, while the red symbols indicate inconsistent information. The vessel's MMSI number is used as a label.

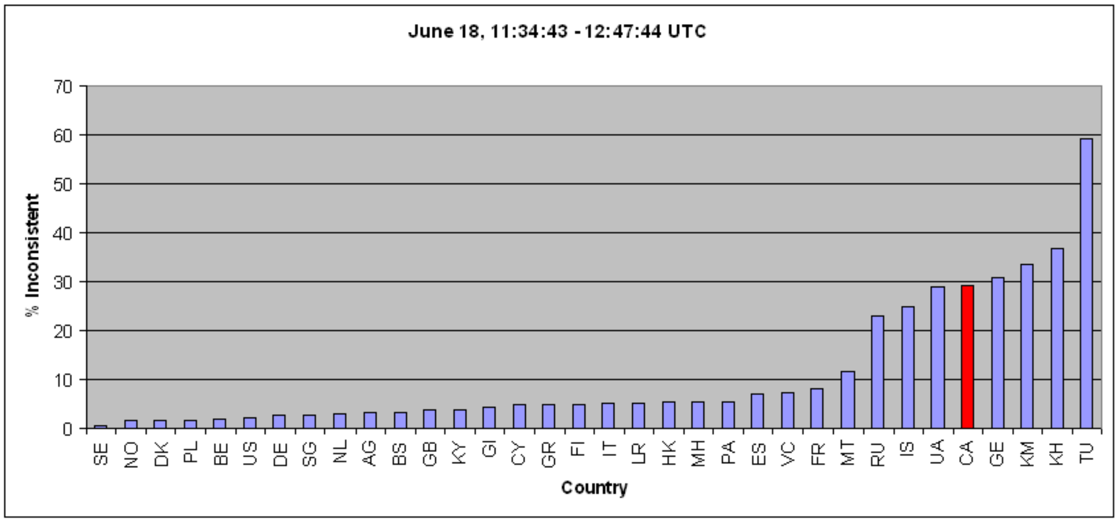

Figure 5: The percentage of inconsistent country indicators using AIS message call sign and MID number. Percentages based on the number of unique vessels for each country, where unique vessels are determined from MMSI number. The minimum number of vessel reports is 57 (Comoros–KM) while the maximum is 3257 (United States–US). Data covers the June 18, 2009 period between 11:34 and 12:47 UTC. Countries are indicated by the International Organization for Standardization (ISO) country code.

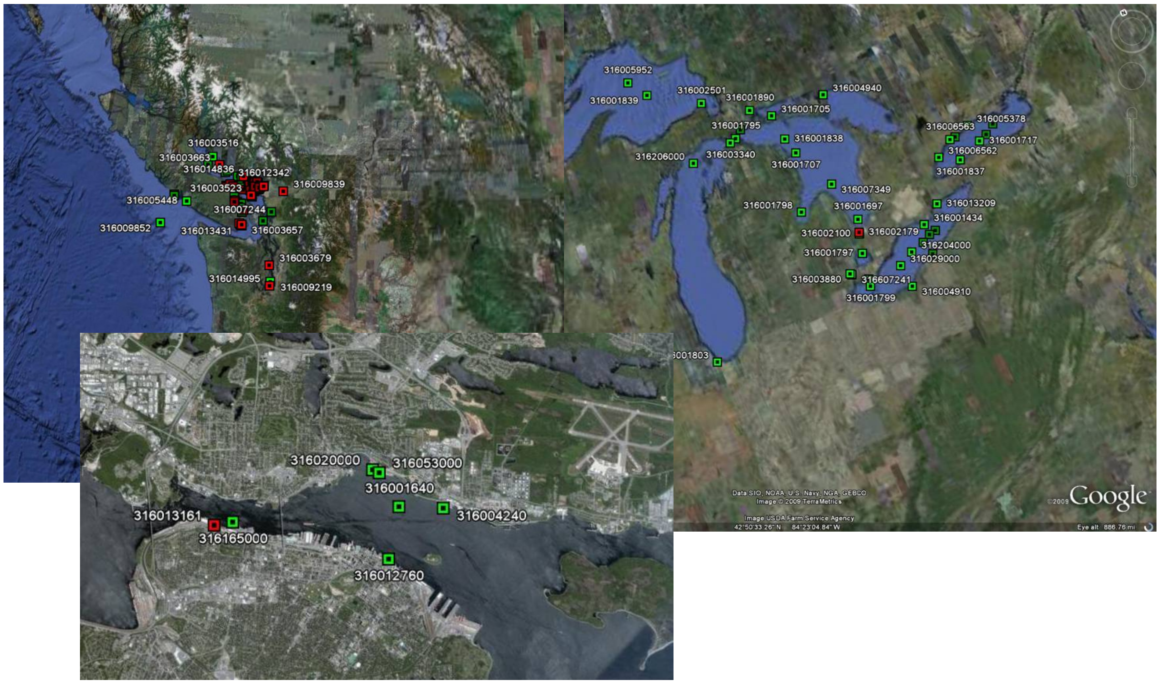

Figure 6: A mosaic showing the location of the 177 Canadian vessels in the MSSIS data sample. Green squares indicate vessels reporting consistent MID and call sign countries; while red squares indicate inconsistent information. The majority of inconsistent reporting can be attributed to vessels on the Canadian west coast.

3.1.3 Consistency of information from multiple sources

Understandability of the data and usefulness of the source is also expected to be related to the consistency of the information across multiple sources. In this situation, trust would likely be enhanced if data from different sources, all indicated consistent values ([14] and [15]).

Sources such as ASIA (using content from the AIS messages collected by the system), SeaSpider [16], and data from the International Telecommunication Union (ITU) can be compared to determine if, for a particular MMSI number, the information provided by the various sources is consistent. Consistency can then be represented using the common traffic-light scheme.

An application was built under WBE02 to automate this type of comparison. The application was built utilizing a service oriented architecture (SOA) to acquire the information from the multiple sources, adjust the various vocabularies used at these sources, and then represent the consistency to a user. A representation for a single vessel then communicates the photograph from the ASIA system, and the information obtained from SeaSpider and the ITU as shown in Figure 7.

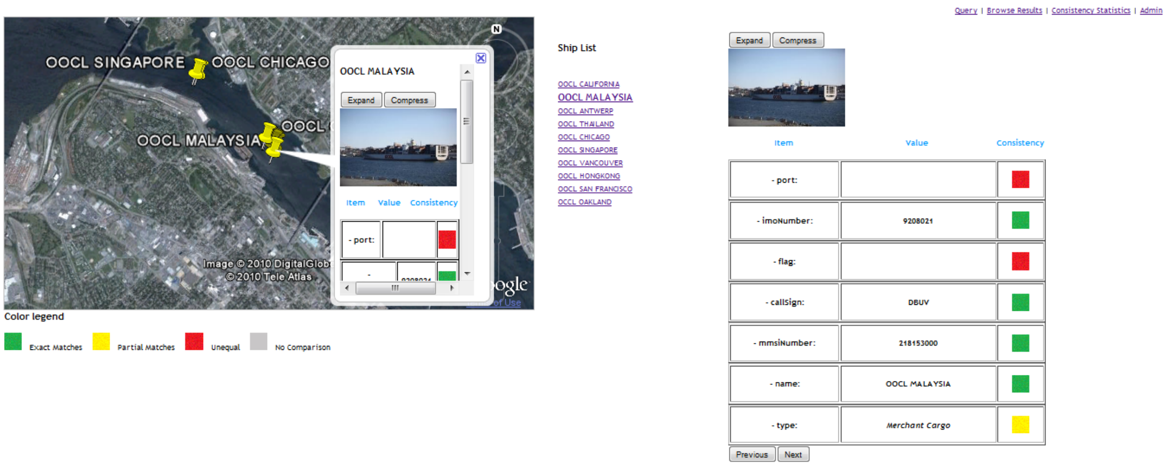

Figure 7: The content of a user information window from the Consistency Application. The vessel image is from ASIA. The traffic light panel shows how consistent the information is for this particular vessel, when taking into account all information sources.

3.1.4 Probabilistic interpolation between AIS receptions

Our knowledge of vessel position based on AIS messages is partially dependent on the frequency of received messages. If received messages are separated by large gaps in time, our knowledge of where a vessel might be located at intermediate times is degraded. This may indicate that the reliability or robustness of the delivery mechanism is unsuitable for the required task.

Under WBE02 there was a mathematical investigation into possible tracks between vessel self-reports. The general concept of a self-report message (e.g., AIS is a type of self-report message) was used in a probabilistic model to identify potential vessels moving through a particular area (see Peters and Hammond [17]). The method used the random generation of physically feasible vessel paths connecting the two self-reports. The method empowers operators to answer probabilistic questions about any characteristic of the unknown true path. For illustrative purposes, the method was demonstrated in a fictitious scenario in which illegal dumping of waste matter has taken place.

The geography of an example problem is shown in Figure 8. The five green polygons represent five islands. In this fictitious example, two successive passes of a satellite in low earth orbit collect the AIS data. The first pass (at time t = 0) finds three vessels at the locations marked with black dots labelled “A(1)”, “A(2)”, and “A(3)”; and the second pass (at time t = 1, which may be considered to be about 12 hours later) finds the same three vessels at the locations respectively marked with black dots labelled “B(1)”, “B(2)”, and “B(3)”. Also superimposed on the problem, is a trusted vessel (i.e., red path) that reports no visual sightings of vessels within the range indicated by the red circles.

Results are displayed as a probably density (PD) map for each vessel. Figure 9 shows an example PD map from Peters and Hammond [17] for vessel 1. The two panels indicate the change in the PD when the algorithm takes into account the lack of any visual sightings from the trusted vessel.

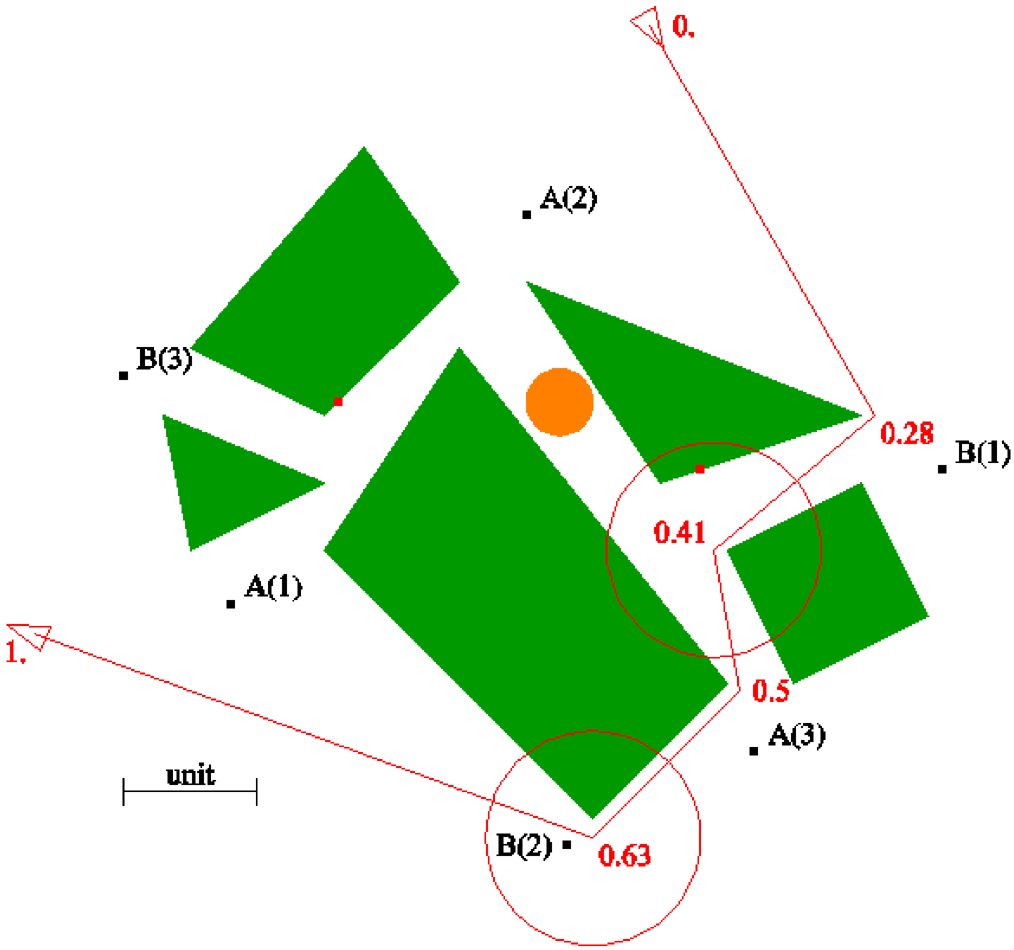

Figure 8: Representation of geographical data for the dumping scenario. The five green polygons represent land masses; the orange circle represents the waste spill; the black dots labelled A(n) and B(n) are the AIS position reports for vessels 1, 2, and 3. The path shown in red represents the trajectory of the military vessel (red numbers are time coordinates) and the large red circles illustrate the range of surveillance.

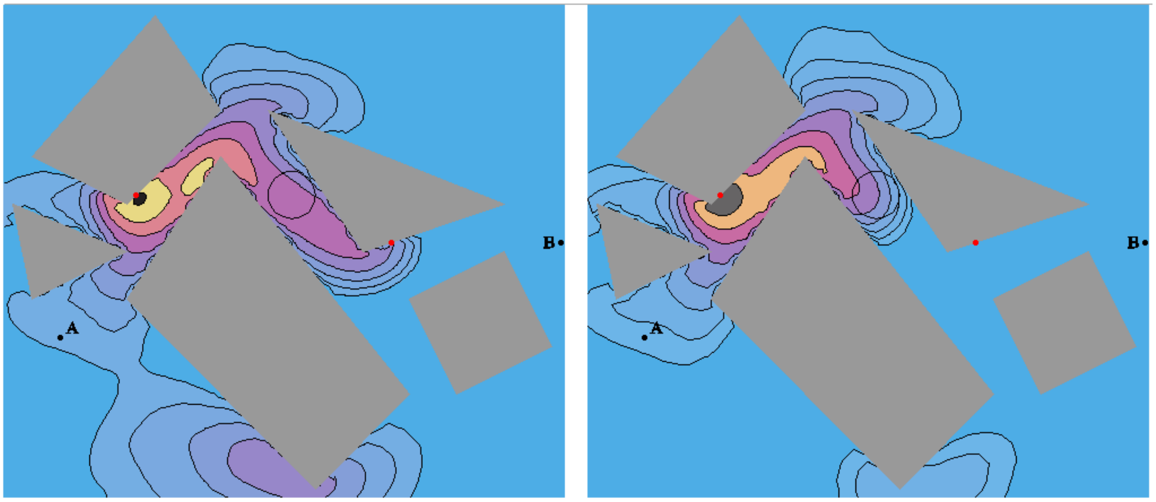

Figure 9: Probability density for position of Vessel 1 at time of dumping (prior distribution in left panel, adjusted for negative data in right panel).

3.2 11HL02 Associated Reports

Reports associated with this breakdown element include:

- visualizing AIS receptions in [11], [12],
- consistency of information in [13], [14], [15], [18], [19], and
- probabilistic interpolation in [17], [20].

4 WBE 11HL03: Architectures, infrastructures and models for trusted sharing of maritime situational information

Work under this breakdown element was focused on understanding the architectures, infrastructure or models that provide MSA data and information.

4.1 11HL03 activities

4.1.1 Raw automatic identification system repository

It seems reasonable to assume that the understandability and usefulness of data should be related to the proper management of those data. A disorganized or haphazard approach to data management will likely degrade a consumer's ability to understand and utilize those data.

As an investigation into the infrastructure requirements for enhancing one's trust in AIS data, a Raw Automatic Identification System Repository (RAISR) was developed under WBE03. The repository acted as a central location for the accumulation of raw AIS messages. The system was modelled after the Canadian National AIS system (CNAS), which was being constructed at the time.

RAISR is a multi-input and multi-output repository for AIS data streams. As RAISR was developed, this vision expanded slightly, with RAISR evolving into a repository for raw National Marine Electronics Association (NMEA) data streams, including AIS.

RAISR was developed by International Communication and Navigation Limited (ICAN) and is constructed from two ICAN products: DataSwitch and DataStore (Figure 10). Both DataSwitch and DataStore were commercial products, but in this instance were modified to meet the particular needs of DRDC Atlantic. RAISR is built upon a Microsoft SQL Server database. DataStore, described in ICAN [21], is the database component of RAISR, and supports querying and playback of NMEA messages. Any computer can connect to the DataStore over the network and interact with it using the ICAN DataStore Application. The DataStore Application provides a query interface to the data within the DataStore.

Data are fed into the DataStore through one or more DataSwitches. The DataSwitch, described by ICAN [22] receives raw data from multiple sources. These sources can be RS-232 serial ports, transmission control protocol (TCP) ports, user datagram protocol (UDP) ports, or files on a computer's hard drive. The DataSwitch then passes these data to clients via TCP or writes the data to an output file. A client can be a DataStore or another computer application such as a chart viewer or data analysis application. The DataSwitch is configured by a web-based administration application.

The RAISR configuration consists of a single DataSwitch and a single DataStore. There are three data feeds coming into the DataSwitch. These feeds are referenced based on the location of the feed. The feeds are termed:

- Sydney, Australia
- DRDC Atlantic, and
- the MSSIS five minute feed.

DataSwitch can act as a filter, setting different data processing rules and output formats for different clients. For example, you could setup a filter to output a reduced stream of AIS data from a subset of sources. The filter could also apply to a specific geographic region, and create output in extensible markup language (XML) or comma separated variable (CSV) format. A second client could then be allowed access to the full stream of NMEA data (e.g., AIS) from all sources.

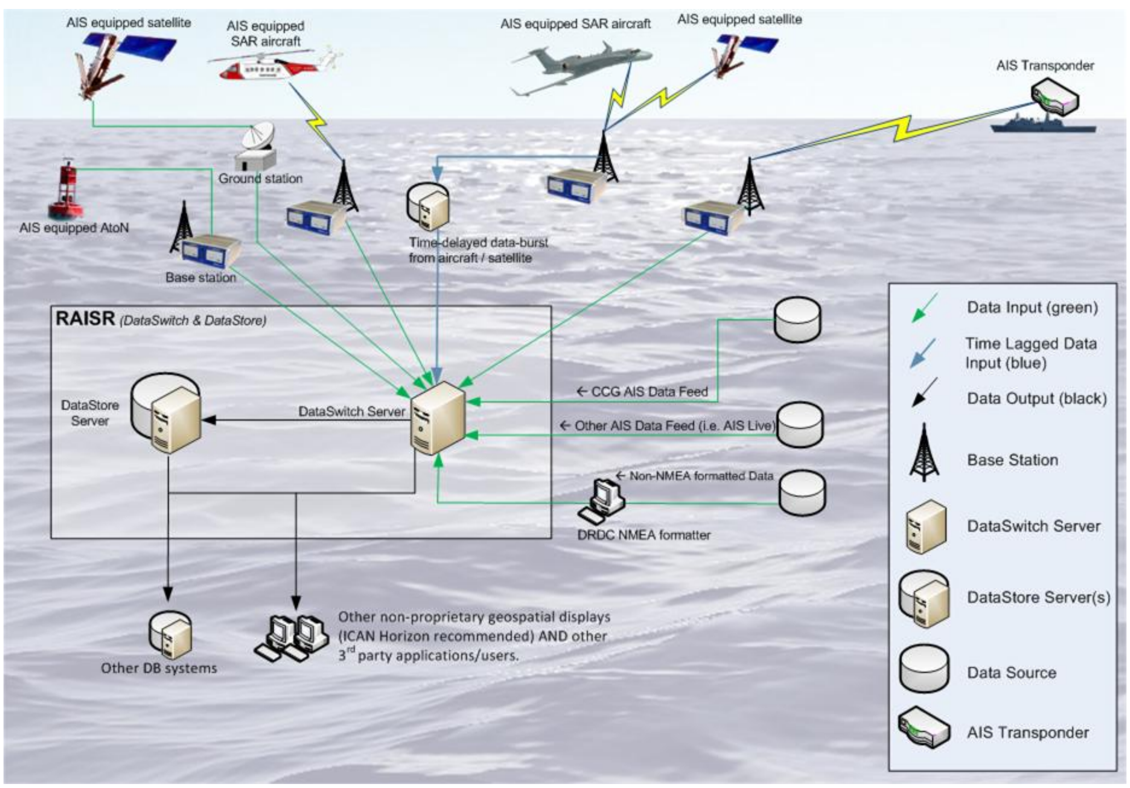

Figure 10: A depiction of RAISR, showing AIS data streams feeding the repository.

4.1.2 First Canadian contribution to MSSIS

Any infrastructure to support global MSA will be dependent on local national contributors to the global distribution mechanism. Trust in the source, data, delivery or processing (see [1]) will be largely dependent on the available information that supports one's ability to develop an understanding of the infrastructure. For AIS data, the first such global aggregator and distributor of AIS data was the Maritime Safety & Security Information System (MSSIS; see Glynn [23]).

Under 11HL03, DRDC Atlantic made Canada's first contribution to MSSIS. The MSSIS is an international data aggregation and distribution system for quasi-real-time situational awareness data. The system relies on contributions from individual member countries, which provide data (not exclusively AIS data) to MSSIS. In turn, MSSIS allows the sharing of these data with all contributing members.

To become a member of MSSIS, you must be a government organization with a safety or security mandate. All data distributed by the MSSIS is unclassified without limits on distribution. MSSIS provides the data (Figure 11) to consumers through a password protected interface. In 2008, MSSIS was recognized by senior Canadian CF personnel as being an important contributor to MSA in the CF.

MSSIS acquires data from individual contributors feeding their data to central servers, using the Transview32 (TV32) software. The TV32 client directs the data feed to a MSSIS server using an encrypted tunnel with secure socket layer (SSL). As of August 2011, four MSSIS servers support the system; those being located in:

– Boston, Massachusetts (US Department of Transportation (DoT) Volpe Center, online in August 2006),
– Norfolk, Virginia (US Navy Second Fleet, online in December 2006),
– Naples, Italy (US Navy Sixth Fleet, online in March 2007), and
– Naples, Italy (NATO Component Command Maritime (CCMAR), online in December 2007).

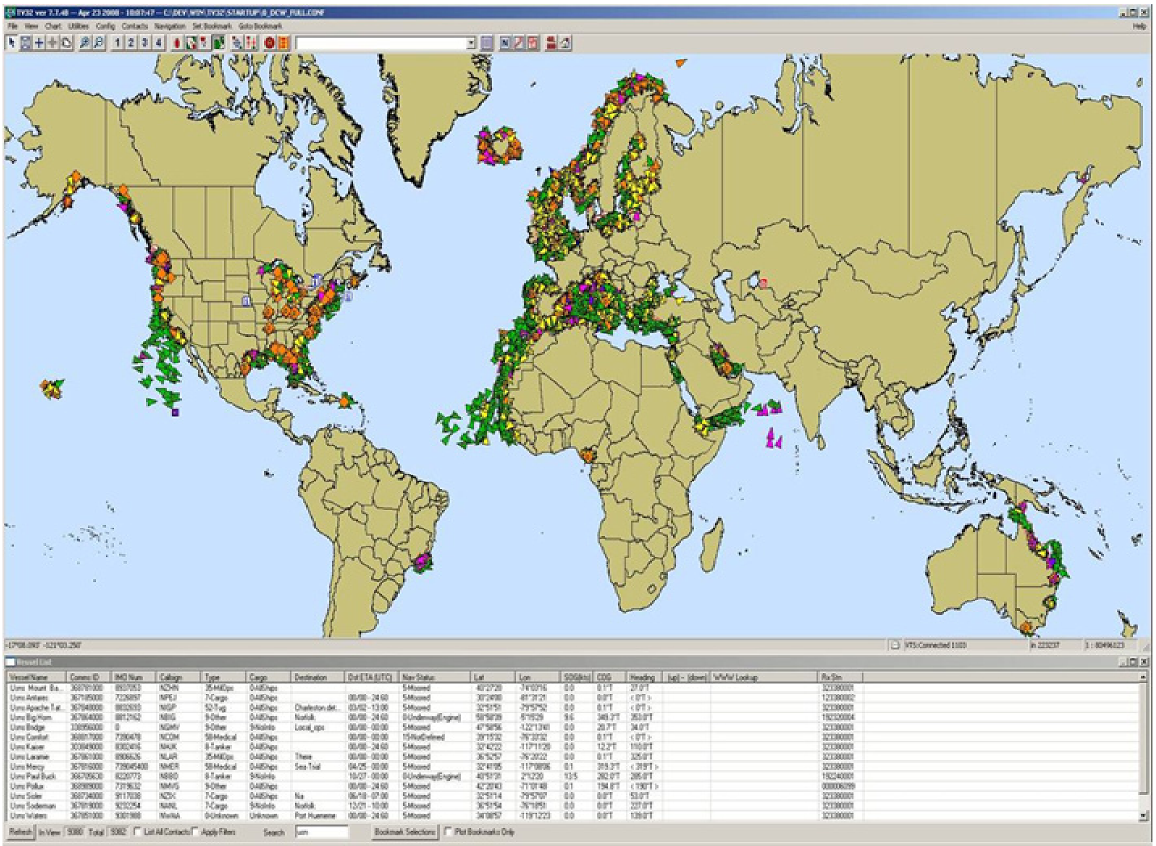

Figure 11: A graphic of the MSSIS display from April 2008.

The individual server sites are connected via a virtual private network (VPN). The central servers do not archive the data. The servers alter the data obtained from the incoming stream, using two types of data decimation:

- duplicate AIS messages, those potentially introduced from multiple receivers receiving the same AIS transmission, are removed
- at most, one message per vessel, in any one minute interval, is allowed to pass to the other servers in the system

Both types of decimation are implemented to preserve bandwidth.

Considering data acquisition from the system, the server architecture and decimation decisions result in important consequences for the users of data. Users (i.e., those obtaining data from the system) connect to a specific server. However, the user has no way of knowing which contributing countries are feeding data to that particular server. This means the connected server may be receiving full rate data directly from a particular contributing country, or decimated data as a result of the contributing country providing its raw data to a different server.

Nevertheless, MSSIS offers an aggregation and lightweight distribution mechanism. The majority of the data stream is composed of standard AIS messages with the addition of a timestamp to the end of the AIS message. This does, however, mean the AIS messages no longer formally comply with the AIS standard. The timestamp is a single integer, representing the number of seconds since January 1, 1970 (i.e., epoch time).

In addition to the modified AIS messages, Volpe Center adds a proprietary Volpe NMEA message to the data stream. This message, designated $PVOL, is for internal system management and acts like a heartbeat message for the system.

Although very useful from a data perspective, the MSSIS architectural and policy decisions have introduced constraints on the system. For example:

– The receiver location and receiver country are not included in the data feed. This provides anonymity for those providing data, but results in the consumers being unable to determine the origin of the data. As well, characteristics of the reception point, such as who maintains it, are also unknown.

– The path followed by the data from the receiver to the TV32 client that feeds the MSSIS, is unknown. This means any alterations to the data before the TV32 client, is unknown to consumers.

– Producers and consumers of MSSIS data have no status information regarding the health of the system. One consequence of this is that data feeds can be added or removed from the system without any prior indication.

4.1.3 Joining the MDA Data Sharing Community of Interest

An infrastructure that supports data sharing often separates the data source from the processing. In the case of the Maritime Domain Awareness Data Sharing Community of Interest (MDA DS COI), DRDC Atlantic membership in the COI provided an opportunity to investigate local data collection, combined with delivery and remote processing, with the goal of supporting MSA information generation.

The MDA DS COI was formed in February 2006 and is co-chaired by the US Coast Guard (USCG) and US Navy. The COI has been quite active, meeting each quarter to brief the members on progress. Sub-groups were also formed to work on data management, technical aspects, and policy issues. In terms of data management, the COI investigated technologies such as the Maritime Information Exchange Mechanism (MIEM), the National Information Exchange Mechanism (NIEM) and the Universal Core (UCore).

DRDC Atlantic was invited to participate in the COI in October 2007 and was the first international member to participate. During the period March 2008 to April 2010, DRDC

Atlantic shared AIS data with the COI, and from the COI gained valuable processing services applied to the DRDC Atlantic data.

The goal of the community was to make MDA-relevant data visible, accessible, and understandable to the larger MDA community [24]. This was to be achieved by using a common vocabulary with the sharing taking place via core enterprise services. The MDA DS COI considered their role to be facilitators of an information sharing process. The intent was not to build systems, but rather to leverage existing systems.

The MDA DS COI infrastructure is based on the SOA, with web services running on the Early Capabilities Baseline (ECB) version of Net Centric Enterprise Services (NCES) run by Defense Information Systems Agency (DISA). The infrastructure utilizes Axis2, XML Interface for Network Services (XINS), CXF[2], and Windows Communication Foundation (WCF). Data producers/consumers use a publish/subscribe paradigm to geographical message channels using Web Service (WS)-Eventing. All messages use WS-Security with US Department of Defense (DoD) public key infrastructure (PKI) certificates. Canadian contributors must have a DND PKI Smartcard on DWAN in order to receive the DoD PKI certificate.

The infrastructure offers services such as Data Augmentation Service (DAS), for augmenting AIS messages with authoritative reference data; an Historical Archive Service (HAS); and an Anomaly Detection Service (ADS). The ADS initially leveraged the NATO Baseline for Rapid Iterative Transformational Experimentation (BRITE) anomaly detection services. Note that unclassified anomalies are shared within the COI.

The MDA DS COI infrastructure is shown in Figure 12. DRDC Atlantic, as part of the infrastructure, was providing data directly to the NCES messaging component. The dashed line from DRDC Atlantic to Volpe represents the data that are entering the MSSIS data stream.

In May 2008, a combination of 11HL activities resulted in the detection and identification of an anomalous vessel in Halifax Harbour. The AIS receiver located at DRDC Atlantic received the AIS message transmission from the vessel. This AIS message was routed to the NCES messaging component of the MDA DS COI, hosted at the Defense Enterprise Computing Centers (DECC), at San Antonio, Texas. Using BRITE services, the vessel identifying numbers (e.g., IMO and MMSI) in the message were compared to those identifiers in the Lloyd's database for vessels. The identifiers did not exist in the Lloyd's database and the vessel was therefore labelled an anomaly. The Google Earth interface to the MDA DS COI then identified the vessel using the red symbology that indicates a vessel anomaly.

[2] CXF = Apache CXF, with the term CXF derived from combining the "Celtix" and "XFire" project names

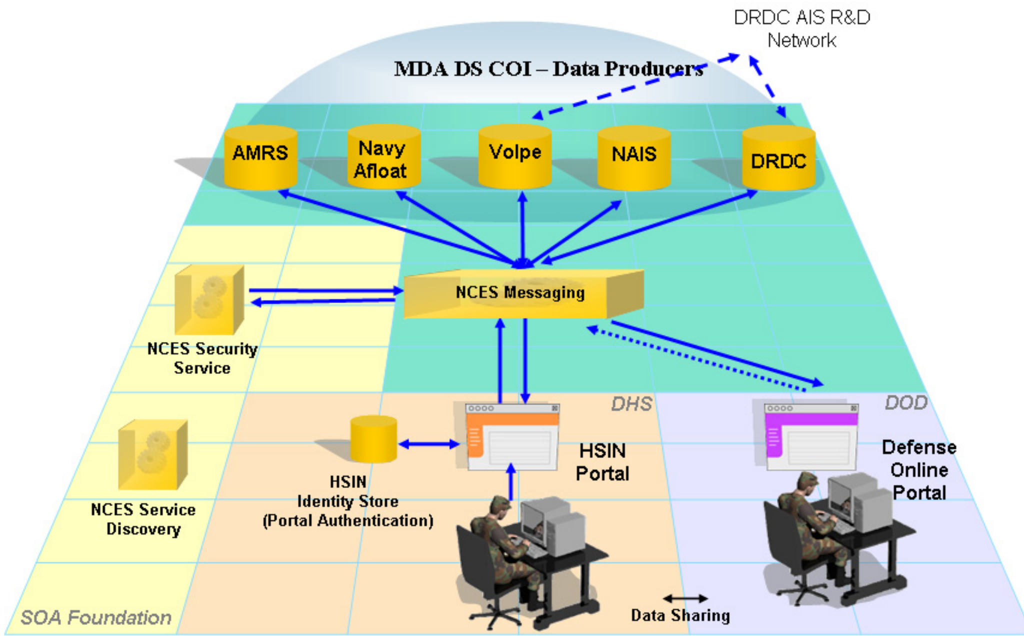

Figure 12: The architecture behind the MDA DS COI. Note the DRDC Atlantic contribution feeding AIS data to the NCES messaging component, which is part of the MDA DS COI.

Concurrent with this, the AIS antenna on the ASIA system also received the vessel's AIS transmission. ASIA obtained a photograph of the vessel as it departed Halifax Harbour (Figure 13). Further investigation indicated this was the maiden voyage of a privately owned yacht.

This example demonstrates the leveraging power of international cooperation and how interoperability can provide functionality far beyond the capabilities of any one partner. Such capabilities are built on the use of defined standards and the trust placed in each partner to provide services, data, etc. for the betterment of the community.

Figure 13: A new privately owned yacht. The yacht is exiting Halifax Harbour in May 2008.

4.1.4 Air surveillance – using ADS-B

Air surveillance was also an investigation under 11HL03, and specifically the use of the Automatic Dependant Surveillance – Broadcast (ADS-B) system. ADS-B is a self-reporting system for air traffic surveillance, analogous to AIS in the marine world (see MacInnis and McIntyre [25]). It is an automated broadcast that is dependent on Global Positioning System (GPS) or another Global Navigation Satellite System (GNSS) for positional data. ADS-B offers unprecedented accuracy in air traffic control and provides controllers with real-time plots of participating aircraft during transoceanic voyages and in other areas where no radar coverage exists. Experts claim this system will revolutionize air traffic management as radar will eventually be replaced as the primary means of control. Once installed, ADS-B maintenance costs will be extremely low when compared to modern radar equipment. While the potential benefits are widely known and documented, it has taken considerable time for ADS-B to be widely implemented. High initial costs, competing data link systems and conflicting legacy technologies are the main contributors to the delay.

DRDC Atlantic purchased an ADS-B receiver under a previous project, 11HF. The receiver was used in experiments designed to assess the availability of ADS-B information and its utility to the recognized maritime picture. The antenna was typically mounted on the roof of a DRDC Atlantic lab building near the shoreline of Halifax Harbour. The theoretical field of view at 40000 feet is 243 nautical miles. This roughly traces a circle around the Canadian Maritime Provinces and parts of Maine (US) and the Gaspé Peninsula, with the southern portion almost entirely ocean (see Figure 14).

The ADS-B equipment was used during 11HL as a data feed to various demonstrations related to the NORAD USNORTHCOM C2 Gap Filler Joint Capability Technology Demonstration project. The demonstrations were focused on showing how air and maritime information could be integrated. This work resulted in DRDC staff receiving a letter of appreciation from the Director Strategy, Policy and Plans, US Air Force.

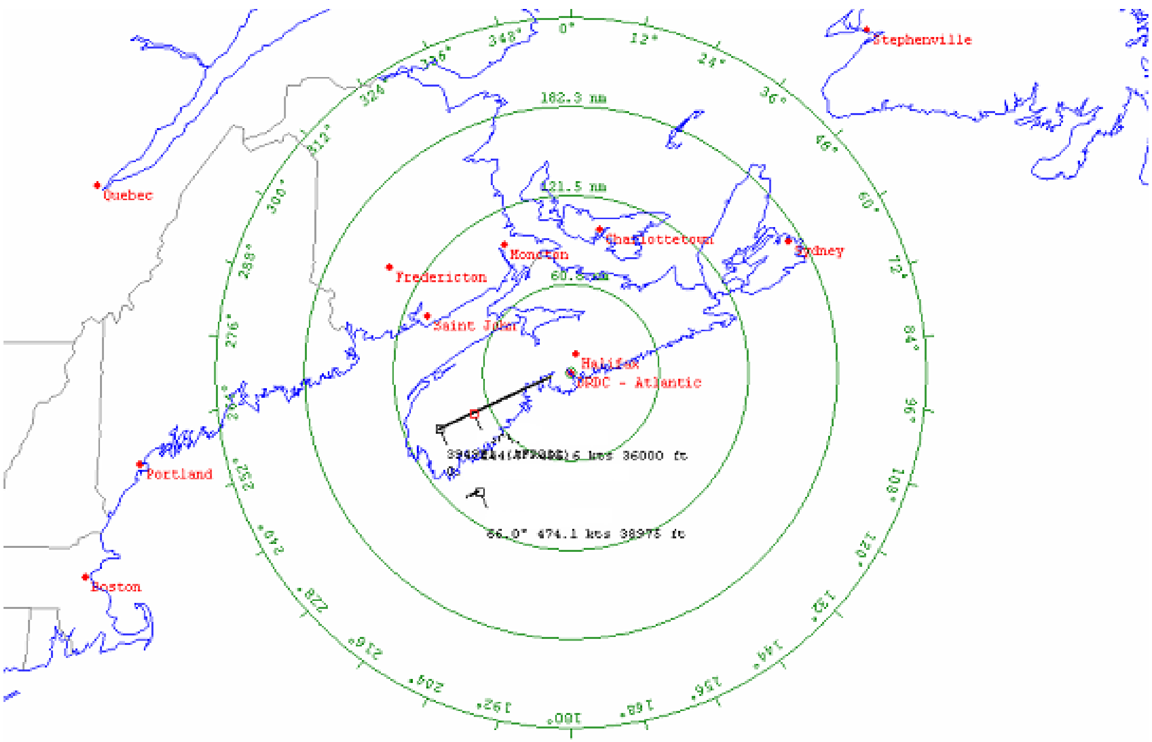

Figure 14: This screen shot of the SBS-1 Basestation software shows the area observed during experimentation. The largest ring marks 243 nautical miles, line of sight at 40000 feet.

The consequence of introducing ADS-B equipment into the market place should be noted. For example, aircraft tracking has recently shown up on the World Wide Web (WWW). The Radar Virtuel web site [26] is run by aviation enthusiasts, and offers a mechanism for connecting an ADS-B receiver to a larger collection network of receivers, and displaying the contacts via a web interface (Figure 15). Although predominately European coverage exists at the moment, some receivers are showing up in North America. This is an excellent example of how inexpensive equipment, combined with the global population and the connectivity offered by the WWW, is changing accessibility of information pertinent to situational awareness.

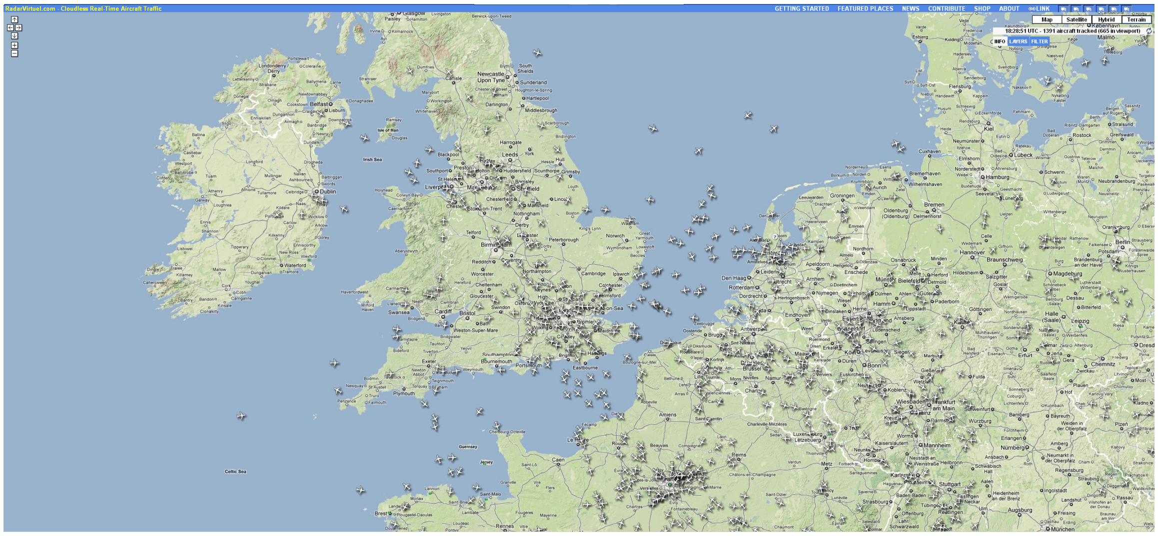

Figure 15: Screen capture from Radar Virtuel web site, showing commercial aircraft over Europe. This capture was taken on July 26, 2011, and shows 665 aircraft in the area. This site is run by private aviation enthusiasts.

4.2 11HL03 associated reports

Reports associated with aspects of this breakdown element include:

– contract reports detailing RAISR development [27], [28], [22], [21],

– descriptions of MSSIS and usage of data from MSSIS [13], [11], [12], and

– ADS-B description (note this is from ARP 11HF) [25].

5 WBE 11HL04: Fundamental investigations of trust management for defence, security and safety applications in maritime domains

Work under this breakdown element was focused on how Maritime Situational Awareness (MSA) data and the underlying system might impact trust in the different application domains.

5.1 11HL04 activities

5.1.1 Operational clarity through situational awareness

Trust is partially contingent on the source and the processes applied to the data. In many respects, this suggests that the proper management and organization of the data at the source, will contribute to the generation of trust by consumers of those data. As a result of this thinking, an examination of information management in the context of CF operations was conducted by Renaud and Isenor [29] to support WBE04. The paper highlighted the diversity and quantity of SA-relevant data that are currently being injected into CF networks, and how increasing the volume of data does not necessarily lead to clarity in situational awareness.

This work included an effort to recast situational awareness from the traditional definition of Endsley [30] into more of an operational context, dealing with the environment, subjects of interest, their activities, and available intelligence, with a goal of inferring and weighing potential outcomes of the situation. Impediments to attaining SA were then described and an information management model was proposed to address the needs of the SA community.

5.1.2 Space-based AIS

New MSA data sets, or new approaches to acquiring familiar data sets, is an important component to understanding the data and processes through which the data flow. The maximum utilization of the information content from the data, in a product like the RMP, is dependent on the reliability of the processes to deliver the data, on the robustness of the system delivering it, and on our understanding and the usefulness of the data. One activity in WBE04 began the examination of space-based AIS (S-AIS) data from this perspective.

Gathering AIS data from land or vessel based receivers was initially the only means of acquiring AIS messages. However, in 2008 commercial satellites [31, 32] were launched that were capable of acquiring AIS messages.

11HL initiated the first DND purchase of S-AIS data from a commercial provider. Space-based AIS reception has an approximate field of view of 5000 km, considerably more than land or vessel-based reception. Combining this large field of view with data from other providers, such as MSSIS, starts the process of filling in the mid-ocean spatial gaps. Figure 16 shows a sample of S-AIS receptions for the North Atlantic Ocean combined with MSSIS data.

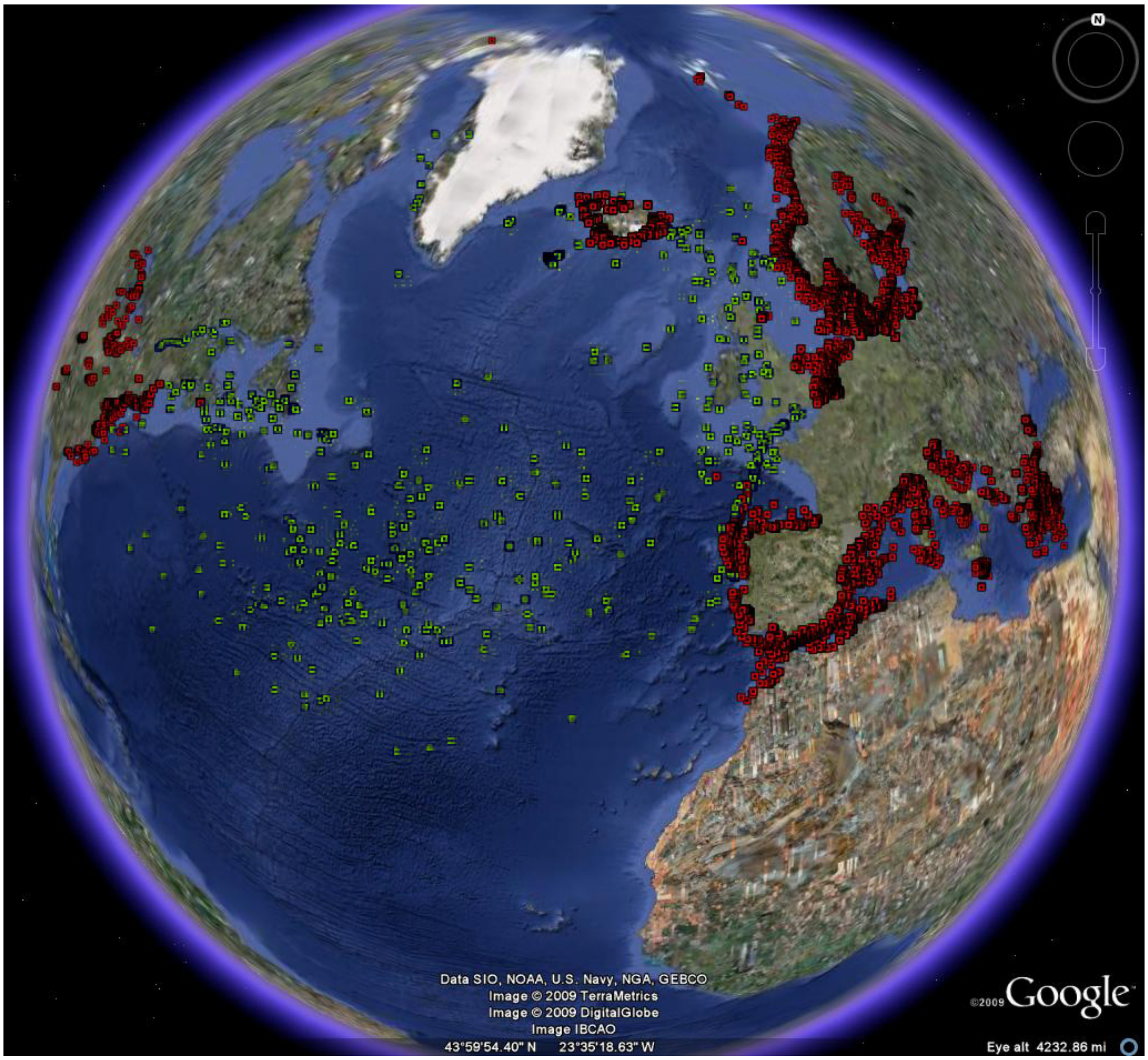

Figure 16: Space-based AIS receptions (shown in green) with MSSIS data (shown in red). Space-based AIS receptions are from June 23, 2009 at 1315Z, while MSSIS data are from the 1 hour interval 1300-1400 Z on the same day.

Combining data from such providers introduces an assortment of questions. For example, S-AIS reception has the limitation that it cannot process a high density of vessels so how much consistency in the information (i.e., the vessels) from the two providers should be expected? What are the implications of the underlying infrastructure on the data received by the customer? What data volumes can be expected? How will the defence and security community deal with this volume? What are the best practices for utilizing these data? Although these questions remain largely unanswered, 11HL began the process of identifying the data and providers that will ultimately contribute to future defence and security operations. Working with DRDC Ottawa, 11HL also assisted with the utilization of S-AIS in studies involving the association between these data and radar contacts, as well as planning future collection and utilization of space-based data [33].

5.1.3 Understanding centralized and decentralized systems

The flow of data from the originating source to the end user is becoming increasingly complex. As an example, consider the complexity of getting an AIS message from a vessel source, the intricacies of AIS messages (see timing section in Isenor *et al.* [1]), the underlying infrastructure through which the AIS message might flow (Figure 10 or Figure 12) including aspects of the WWW, all to result in a symbol geospatially located (Figure 11 or Figure 16) for user viewing.

These underlying complexities can impact reliability, robustness, usefulness, etc. of the system and thereby impact our trust in the system. To investigate these complexities, a study co-funded by 11HL and Transport Canada, examined the implications of centralized and decentralized architectures and the flow of vessel tracking data in these systems. Song *et al.* [34] investigated the centralized and decentralized self-reporting vessel systems, including general architecture characteristics, functionality and examples of existing systems. Vessel tracking for safety and security in support of MSA was also considered, as was the information exchange to support MSA.

5.1.4 Northern Situational Awareness

From a federal government perspective, Canada's north may be considered a multi-departmental and remote region of the country. The expense of operating in this region drives the sources, data, delivery mechanism and processing techniques towards a multi-department solution to the northern MSA problem. In situations with such diversity in the sources (i.e., the departments involved), trusted northern situational awareness may be a lofty objective.

The 11HL project made a contribution to understanding the sources and data applicable to Northern situational awareness. With support from the PSTP [35], three contracted efforts examined three issues important to northern awareness:

- a review of space-based radar,
- a review of self-reporting technologies, and

– a review of land, air, and sea based radar.

The review of space-based radar [36] considered existing systems such as RADARSAT-1 and 2, and future systems such as the RADARSAT constellation. The report also evaluated the operational capabilities offered by space-based radar, and potential applications to vessel tracking, vessel-ice discrimination, etc.

The review of self-reporting technologies [37] examined the carriage requirements that often drives implementation of self-reporting systems. AIS was reviewed in detail. ADS-B was also included, as were other vessel-based systems such as LRIT and Own Ship Weather Messaging. Infrastructure developments associated with these self-reporting systems were also described.

Land, air, and sea-based radar was the focus of the third report [38]. This report examined existing and planned radar systems and the operational capabilities of those systems in the Arctic. This report also described the information management and telecommunications issues associated with these systems.

The PSTP project [35] also included the planning and hosting of a workshop devoted to the topic of Northern Situational Awareness. The 2010 Northern Situational Awareness Workshop (NSA2010) was held in St. John's Newfoundland, October 13-14, 2010 and was co-funded by 11HL. The workshop, described by McIntyre *et al.* [39], focused on gathering operational requirements/needs from non-defence and defence organizations operating in the North. Through a complementary project, additional support for the workshop was also obtained from Transport Canada (TC). The workshop achieved a good mix of current awareness needs in the North and future technological solutions with potential help to build this situational awareness.

The overall objective of NSA2010 was to gather information needs from various types of organizations with operations in the north. The types of operations were grouped into four themes:

– Environmental Protection - Protection of the environment is a top public priority. The goal of this session was to develop an understanding of the special challenges of environmental protection in vast, remote and sensitive Arctic regions as human activity increases.

– Search and Rescue (SAR) - Incidents occur in the Arctic where lives may be at risk and SAR operations must be mounted. The special challenges of SAR in the north and the need for new approaches was the topic of this session.

– Defence and Security – Defence and security interests have significant information requirements to provide indications and warnings of major threats or hazards to our continent. The rapidly changing information landscape, with exponential growth of openly available commercial data, was addressed in this session.

– Resource Exploration and Development - Polar Regions represent a major untapped source of mineral, oil, and gas resources. This session investigated the situational awareness challenges of exploration, development, processing and transportation of resources.

In addition to gathering information needs, technology-based presentations addressing solutions for northern operations were provided. Technologies such as satellites, radars, self-reporting systems, acoustics, magneto-inductive communications, etc. were covered. These presentations provide technology roadmaps outlining current capabilities and future technology trends. A summary diagram of workshop participants is shown in Figure 17.

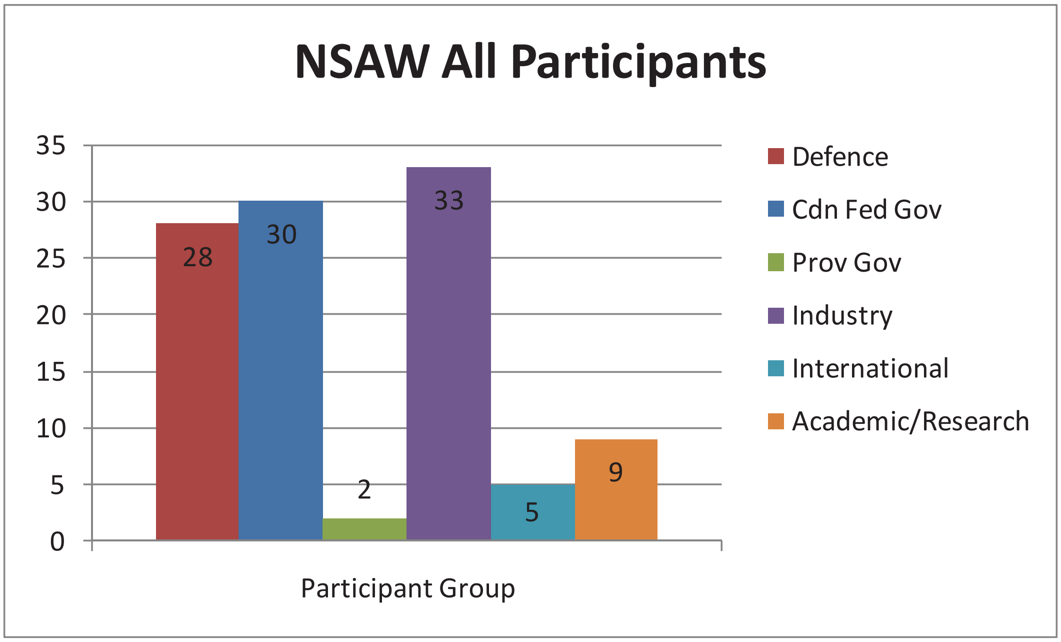

Figure 17: Histogram of workshop participants.

5.2 11HL04 associated reports

Reports associated with aspects of this breakdown element include:

– an examination of situational awareness from an operational standpoint [29],

– situational awareness with a focus on the Canadian north [36], [37], [38], [40], and

– centralized and decentralized systems for vessel tracking [34].

6 Outcomes and concluding remarks

The 11HL project focus was on technologies that provide data and information in support of MSA, and in particular how the technologies may contribute to the creation of trust for defence and security decision makers. The concept of trust represented a guiding principle for the project, while allowing for investigations covering diverse SA topics such as:

- self-reporting systems,
- collection mechanisms on land, sea, air, or in space,
- information architectures,
- data aggregation systems, and
- the use of the data to develop awareness.

All represent integral components of a MSA system.

6.1 Outcomes related to Defence S&T Strategy

Understanding these existing and evolving components from a defence and security perspective, represents the ongoing work of MIKM group and its partners. To conclude this final report, consider the 11HL project and its contribution to progressing solutions related to the Defence S&T Strategy [41] outcomes 1-3.

6.1.1 Outcome 1: Trusted situational awareness

Trusted situational awareness represents the foundation from which intent prediction and decision making are constructed. Admittedly, trust is a difficult concept to quantify. Equally difficult are the relationships between trust and the systems that combine the information allowing for situational awareness and ultimately operational clarity.

11HL identified relationships between broad system categories and trust components, allowing one to gain an understanding of the complexities in such relationships. The use of self-reporting system information, such as from AIS, was also a major driver for the project and in particular how such information may contribute to trusted situational awareness. 11HL drew attention to the fact that the use of AIS information in generating situational awareness represents a fundamental shift in the manner in which situational awareness is developed.

11HL also recognized that AIS introduces other problems related to the authenticity of the information. To be valuable, the self-report information should not be unconditionally accepted. To be trusted, the self-report information needs to be corroborated using other sources or techniques, such as the consistency within the message, the consistency across sources, using information obtained from imagery, or the use of predictive techniques to fill in spatial-temporal gaps between message receptions.

AIS will be a contributor to the development of trusted situational awareness. 11HL drew attention to the need for authentication of the AIS information, and how this authentication is very different from the traditional defence and security problem of estimation.

6.1.2 Outcome 2: Robust operational command and control in Canada and abroad

11HL examined the data and information inputs required for enhancing the command and control structure. Over the past 5 years, potential data and information inputs have drastically changed. No longer do sensors have to provide estimates of a vessel position to be combined with static arrival reports. With technologies such as AIS, the vessel position and identity is part of the message and represents key information for the decision makers.

This type of self-reporting has changed the landscape for maritime situational awareness. The introduction of AIS as an inexpensive collision avoidance system, and the subsequent use of AIS in a security-surveillance tasking, has effectively allowed for the realization of global MSA. Never before has a global picture of vessel traffic been a realizable goal.

However, in a broader perspective, it is the technology combined with connectivity offered by the WWW that is the true enabler. Global data aggregators like MSSIS, or in the air-domain the Radar Virtual web site, are examples of inexpensive technology that combined with the global population to create a collection and sharing community for MSA-relevant data. This represents the information paradigm shift in global MSA.

6.1.3 Outcome 3: Seamless interoperability with OGDs, partners, and allied forces

Finally, 11HL contributed to the progression and understanding of issues related to interoperability with defence and security partners. 11HL had a collaborative component that engaged US security partners via DRDC's contributions to MSSIS and the MDA DS COI. These collaborations culminated with the DRDC Atlantic AIS data feed to both MSSIS and the DS COI.

Establishing the data feed exposed nuances in both the data and technical aspects of data sharing. More importantly the feed provided an opportunity to expose the benefits of interoperability with partners. The AIS antenna at DRDC Atlantic received AIS messages from the vessels passing through Halifax Harbour. These data were streamed into the US NCES messaging system at DECC, where they were used in NATO BRITE services that checked the information content. These services identified a vessel in Halifax Harbour that was not in the historic databases. Simultaneously, the ASIA system photographed the vessel in question, thereby providing visual confirmation of vessel characteristics.

This sequence of events provided a concrete example of the type of interoperability sought by national security partners. Such capabilities are built on the use of defined standards and the trust placed in each partner to provide services, data, etc. for the betterment of the community. Canadian defence and security issues of the future will likely utilize a similar model.

6.2 Looking Forward

11HL provided the focus for examining trust as it pertains to Maritime Situational Awareness. The project concentrated on maritime information pertaining to vessels and how vessel-related information can be compared and combined to contribute to enhanced trust.

The project had obvious developmental and experimental successes, such as those related to ASIA deployment at the Vancouver 2010 Olympics or the integration of data sources within the MSSIS architecture. However, perhaps less obvious was the successful interdepartmental relationships and leveraging accomplished through 11HL. 11HL had the support of other labs within the DRDC family (CSS, DRDC Ottawa) but also formed partnerships with other departments and agencies, such a Transport Canada, Fisheries and Oceans, and Canadian Coast Guard. Such partnerships are extremely rewarding, but are difficult and time consuming to form and nurture.

The deliverables, knowledge and partnerships from 11HL are now being applied to 11HO. This ARP, titled *Situational Information for Enabling Development of Northern Awareness* (SEDNA) will focus on the development of situational awareness in the Arctic. The Arctic is an important icon in the Canadian psyche, with the majority (74%) of Canadians willing “to invest heavily on securing sovereignty over its Arctic land” [42]. Indeed, part of our national identify is represented by the Arctic and as a result, effective strategies for the monitoring and assessment of the northern maritime situation represent important contributions to our security and sovereignty.

References

[1] Isenor, A.W., Lapinski, A.-L.S. and MacInnis, A. (2012), Trust in automated maritime situational awareness systems with application to AIS, (DRDC Atlantic TM 2011-279, *In preparation*) Defence R&D Canada.

[2] Hammond, T.R., Lapinski, A.-L.S., Webb, S. and Chapman, D.M.F. (2007), A Functional Description of an Automated Ship Image Acquisition (ASIA) System, (DRDC Atlantic TM 2006-250) Defence R&D Canada - Atlantic, Dartmouth NS (CAN).

[3] A.U.G. Signals Ltd (2009), Image Processing Support (ASIA), (unpublished).

[4] Hammond, T., Pelot, R. and Leadbeater, N. (2011), Sensor Interaction for Small Ship Tracking and Awareness in Harbour, From the Public Security S&T Summer Symposium 2011.

[5] Hammond, T. (2008), Automated Ship Image Acquisition, *The Maritime Warfare Bulletin*, 9-11.

[6] Hammond, T.R. (2008), Automated Ship Image Acquisition, In *Proceedings of SPIE, Unattended Ground, Sea, and Air Sensor Technologies and Applications*, 696319-1,8.

[7] MacInnis, A. and Webb, S. (2010), ASIA System Deployment at MCTS Comox February/March 2010 User Manual, (unpublished).

[8] Omnitech Electronics Inc. (2010), Automated Ship Image Acquisition System: Feasibility of Multi-Photo Capability and Enhanced Range Functionality, (unpublished).

[9] A.U.G. Signals Ltd (2009), User Manual, (unpublished).

[10] McIntyre, M. (2011), Wide-Area Surveillance Support, *DRDC internal Publication (Leo Online)*, (26 March 2010).

[11] Lapinski, A.-L.S. and Isenor, A.W. (2010), Mapping AIS coverage for trusted surveillance, From the Proceedings of Unmanned/Unattended Sensors and Sensor Networks VII, SPIE, Toulouse, France.

[12] Lapinski, A.-L.S. and Isenor, A.W. (2011), Estimating Reception Coverage Characteristics of AIS, *Journal of Navigation*, 64 (4).

[13] Isenor, A.W., Penney, M. and Webb, S. (2010), Investigating characteristics of static information contained in automatic identification system data (DRDC Atlantic TM 2009-244) Defence R&D Canada.

[14] St-Hilaire, M.-O. (2010), Determining the consistency of information between multiple systems used in maritime domain awareness, (DRDC Atlantic CR 2010-025) Defence Research and Development Canada.

[15] St-Hilaire, M.-O. (2011), Addition of an Open-Web Data Source Service to the Consistency Application, (DRDC Atlantic CR 2011-038) Defence Research and Development Canada.

[16] Tatar, S. and Chapman, D.M.F. (2007), SeaSpider: Automated information gathering on vessel movements in support of Maritime Domain Awareness, (DRDC Atlantic TM 2007-294) Defence R&D Canada - Atlantic.

[17] Peters, D.J. and Hammond, T.R. (2011), Interpolation between AIS reports: Probabilistic inferences over vessel path space, *Journal of Navigation*, 64, 1-13.

[18] St-Hilaire, M.-O. (2010), User manual for the MIKM consistency application, (DRDC Atlantic CR 2010-056) Defence Research and Development Canada.

[19] St-Hilaire, M.-O. and Mayrand, M. (2010), Installation and developer guide for the MIKM consistency application, (DRDC Atlantic CR 2010-057) Defence Research and Development Canada.

[20] Hammond, T. and Peters, D.J. (2009), Probabilistic interpolation between position reports, From the NATO Workshop on Data Fusion and Anomaly Detection for Maritime Situational Awareness, La Spezia, Italy.

[21] ICAN (2009), DataStore User Manual, International Communications and Navigation Limited (unpublished).

[22] ICAN (2009), DataSwitch User Manual, International Communications and Navigation Limited (unpublished).

[23] Glynn, A. (2010), Safe Seas: New system improves maritime security, *Agora*, 66-67.

[24] Department of Defense (2004), Data Sharing in a Net-Centric Department of Defense, (DOD 8320.2).

[25] MacInnis, A. and McIntyre, M. (2007), Automatic Dependant Surveillance - Broadcast: State of the Technology and State of Implementation, (DRDC Atlantic TM 2007-392) Defence R&D Canada - Atlantic.

[26] Radar Virtuel Cloudless Real-time Aircraft Traffic (online), http://www.radarvirtuel.com/ (Access date: July 26, 2011).

[27] ICAN (2009), Functional Design Specification: Raw Automatic Identification System Repository (RAISR), International Communications and Navigation Limited (unpublished).

[28] ICAN (2009), Detailed Design Specification Raw Automatic Identification System Repository (RAISR), International Communications and Navigation Limited (unpublished).

[29] Renaud, W.M. and Isenor, A.W. (2011), Situational Awareness: Inspiring Operational Clarity, *Canadian Military Journal*, 11 (1).

[30] Endsley, M.R. (1988), Design and evaluation for situation awareness enhancement, In *Proceedings of Human Factors Society 32nd Annual Meeting*, 97-101.

[31] Newland, F., Coleshill, E., DSouza, I. and Cain, J. (2009), Nanosatellite Tracking of Ships – Review of the first year of operations, From the AIAA 7th Responsive Space Conference.

[32] ORBCOMM, AIS - ORBCOMM (online), http://www.orbcomm.com/services-ais.htm (Access date: August 2, 2011).

[33] Vachon, P.W., English, R.A., Sandirasegaram, N., Wolfe, J., Low, M., Tremblay, P., Wang, X., Isenor, A.W. and McIntyre, M. (2010), M3MSat: Science Plan, (DRDC Ottawa TM 2010-152) Defence R&D Canada.

[34] Song, R., Mason, P.C. and McIntyre, M. (2010), An investigation of centralized and decentralized systems for tracking cooperative vessels in the North, (DRDC Ottawa TR 2010-231 (in preparation)) Defence R&D Canada.

[35] Meunier, P. (2010), Impact of Emerging Maritime Infomration and Sensor Systems on Northern Situational Awareness, (Project Brochure) Defence R&D Canada - Centre for Security Science, Public Security Technical Program.

[36] Fowler, C., Adlaka, P., Yue, B., Hogan, L., McIntyre, M. and Stoddard, M. (2011), Review of Space-based Systems, (In preparation) Defence R&D Canada.

[37] Chaulk, N., McIntyre, M. and Stoddard, M. (2011), Review of Self-Reporting Technologies for Northern Maritime Situational Awareness (in preparation) Defence R&D Canada.

[38] Dawe, B., Ryan, J., O'Keefe, B., McIntyre, M. and Stoddard, M. (2011), A Radar Study for Maritime Northern Situational Awareness (in preparation) Defence R&D Canada.

[39] McIntyre, M., Stoddard, M.A., Adlaka, P., Hogan, L. and Fowler, C. (2010), Northern Situational Awareness 2010: Workshop Summary Report, (DRDC Atlantic TM 2010-336 (in preparation)) Defence R&D Canada.

[40] Peori, K. and Thibodeau, M. (2010), Preliminary Study on Information Architecture Development for Arctic Situational Awareness (unpublished).

[41] Department of National Defence (2006), Defence S&T Strategy; Science and Technology for a Secure Canada, 50.

[42] Angus Reid Strategies Canadians Concerned about Russia; Want Action on Arctic Sovereignty (online), http://www.visioncritical.com/wp-content/uploads/pdfs/2008.08.21_ArcticRussia.pdf (Access date: October 24, 2011).

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List of symbols/abbreviations/acronyms/initialisms

ADS	Anomaly Detection Service
ADS-B	Automatic Dependant Surveillance – Broadcast
AG	Action Group
AIS	Automatic Identification System
ARP	Applied Research Project
ASIA	Automated Ship Image Acquisition
BRITE	Baseline for Rapid Iterative Transformational Experimentation
CA	Canada
CAN	Canada
CCMAR	Component Command Maritime
CF	Canadian Forces
CNAS	Canadian National AIS system
COI	community of interest
CSS	Centre for Security Science
CSV	comma separated variable
CXF	Apache Celtix XFire
DAS	Data Augmentation Service
DECC	Defense Enterprise Computing Centers
DIR	Defence Industrial Research
DISA	Defense Information Systems Agency
DND	Department of National Defence
DoD	US Department of Defense
DoT	Department of Transportation (US)
DRDC	Defence Research & Development Canada
DRDKIM	Director Research and Development Knowledge and Information Management
ECB	Early Capabilities Baseline
ES	Spain
FR	France
FTE	full time equivalent

GNSS	Global Navigation Satellite System
GPS	global positioning system
HAS	Historical Archive Service
http	hyper text transfer protocol
ICAN	International Communication and Navigation Limited
IMO	International Maritime Organization
ISO	International Organization for Standardization
IST	Information Systems Technology (a Panel in NATO)
ITU	International Telecommunication Union
KM	Comoros
LRIT	Long Range Identification and Tracking
MDA	Maritime Domain Awareness
MDA DS COI	MDA Data Sharing Community of Interest
MID	Maritime Identification Digit
MIEM	Maritime Information Exchange Mechanism
MIKM	Maritime Information and Knowledge Management
MMSI	Maritime Mobile Service Identity
MSA	Maritime Situational Awareness
MSSIS	Maritime Safety & Security Information System
NATO	North Atlantic Treaty Organization
NCES	Net Centric Enterprise Services
NIEM	National Information Exchange Mechanism
NMEA	National Marine Electronics Association
NSA2010	Northern Situational Awareness Workshop 2010
PA	project arrangement
PC	personal computer
PD	probably density
PKI	public key infrastructure
PSTP	Public Security Technical Program
R&D	Research & Development
RAISR	Raw AIS Repository
RJOCA	Regional Joint Operations Centre Atlantic

RMP	Recognized Maritime Picture
SA	Situational Awareness
S-AIS	Spacebased AIS
SAR	Search and Rescue
SEDNA	Situational Information for Enabling Development of Northern Awareness
SICCPA	Sensor Integration for Close-Coastal and Port Awareness
SOA	Service Oriented Architecture
SRS	self-reporting system
SSL	secure socket layer
TC	Transport Canada
TCP	transmission control protocol
TD	Technology Demonstration
TTCP	The Technical Cooperation Panel
TV32	Transview32
UCore	Universal Core
UDP	user datagram protocol
US	United States
USCG	United States Coast Guard
UTC	Universal Time Coordinated
VC	Saint Vincent and the Grenadines
VPN	virtual private network
WBE	Work Breakdown Element
WCF	Windows Communication Foundation
WS	web service
WWW	World Wide Web
XINS	XML Interface for Network Services
XML	eXtensible Markup Langauge

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The Applied Research Project (ARP) titled *Technologies for Trusted Maritime Situational Awareness* and denoted 11HL, was initiated under the 1H thrust Maritime Domain Awareness in April 2008. The following is the final report for this three year project. The project focused on technologies that provide data and information in support of Maritime Situational Awareness (MSA). The technologies were considered relative to their contribution to the creation of trust. Some of the activities included the utilization of a vessel's Automatic Identification System (AIS) messages for camera cuing and vessel imagery collection; investigations involving AIS utilization for visualizing surveillance regions, consistency checking as it relates to trust enhancement, and defining probabilistic vessel tracks between AIS messages; investigations into architectures relevant to the trusted distribution of MSA data; and investigations into the trust implications of evolving data sources and system architectures. This report provides an overview of the 11HL project using previously reported results, and listings of reports and papers that resulted from 11HL.

Le projet de recherche appliquée (PRA) intitulé *Technologies assurant la fiabilité de la connaissance de la situation maritime* et désigné par les caractères 11HL a été lancé dans le cadre de la *Connaissance du domaine maritime*, 1H, en avril 2008. Le document suivant est le rapport final pour ce projet de trois ans. Le projet portait surtout sur les technologies qui fournissent des données et des renseignements en appui à la connaissance de la situation maritime. Ces technologies ont été évaluées en fonction de leur contribution à la création de la fiabilité. Certaines des activités comprenaient l'utilisation des messages du système d'identification automatique (SIA) d'un navire pour le repérage des caméras et la collecte d'images du navire, des enquêtes nécessitant l'utilisation du SIA afin de visualiser les régions de surveillance, des vérifications de l'uniformité puisqu'elle est en lien direct avec l'amélioration de la fiabilité et la définition des trajectoires probabilistes des navires entre les messages du SIA, des enquêtes portant sur des architectures pertinentes à la distribution fiable des données de connaissance de la situation maritime, ainsi que des enquêtes portant sur les incidences de la fiabilité des sources de données évolutives et des architectures du système. Le présent rapport fournit un aperçu du projet 11HL à l'aide des résultats obtenus précédemment et des listes de rapports et de documents produits dans le cadre du projet 11HL.

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