



Fisheries and Oceans
Canada
Coast Guard

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Garde côtière

DFO/5584

AUTOMATIC IDENTIFICATION SYSTEM (*AIS*)
EVALUATION FOR CANADIAN COAST GUARD
AND
MARINE INDUSTRY REQUIREMENTS

Canada

June 1998

Published by:

Technical and Operational Services Directorate
Fisheries and Oceans Canada
Canadian Coast Guard
Ottawa, Ontario
K1A 0N7

Second Edition - June 1998

DFO/5584

First Edition - August 1997 published by:

The Technical Services Directorate
Electronic & Informatics Systems Division
Laurentian Region

<http://www.ccg-gcc.gc.ca>



Printed on recycled paper

ACKNOWLEDGMENTS

We hereby wish to acknowledge that this final report was prepared by “la Direction des services techniques systèmes électronique et informatiques, Région Laurentienne” in particular Gilles Ringuette and J.C. Cyr.

AIS Steering Committee

I wish to acknowledge the work done by my colleague, Bernard Bisson, who coordinated the deployment and installation of the (AIS) equipment throughout the project. Without his assistance, the test bed could never have been carried out.

I would also like to thank the officers of *Le Brave* for welcoming us aboard their vessel, as well as the pilots of the *Corporation du St-Laurent Central*, in particular Mr. Claude Dubé and Mr. Marcel Grégoire, for participating in the trials aboard *Le Brave*, for their comments on use of on-board (AIS), DGPS and ECDIS, and for explaining the shipping context on the St. Lawrence River.

Finally, I would also like to thank Paul Morin and Gérard Buzaré of MCTS for their active involvement in the operational evaluation of the (AIS) system and for enabling me to have a better understanding of the mandate and operations of CCG MCTS centres.

Gilles Ringuette

EXECUTIVE SUMMARY

This report contains the findings of the (AIS) pilot project conducted jointly by the Canadian Coast Guard (CCG) and the marine industry between March 1996 and December 1996 on the St. Lawrence River between the cities of Montreal and Quebec. Two competing (AIS) technologies were tested, the first using a Digital Selective Calling (DSC) protocol and the other using a Self-Synchronizing Time Division Multiplex Access (STDMA) protocol.

DESCRIPTION OF SYSTEMS BEING EVALUATED AND OF TEST BED:

GP&C / Norcontrol (AIS) Broadcast System:

The system supplied by Norcontrol (principal supplier) is based on use of the Swedish Space Corporation (SSC) GP&C broadcast transponder. This transponder is based on a TDMA protocol (Time Division Multiple Access) which features use of a single radio frequency divided into 2250 time slots/minute, and which is therefore able to handle up to 2250 reports/minute.

The system's architecture is based a single set of equipment that can be used as a ship-board transponder or at shore stations to transmit, receive and rebroadcast messages and information originating from vessels. Each of the shore stations is linked to a control and display terminal via a 9600 bps digital telephone line. Two (2) shore stations were installed, one at Mont-Bélair (near Quebec) and the other at Sorel, to ensure continuous radio coverage from Montmagny to just east of Montreal. The system operates on the single frequency of 142.25 MHz. This enables direct ship-to-ship communication as well as shore-to-ship and ship-to-shore.

The theory behind the GP&C (AIS) broadcast system is relatively simple. When operational, the transponder listens to the traffic on the system's single radio frequency for 3 minutes to determine the available time slots and automatically uses one that is free. Each transponder then automatically and continuously broadcasts its ID, position and information to all other transponders (ships or shore stations) capable of receiving them.

Ross Engineering (AIS)-DSC System:

The system supplied by Ross Engineering is based on the use of transponders that include a 12-channel Trimble DGPS receiver, an (AIS) controller and a DSC-500 radio operating in the VHF marine band. These transponders can transmit and receive position and information reports on participating vessels via common Channel 70 and on the selected duplex working frequency.

The system's communication protocol is based on Digital Selective Calling - DSC - adapted for vessel traffic services. Information gathered by the transponder is processed and sent via a serial port to an ECS-type display and navigation system supplied by Ross Engineering. Transponder information is also available in an NMEA format which is compatible with standard ECDIS systems.

The Ross Engineering system definition requires a shore station using 2 VHF channels, i.e., Channel 70 as a calling frequency and a duplex working channel to which ship/shore communications are transferred to keep the calling channel open. Each of the shore sites is linked via telephone to a control and display station at the MCTS centre.

The system's architecture is based on a network of shore-based communication sites, with each one individually linked via dedicated digital telephone line to a control and display station at the MCTS centre. Each network site uses 2 frequencies, common Channel 70 and a separate duplex channel. Four shore sites were installed to cover the whole network, i.e., at Lauzon, Trois-Rivières, Sorel and Longueuil.

The system developed by Ross was originally designed for vessel traffic regulation within a limited area using a single shore-based control site. For our evaluation 4 shore sites were installed to ensure radio coverage from Quebec to Montreal. Three sites (Ile Charron, Sorel and Trois-Rivières) were linked by telephone line to the MCTS centre in Longueuil. The fourth site, Lauzon, was linked to the MCTS-Quebec. The use of several adjacent sites (to our knowledge, a first) which was necessary to ensure full radio coverage, does however present the additional challenge of ensuring that operations are both transparent to the user and interference-free.

The Ross system relies on the operation of a shore-based site to manage and synchronize shore-to-ship and ship-to-shore communication. The shore station verifies the presence of new vessels in its sector by broadcasting an all ship call on Channel 70. New vessels are automatically identified, added to the base station's assignment table and informed by the station to transfer ship/shore communication to the shore-based communication site's (duplex) working frequency.

The Ross Engineering system definition is dependent on the use of shore sites to rebroadcast traffic information to vessels. It does not allow for direct ship-to-ship communication where vessels can exchange position information directly and display it on their screens; both vessels must be within the same (AIS) coverage area in order to receive information from each other on the position of the approaching vessel.

As of February 26, 9 vessels were equipped (4 commercial vessels, 2 ferries and 3 CCG vessels) with one or other of the two types of VHF-DSC transponders.

ANALYSIS AND RESULTS:

Comparative Analysis:

The Ross Engineering (AIS)-DSC system operates on the DSC protocol, adapted for marine traffic surveillance and relies on the use of active shore-based communication sites to ensure radio coverage of a given area. The shore site is essential to the system's operations, for vessel surveillance, and for rebroadcasting information. Communication takes place initially on Channel 70 and subsequently on an additional duplex frequency which is different from one site to the next where radio coverage of these sites overlaps. The DSC protocol being used (adapted to comply with proposed Rec. ITU-R M.825 for use with vessel traffic systems) is recognized primarily for its robustness rather than its transmission speed. It is, however, recognized internationally and already includes a number of messages defined for MCTS applications.

With the GP&C/Norcontrol (AIS) broadcast system, shore sites are not necessary for vessels to communicate with each other; the fixed transponders installed at shore sites act as mobile stations and information received is transmitted to the MCTS centre; the fixed sites also serve as passive repeater stations for rebroadcasting traffic information received over a greater coverage area. The TDMA protocol used by the GP&C broadcast system performs much better but has not yet been adopted internationally for marine use. Other systems in use in other parts of the world also use a TDMA-type protocol, which could make it more difficult to standardize a single protocol.

The ship handling capacity of the (AIS)-DSC system is less than for the (AIS) broadcast system, in proportion to the rate of the protocol being used (1200 bps vs. 9600 bps). The maximum capacity is also limited in the same ratio (250 reports/minutes vs. 2250 reports/minute). The impact may or may not be significant, depending on the number of vessels being tracked. In order to track approximately 30 vessels, the Ross system would be limited to a reporting rate of every 10 seconds ($180/250$ vessels/minute = 72%) while the GP&C broadcast system tracking the same number of vessels would enable reporting every second, for a radio channel utilization rate that is almost the same ($1800/2250$ vessels/minute = 80%).

Operational Evaluation:

An (AIS) system for tracking vessel traffic is useful in areas that have a VHF communication system only (no radar surveillance). The (AIS) system provides accurate vessel positions, reducing the need to exchange information with the vessel, increases communication efficiency, facilitates decision-making and allows for a reduction in the vessel proximity safety margin.

Overall, the MCTS believes that an (AIS) system would be very effective for tracking vessel traffic, as long as all vessels are equipped. Information transmitted by MCTS centres to mariners generally involves an exchange of information (additional requests or other questions) between the stations, and it is likely that VHF voice communication would still be necessary.

Minimum (AIS) system requirements for MCTS centres are:

- position reporting rate of once every 1 to 2 seconds in high traffic port areas and at least once every 10 seconds in areas covered only by VHF;
- integrated radar and (AIS) control and display system;
- ability to track and display tags of several vessels simultaneously;
- ability of control and display system to record and act as a simulator.

Operational evaluation of the Ross system on board commercial vessels did not take place because the Ross transponders could not be interfaced with the ECDIS on participating vessels. The display systems (laptop) that were evaluated were found to be too small by some pilots and should be integrated into the on-board ECDIS systems used for electronic navigation. For pilots, any such system should above all provide them with the necessary information to steer the vessel, so that appropriate directions can be given to the helmsman.

Technical Performance:

The GP&C/Norcontrol system had better overall reliability. The Ross system (modems, radio, transponders and software) experienced a number of failures, modifications and updates over the course of the evaluation period, which brought down the reliability rate to approximately 50% until the month of August 1996. Since the last version of the system was installed at that time, the reliability rate has risen to approximately 75% (3 out of 4 sites operational).

Cost Effectiveness:

The costs involved in deploying the (AIS) infrastructures vary according to the territory to be covered. The Ross system costs less (approx. 30%). Vessel equipment costs vary a great deal depending on the type of equipment and the chosen configuration.

Any future installation of an (AIS) system could result in direct operational savings; however, these savings cannot be realized until all commercial vessels are equipped -subsequent to regulations being adopted to this effect. Potential savings were not quantified in this project.

Conclusion:

Availability and use of an (AIS) system in VHF coverage areas would be an advantage because it would allow for a reduction in the number of information exchanges between vessels, thereby optimizing radio communications. (AIS) complements the radar surveillance system in that targets can be automatically identified and displayed on radar. The system might eventually be considered as a replacement for radar, but it would have to be more reliable and could only be used in situations where all vessels are equipped with (AIS) transponders. (AIS) information reporting rates would also have to be sufficiently rapid (every 1 to 2 seconds) in areas currently monitored by radar.

The (AIS) messaging function is not, however, effective enough to replace all VHF radio communications that are also used to transmit brief and fast messages between MCTS operators and shipboard personnel (pilots, officers, etc). Availability of on-board (AIS) information would be helpful in decision-making, but this information should be integrated into the vessel's ECDIS. Trials of an integrated (AIS) and ECDIS, which were originally included as an objective in this project, were not completed by the CSA, which chose to concentrate instead on developing a new communication and positioning system using satellite technology.

Pilots want to know about traffic in their vicinity (approx. 15 km above and below the vessel). Therefore, an integrated (AIS)-ECDIS system would first and foremost have to enable them to make decisions about ship movement and headings so that instructions can be passed on to the helmsman. Pilots prefer to use VHF radio communications to relay information back and forth. They would, however, appreciate a system that would regularly broadcast shipping information (weather, traffic, etc.) on a screen, as long as the system did not require excessive keyboard use.

The (AIS)-Broadcast system definition requires a simpler shore-based infrastructure than the (AIS)-DSC to ensure ship/shore communication. This is especially true along a waterway that needs radio coverage from several adjacent sites. The system that uses the DSC protocol (Ross Engineering) is suitably adapted to collect position data transmitted to MCTS centres. However, this architecture that is based on the use of shore sites with various duplex frequencies is less efficient for rebroadcasting information to vessels, and particularly inefficient for communication between vessels. As with the DSC system, the architecture of the GP&C broadcast system allows for the reception of data transmitted by vessels; however, rebroadcasting data to vessels and ship-to-ship communication are simpler through the use of a single frequency.

The ship handling capacity of the (AIS) broadcast system is 10 times greater than for the (AIS)-DSC system. This greater capacity means that the (AIS) broadcast system can track several dozen vessels at a reporting rate of once every 1 or 2 seconds, which is a requirement for both MCTS within ports (as a possible replacement for the radar surveillance system) and for vessels that are approaching or following each other (convoy).

The cost for a shore-based infrastructure capable of receiving, displaying (at the MCTS centre) and rebroadcasting (AIS) information increases in proportion to the amount of coverage and the number of sites required. Costs vary between \$229K and \$386K depending on the technology and the number of sites under consideration (3 to 5 sites) for an average of approximately \$77K per site. The costs involved in implementing an (AIS) system in areas currently covered by radar would be in the order of \$230K, depending on the technology, and for the entire territory (Montreal to Sept-Iles), in the order of \$385K.

The costs for shipboard equipment are less with the Ross (AIS)-DSC system which offers a \$6.7K option that includes a DSC unit and an (AIS) interface that can be linked to the vessel's GPS or ECDIS. The (AIS) transponder that comes with the broadcast system includes the GPS and sells for \$15K, or more than double the (AIS)-DSC option.

Recommendations:

1. Support IMO development of a performance standard for an (AIS)-Broadcast system and adoption of international standards for marine use;
2. Study at the national level the advisability and feasibility of using and implementing (AIS) according to the existing CCG radar or VHF coverage areas;
3. In conjunction with involved parties, complete a detailed evaluation of the potential real benefits of using an (AIS) system for the CCG and the environment as well as for the shipping industry;
4. In conjunction with the GCC-RL Marine Programs Branch evaluate the possibility of optimizing our (AIS) infrastructure and equipment that are in use in our region, particularly for traffic-tracking, ice-breaking, search and rescue, and dredging surveillance operations;
5. Evaluate the feasibility of using an (AIS) satellite system in areas that are not covered by shore sites (Gulf and Arctic);
6. Continue working toward integration of (AIS) with onboard ECDIS and the CCG's INNAV system.

Participants Post Project Comments

Various comments, solicited from project participants and interested parties, received after review of the circulation of the Draft report in April 1997 are included as Appendix I.

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TABLE OF CONTENTS (cont'd)**LIST OF ABBREVIATIONS AND ACRONYMS**

AIS:	Automatic Identification System
ECS:	Electronic Chart System
ECDIS:	Electronic Chart Display and Information System
DSC:	Digital Selective Calling

1. DESCRIPTION OF (AIS) SYSTEM

Automatic Identification System (AIS) is a new technology that has the potential to greatly improve Vessel Traffic Services (VTS) and marine industry operations. Using a Global Positioning System (GPS) to determine position and a VHF telecommunication channel, a participating vessel can relay its position as well as other important identification parameters to a VTS centre on shore and/or to other vessels in the vicinity.

2. CONTEXT

2.1. MCTS CONTEXT - COMMERCIAL SHIPPING

The mandate of the Canadian Coast Guard (CCG) is to ensure that vessels travel through Canadian waters efficiently and safely while respecting the environment. In order to fulfill its mandate, the CCG operates Marine Communication and Traffic Service Centres (MCTS) which monitor and co-ordinate vessel traffic in specific sectors under their control. MCTS centres also broadcast a wide variety of information to assist mariners in navigating Canadian waterways efficiently, safely and with respect for the environment.

To provide these services, MCTS centres use radar surveillance systems and mobile marine radio communication networks. This equipment enables MCTS centres to track vessel movement and to communicate with ships when necessary.

In order to reduce costs and increase efficiency, CCG personnel are having to evaluate and study the potential of new systems coming out of the latest technological developments.

Figure 1 illustrates the (AIS) system definition in addition to current communication and tracking systems used by MCTS centres.

2.2. PROJECT CONTEXT

In the fall of 1994, the Canadian Coast Guard (CCG) was about to award a contract for the purchase of a new radar VTS for its centre in Sarnia. The intention of the project was to deploy three new radars located, respectively, at the north and south entrances of the St. Clair River at Bluewater and at Bar Point, and the third at the Sarnia VTS centre itself. However, the Canadian marine industry, represented by the Marine Advisory Board, persuaded the Canadian Coast Guard Commissioner to cancel the project, arguing that radar use would unjustifiably increase VTS systems costs in general and that there were more appropriate and less costly technologies available that would produce the same results. The proposed technology was the Automatic Identification System (AIS). Following a number of lively debates between the CCG and the Canadian marine industry, the project was canceled.

Context

However, at that time, neither side had in-depth knowledge about the operational and technical specifications of the technology, nor an accurate idea of what it would cost to implement. As a result, the CCG and the marine industry formed a study group to examine the technical feasibility of implementing a DGPS (AIS) system for the Detroit/St. Clair River system between 1995 and 1998 with particular reference to availability of reasonably priced shipboard equipment and alternative means of transmitting data to shore and to other vessels.¹ The study group was made up of three independent working groups with each one looking into a specific aspect of the problem as follows :

Working Group A examined VTS operational requirements and industry requirements.

Working Group B examined the technical feasibility and costs involved.

Working Group C examined the requirements and commitments of a universal shipboard system.

Reports from these studies were to be submitted orally to the Marine Advisory Board on January 31, 1995 and “published before February 24, 1995”.² Although the oral presentation to the Marine Advisory Board did finally take place, a written report was never submitted. Nevertheless, the Marine Advisory Board and the Canadian Coast Guard concluded that there were too many unknowns and too many unanswered questions regarding application of the new (AIS) technology to proceed immediately with formal implementation of the project at Sarnia VTS. The CCG and the Marine Advisory Board therefore decided to develop an (AIS) pilot project which would include a detailed study of the many operational and technical factors that might influence introduction of (AIS) in Canada. The two agencies decided that the pilot project would take place in the sector that covers the St. Lawrence between Montreal and Quebec.

The management and implementation of this pilot project were assigned to a project team made up of three committees, each one with its own area of responsibility. The (AIS) Steering Committee was responsible for general management and control of the project. The Project Management Committee undertook comprehensive planning, co-ordination and management of the pilot project. Responsibility for routine operation of the project, specific trials and recording of results were assigned to the Project Implementation Committee - Laurentian Region. Appendix H provides the current list of members on each of the three committees.

¹ Terms of Reference: Study Group on (AIS) Application to Sarnia VTS, December 2, 1994.

² Terms of Reference: Study Group on (AIS) Application to Sarnia VTS, December 2, 1994.

AIS SYSTEM DEFINITION

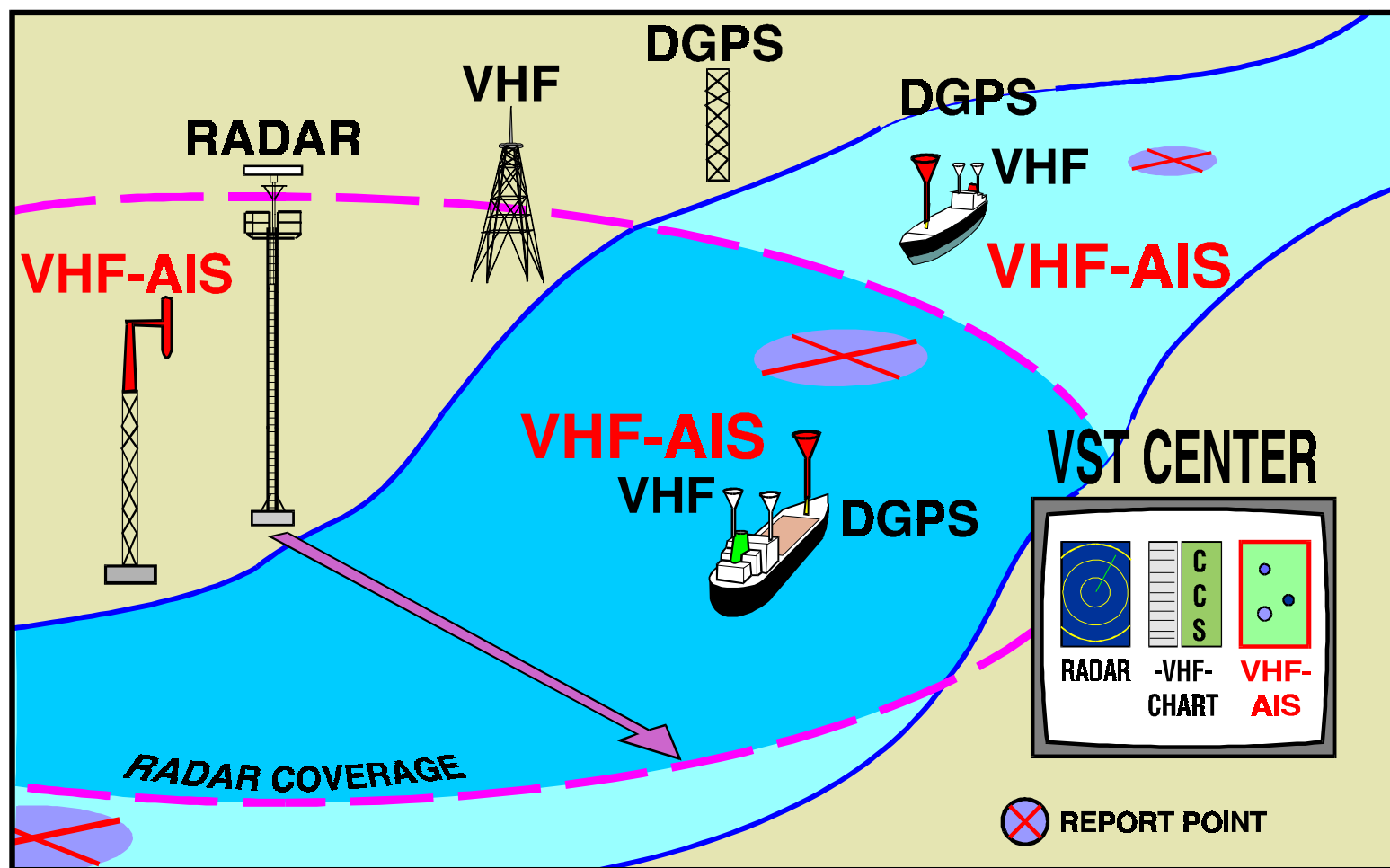


Figure 1 - (AIS) System Definition

3. PROJECT OBJECTIVES

The primary goal of this joint CCG and marine industry R&D project is to install and evaluate 2 (AIS) technologies on the St. Lawrence River between Quebec and Montreal.

The main objectives of the project are to:

- Install and evaluate 2 (AIS) technologies between Quebec and Montreal;
- Evaluate use of the (AIS) system with marine industry ships, pilots and CCG vessels;
- Assess the possible applications and economic advantages to the CCG and marine industry of using the (AIS) system.

Based on the primary objectives, several specific objectives were subsequently identified. Four (4) participants in the project - two (2) representatives from the marine industry (CSA and Shipping Federation) and two (2) groups from within the CCG (MCTS and Technical Services) - took part in developing the project's specific objectives.

These objectives were analyzed and divided into 14 test modules containing similar goals. Detailed tables in Appendix A provide all of the participants' objectives as well as the level to which each of the objectives has been achieved.

4. SCOPE OF THE REPORT

This report contains the findings of the (AIS) pilot project conducted jointly by the Canadian Coast Guard (CCG) and the marine industry between March 1996 and December 1996 on the St. Lawrence River between the cities of Montreal and Quebec. Two competing (AIS) technologies were tested, the first using a Digital Selective Calling (DSC) protocol and the other using a Self-Synchronizing Time Division Multiplex Access (STDMA) protocol.

The report describes the infrastructures put into place and their system definitions which fulfills the first objective of the project.

The report also describes the methodology used to evaluate the installed (AIS) systems and the results that were obtained. It also describes the operational and technical analysis, thereby fulfilling the project's second objective.

An assessment of how much it would cost to implement an (AIS) service based on various options and their potential economic advantages for MCTS centres and the marine industry are also contained in this report.

Recommendations derived from the evaluation's conclusions will be made, with consideration being given to current trends and international standardization.

5. DESCRIPTION OF EVALUATED SYSTEMS AND TEST BED

This section describes the architecture and system definition of the two (2) systems that were evaluated. Trials conducted between Quebec and Montreal are also described, as well as the ease with which the systems were set up and implemented and the resources that were committed to completing this project.

5.1. NORCONTROL/SSC SYSTEM

5.1.1. Description of the System

The system supplied by Norcontrol (principal supplier) is based on use of the Swedish Space Corporation (SSC) GP&C broadcast transponder. This transponder runs on a TDMA protocol (Time Domain Multiple Access) which features use of a single radio frequency divided into 2250 time slots/minute, and is therefore able to accommodate up to 2250 reports/minute.

Synchronization of transponder communications relies on the GPS's precision clock included in each unit. GPS accuracy allows for the least amount of time between messages. Information is transmitted asynchronously on the radio channel.

Two (2) operating modes are possible: autonomous (or 'slave') and controlled (or 'master'). Mode selection is parameterized in the units and the mode must be selected when the equipment is being configured.

- In slave mode, the assignment of time slots is controlled by each transponder in accordance with a sophisticated algorithm that avoids "message collisions". This was the only mode used during trials.
- In the second master mode, time slots are assigned by a shore-based station which, among other things, determines how often reports are to be transmitted.

The transponder is made up of a 6-channel Leica/Magnavox GPS receiver, a communications processor and a VHF radio operating in the aviation band (118 - 142 MHz). Its primary functions are to determine position and transmit this information, including information identifying the mobile user, on the communication channel. The transponder also receives similar information transmitted by other transponders. The VHF radio has an output level of 10W, is software-controlled, and can communicate on the radio band at a gross rate of 9600 bps.

The same type of transponder (using a different configuration and parameters) in slave mode can be used either as a mobile or shore station. A shore station can also be configured as a repeater station, thus allowing rebroadcasting of messages or reports received in a given sector (over often greater distances, depending on the type of installation).

Transponder output takes place via a serial communication port at 9600 bps and information is displayed on a navigation system or compatible display.

In our project, both MCTS control centres and ships used display systems supplied by Norcontrol. The shipboard displays were laptops that use essentially the same software as the computers at MCTS which are table-top models with 21-inch screens.

5.1.2. Communication Protocol

Radio Communication Protocol:

The GP&C transponder's radio communication protocol uses messages that are 256 bits long and are transmitted at 9600 bps which sets message length at 26.67 ms. At this speed, 2250 messages per minute are possible. The modulating system used is the Gaussian Minimum Shift Keying (GMSK).

The communication link can be used in 'master' mode or 'slave' mode. In slave mode, which was used in our evaluation and is recommended for marine use¹, each transponder first listens to communications over the radio link for approximately 3 minutes in order to seek and use an available time slot.

A certain number of bits from each message are used to complete the automatic organization of slave mode. These bits are used to identify and take over a time slot to be used for the next message. Other vessels within the VHF coverage area will therefore be able to determine which time slots are available for their own use. This reduces the risk of 'message collisions; and corrupted messages that might be caused by transponders using the same time slots.

Each message has the following format:

Preamble	Start Flag	Data block	CRC	End Flag	Pause
5 bytes	2 bytes	20 bytes	2 bytes	1 byte	2 bytes

The data block (20 bytes) is made up as follows:

Bits	Designation	Note
8	Message type	
40	Mobile identification	
6	Type of ship	
2	Navigation status	
24	Latitude	
25	Longitude	
11	Speed over ground (SOG)	
12	Course over Ground (COG)	
9	Heading	
6	Time stamp UTC seconds	
1	GPS sync	
1	Position sensor accuracy	
13	Time-slot allocation	
2	Number of allocated time-slots	
160		

¹ *Navigational Aids and related matters - VHF Transponder Using The GP&C (GNSS) Technique*, Technical information paper submitted by Sweden for the 41st Session of the IMO Sub-Committee on Safety of Navigation, Fall 1994.

Serial Link Communication Protocol:

Communication between the transponder and the control station or navigation system (ECS or ECDIS) takes place via a serial link and a different protocol using ASCII characters. Depending on the configuration, messages can begin with \$PRGPS, which makes them compatible with the NMEA-0183 standard. Where NMEA compatibility is not a requirement, the header is left out (with the \$ character only designating the beginning of the message), thus reducing the length of the transmitted message. For example:

Position Message (Input and Output):

\$ITTTTTTTTXXXXXXXXYYYSSDDDDZZZZNTTS*##+CR+LF, where:

I= type (1*ASCII HEX) 1= own position 2= other ship position

T= 8-character identification i.e.: RADISSON (8* ASCII)

X= latitude in 1/1000 min. (7* ASCII)

Y= longitude in 1/1000 min. (7*ASCII)

S= speed in knots (3* ASCII)

D= heading in 1/10 degrees (3* ASCII)

Z= altitude in feet (5* ASCII)

N= navigation status (1* ASCII), 3 = 3D navigation

T= time stamp UTC seconds UTC (2* ASCII)

S= free

With a 9600 bps link, messages in this ASCII format will last 45.8 ms., with a maximum of 21 reports/sec., or 1260 reports/minute. In order to take advantage of the radio protocol efficiency, a 19200 bps link should be used.

5.1.3. System Architecture

The system's architecture is based on one set of equipment that can be used as a ship-board transponder or at shore stations to transmit, receive and rebroadcast messages and vessel information.

Each of the shore stations is linked to a control and display station via a 9600 bps digital telephone line. Two (2) shore stations were installed, one at Mont-Bélair (near Quebec) and the other at Sorel, to ensure continuous radio coverage from Montmagny to just east of Montreal.

Figure 2 shows the architecture of the GP&C/Norcontrol broadcast system under evaluation.

GP&C ARCHITECTURE NORCONTROL / SSC SYSTEM

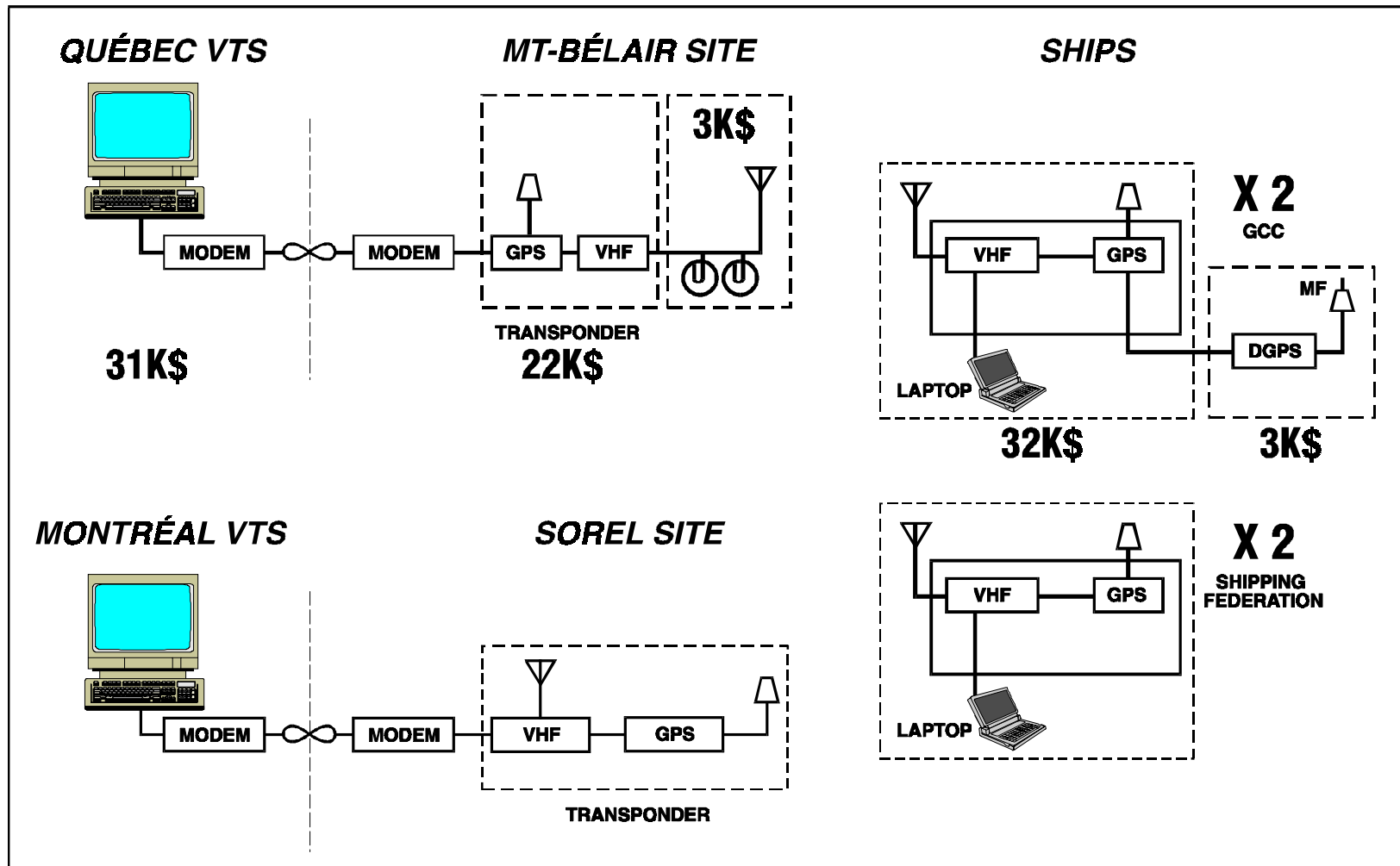


Figure 2 - Architecture of the GP&C NorControl (AIS) Broadcast System

5.2. ROSS ENGINEERING SYSTEM

5.2.1. Description of System

The system supplied by Ross Engineering is based on the use of a transponder that includes a 12-channel Trimble DGPS receiver, an (AIS) controller and a DSC-500 radio operating in the VHF marine band. These transponders can transmit and receive position and information reports on participating vessels via common Channel 70 and on the selected duplex working frequency.

The system's communication protocol is based on Digital Selective Calling (DSC) modified for marine traffic services. Information gathered by the transponder is processed and directed via a serial port to an ECS-type display and navigation station supplied by Ross Engineering. Transponder information is also available in an NMEA format compatible with standardized ECDIS systems.

DSC-500 radios configured with the AIS-VTS protocol and linked to a shipboard GPS receiver are also used to increase the "population" of targets (vessels) on the river and transmit their positions to shore. These mobile units can also be linked to a shipboard display or navigation system through the addition of an independent (AIS) controller (only available since the fall of 1996) to display a vessel's own position and those transmitted by other vessels.

The Ross Engineering system definition requires a shore station using 2 VHF channels, i.e., Channel 70 as a calling frequency and a duplex working channel to which ship-shore communications are then transferred, thus keeping the calling channel open. Each of the shore sites is linked via telephone line to a control and display terminal at the MCTS centre.

5.2.2. Communication Protocol

The general communication protocol used for DSC is defined in ITU-R Recommendation 493. Each message is made up of a specific number of fields containing information about the sender and receiver of the message, the type of message, its content, etc.

Frequency Shift Keying (FSK) type modulation is used at 100 bps in the MF or HF band and at 1200 bps in the VHF band. The DSC protocol uses a 10-bit format for each transmitted character; 7 bits are used to define the character and three are reserved as "checksum" to check the individual reception of each character. Under the original DSC protocol, each character is also transmitted twice at various predefined intervals in order to increase transmission redundancy and dependability.

This original DSC protocol therefore adheres to fairly strict standards (particularly for digital transmission). The number of different message types and the amount of data that can be transmitted via these messages is somewhat limited. The primary objective of the DSC protocol is to provide improved emergency call service and not a digital communication service. Modifications to the original protocol have therefore been proposed, particularly for use in vessel traffic services.

ITU-R Recommendation 825 defines the use of messages for transmitting positions and other vessel information and information about vessel movements, as well as the transmission of text documents. From the original DSC format, Recommendation 825 maintains the use of 10 bits per character but does away with the necessity of re-transmitting each character twice on the duplex channel, thereby reducing transmission time and increasing overall capacity.

Ross Engineering installed in the system we evaluated during our trials the latest modifications that are proposed to Rec. ITU-R M.825, according to which each position report is 25 characters long at 10 bits per character transmitted at 1200 bps, which means a transmission length of 238.266 ms. per report. A volume of slightly more than 4 reports per minute are therefore possible.¹

5.2.3. System Architecture

The system architecture is based on a network of shore-based communication sites, each linked individually via a dedicated digital telephone line to a control and display station at the MCTS.

Each site on the network uses 2 frequencies: the common Channel 70 and a separate duplex channel. Four shore sites were installed to provide coverage for the entire network - at Lauzon, Trois-Rivières, Sorel and Longueuil.

Figure 3 illustrates the architecture of the Ross Engineering (AIS)-DSC system.

¹ "Preliminary draft proposal to modify recommendation ITU-R M.825", Characteristics of a transponder system using digital selective calling techniques for use with vessel traffic services and ship-to-ship identification - High efficiency transponder, Question ITU-R 28/8, Document US8BX 10, September 4, 1996, Working Party 8B.

ROSS SYSTEM VHF-DSC ARCHITECTURE

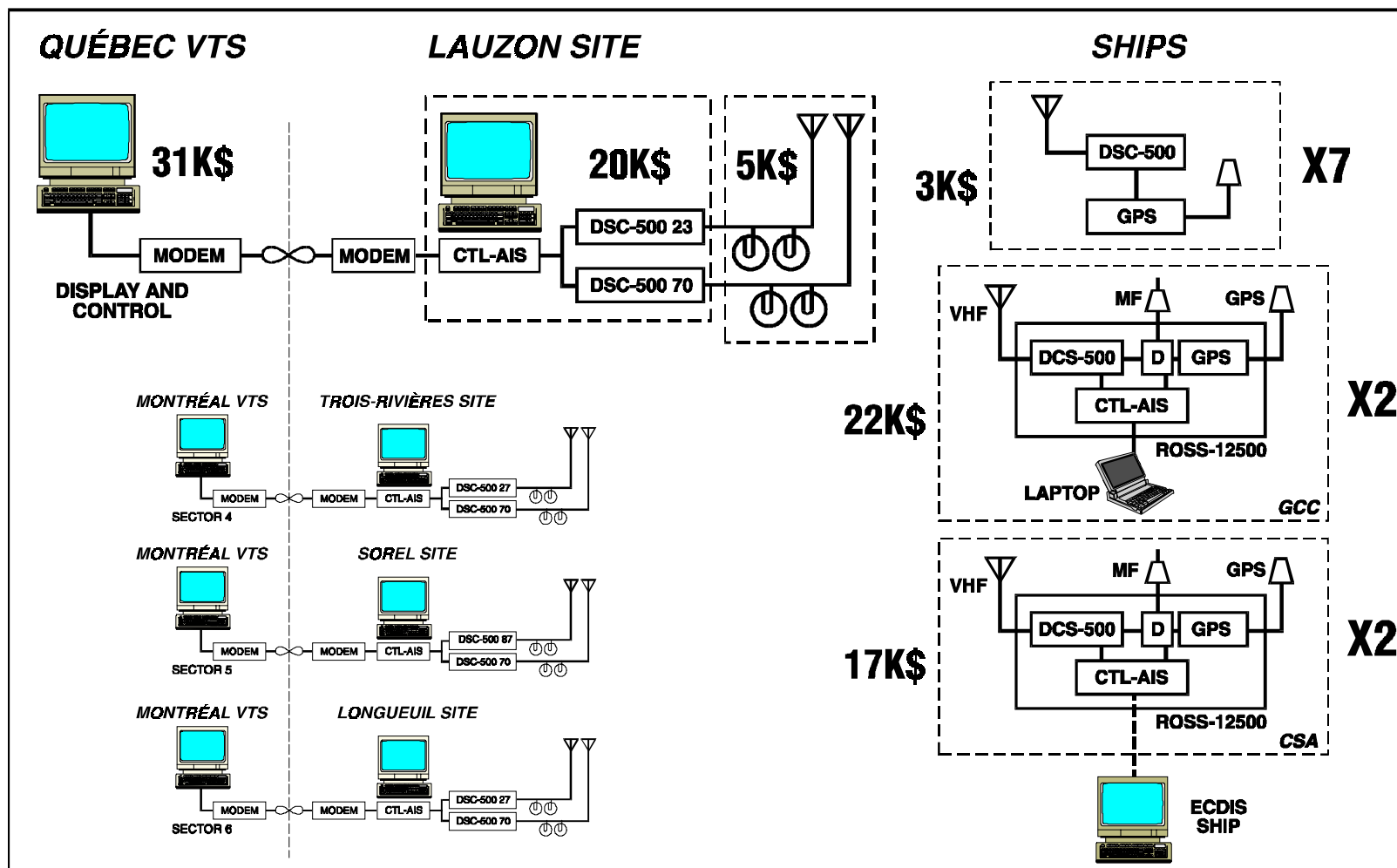


Figure 3 - Architecture of the Ross Engineering (AIS) DSC System

5.3. DESCRIPTION OF TEST BED BETWEEN MONTREAL AND QUEBEC

A. Ross Eng.

The system developed by Ross was originally designed to be used for traffic surveillance within an area limited to a single shore-based control site. For our evaluation, 4 shore sites were installed to ensure radio coverage from Quebec to Montreal. Three sites (Ile Charron, Sorel and Trois-Rivières) were linked by telephone line to the MCTS centre in Longueuil. The fourth site, Lauzon, was linked to the MCTS centre in Quebec.

A control and display station was installed for each of the MCTS traffic sectors, i.e., 1 in Quebec (Sector 3) and 3 at Longueuil (Sectors 4, 5 and 6).

The Quebec sector (Lauzon site and MCTS-Quebec) was installed over the summer of 95 and was functional with an initial version of the software by July of 1995. Installation at the three other sites and the Longueuil MCTS centre was carried out during the fall of 1995 and January 1996. Ship installations took place over the same period.

We should point out that, to our knowledge, this type of deployment of several sites along the shores of a river is a first. Using several adjacent sites to provide complete radio coverage also has the additional challenge of providing operations that are both transparent to the user and interference-free (see Sections 7.1.1 and 7.1.3). Other known examples where Ross Engineering's DSC protocol is being used are generally at harbour entrances (Tampa Bay, Tofino, Los Angeles, etc.) where a single communication site is used, and where there is no risk of interference and no information to be managed between sites.

B. GP&C

A first shore installation was set up at the Mont-Bélair site and linked by telephone line to MCTS-Quebec in the fall of 1995.

The system functions on a single frequency of 142.25 MHz. This feature allows for direct two-way ship-to-ship and ship-to-shore communication.

Installation of the GP&C/Norcontrol system began in September 1995 at Quebec and was completed in December 1995 with relocation of the Mont-Bélair shore site.

A second GP&C site was then added in May of 1996 at Sorel, at the same site where a Ross shore station had been installed. Sorel is the only location where the 2 systems are at the same site. This allows us to compare the respective coverage for each technology.

Four vessels were equipped with GP&C transponders - 2 commercial vessels (*Le Brave* and *Emerald Star*) and 2 CCG vessels (*Radisson* and *Laurier*). Shipboard installations took place during the fall of 1995 and the vessels operated through the winter and the spring of 1996.

As of February 26, 9 ships were equipped with one or other of the two types of VHF-DSC transponders. The diagram in Figure 4 shows the deployment of the equipment over the territory and over the participating vessels for both of the technologies being evaluated.

Due to changes in the assignments of CCG vessels and some commercial vessels, mobile units were reallocated and Figure 5 illustrates how the equipment was deployed on the participating vessels as of September 20, 1996.

Table I shows the capabilities of the various types of transponders that were used.

Table I
Transponder Capabilities

Type of transponder	Position TX-RX	Position TX only	Display system	Display system
			Laptop	ECDIS
GP&C	X		X	not available
Ross DSC-12500	X		X	not available
DSC-500		X	N/A	N/A

Table II provides the physical characteristics of the facilities and the theoretical coverage that can be expected.

Table II
Characteristics of Facilities and Theoretical Coverage

(AIS) System	Radio site	Antenna height above sea level	Transmitter strength	Theoretical radio coverage
(AIS)-DSC Ross Eng.	Ile Charron	45 metres	7.5 / 25 watts	60 km
	Sorel	21 metres	7.5 / 55 watts	45 km
	Trois-Rivières	33 metres	7.5 / 55 watts	115 km
	Lauzon	158 metres	25 / 55 watts	100 km
(AIS) Broadcast GP&C	Sorel	44 metres	10 watts	35 km
	Mont-Bélair	350 metres	10 watts	150 km

AIS COVERAGE OVER THE TERRITORY

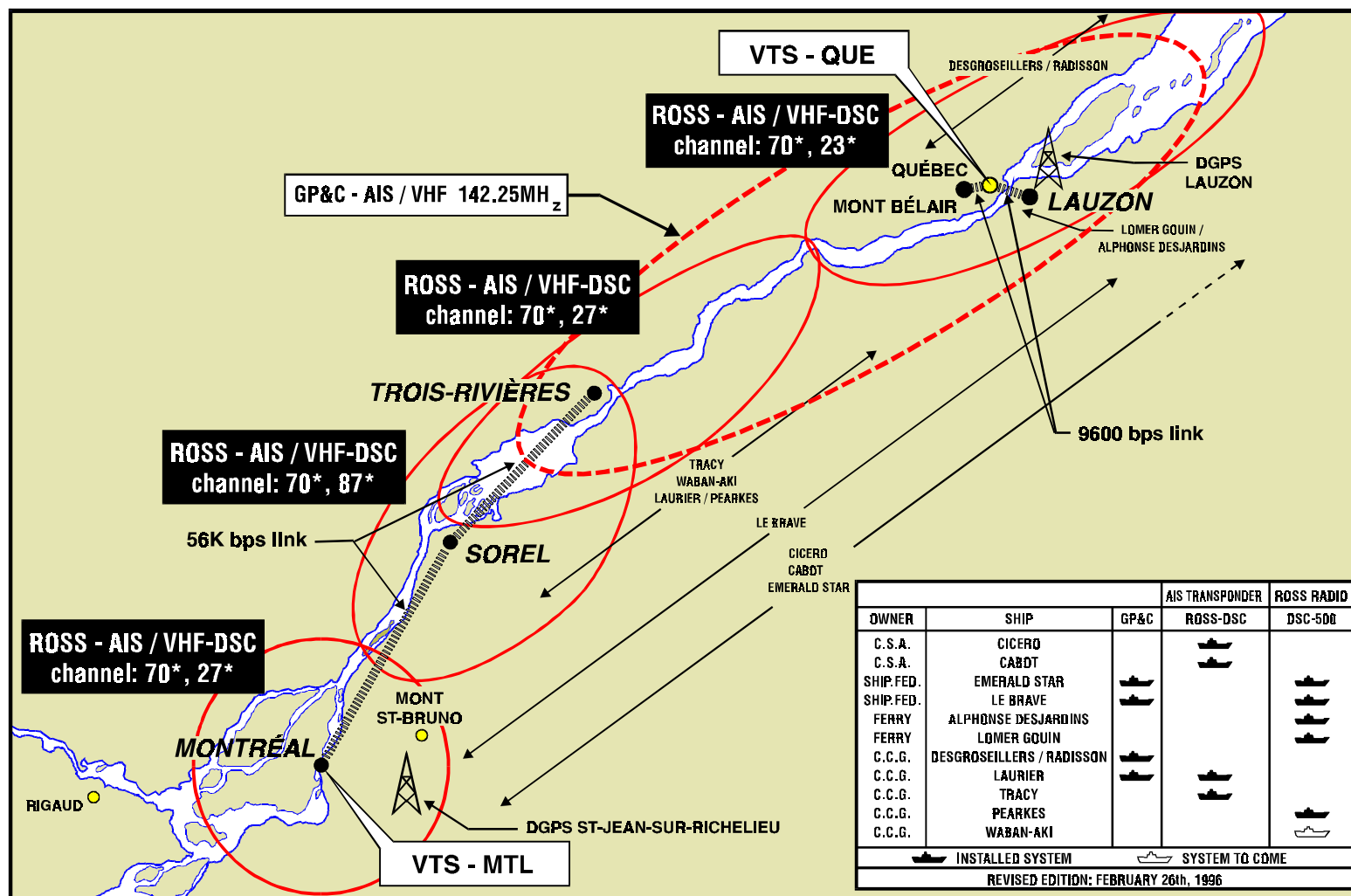


Figure 4 - Deployment of equipment for the two technologies under evaluation (February 1996)

AIS COVERAGE OVER THE TERRITORY

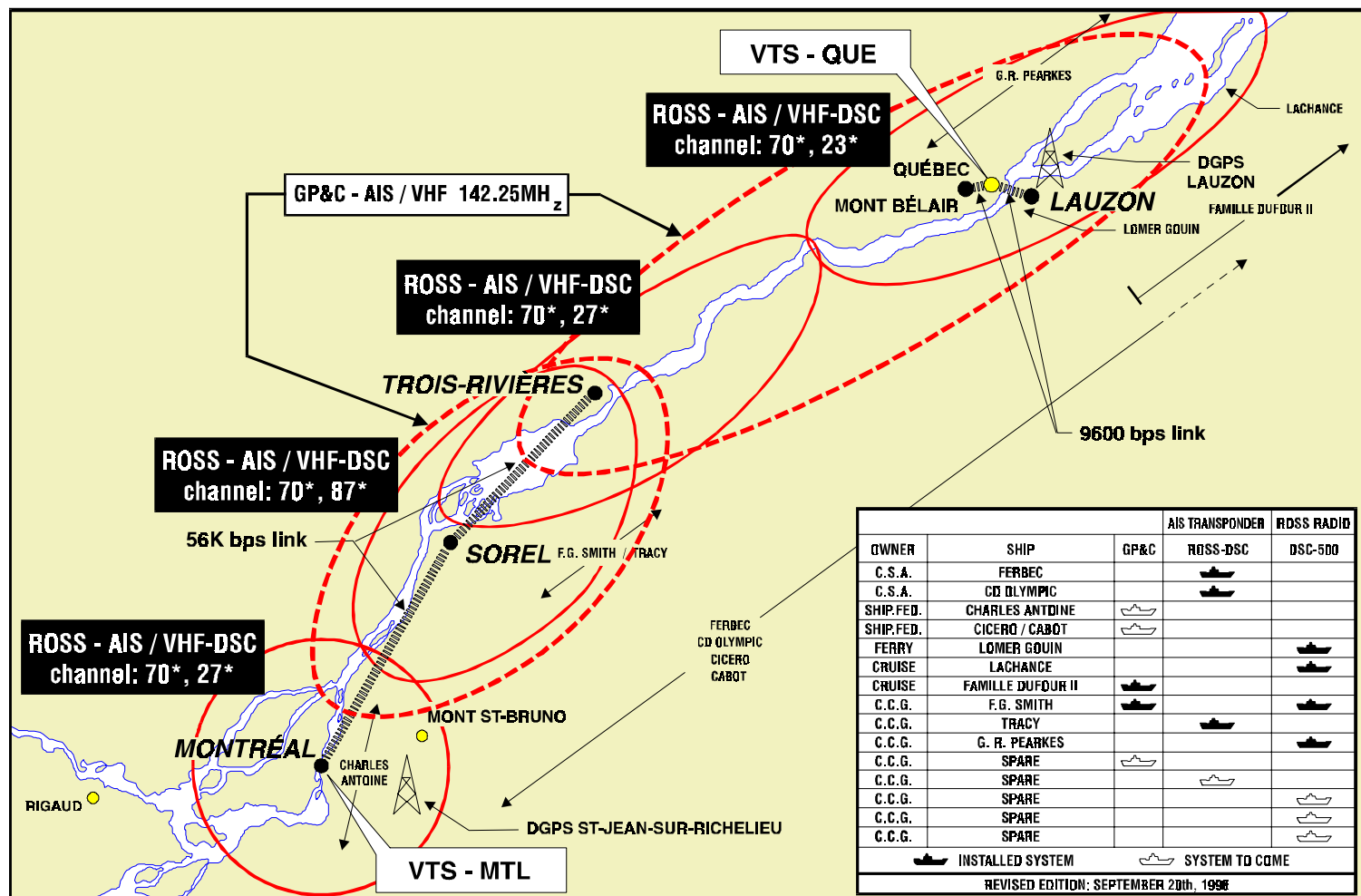


Figure 5 - Deployment of equipment for the two technologies used (September 1996)

5.4. INSTALLATION AND START-UP

This section describes what was involved in setting up the (AIS) test bed and the major difficulties in getting them up and running.

It should be noted that a great deal of unscheduled time (approx. 6 p/m) had to be spent on the Ross system alone (as compared to the GP&C system) in order to get it operational and for technical support after it was initially installed. This was the result of the many system failures and frequent updates of the equipment and software. The unreliability of the Ross system significantly limited the level of evaluation and operational trials that could be conducted.

From March 1995 to September 1996, a total of 25.75 person-months and a budget of \$475K had been expended on the project by the various participants. The CCG alone committed 20 person-months and \$375K. Table III indicates the time and budgets committed to the project by each of the participating groups. A detailed list of resources spent on each of the systems and project activities is provided in Appendix B.

Table III

Time and budgets committed to the project

	CCG	CSA / SHIP.FED	PILOTS	CHS
Total Time	20 p.m.	4 p.m.	0.75 p.m.	1 p.m.
Budget (\$K)	\$ 375K	\$100K		

5.4.1. Ross Engineering.

The Ross Engineering system, based on use of Channel 70 (156.525 MHz) and additional duplex channels, required additions or modifications to antenna and filtration systems at the communication sites being used. The proximity of some MCTS working channels to the new frequencies that had to be added - particularly Channel 10 (156.5 MHz) at Longueuil - even made it necessary to relocate to Ile Charron the site originally planned for the MCTS centre at Longueuil to cover Sector 6 (Port of Montreal-Cap St-Michel).

This technology requires a significant amount of installation at the sites, but could be simplified by dropping some duplex channels (proposal currently under consideration by MCTS). This reduction would allow some infrastructure (antennas and cavities) or even existing frequencies to be reused.

In addition, throughout the project, Ross Engineering had to make changes to system equipment and software. These modifications were necessary to correct various problems that were preventing the system from functioning properly and also to increase performance (particularly with regard to ship handling capacity). These numerous changes required CCG personnel to return frequently to all the sites and vessels, thereby delaying valid trials. Table IV outlines the various changes and installation stages required by the Ross Engineering system during the evaluation period:

Table IV
Changes and Installation Stages
(Ross Engineering (AIS)-DSC System)

Period	Ross Engineering System Stage/Activity
Summer 95	Installation and start-up of Quebec/Lauzon site on Channel 70
Fall 95	- Installation and start-up of 3 Montreal sector sites and Longueuil MCTS centre on Channel 70 - Software update for operations with working duplex channel
Jan. - Mar. 96	- Several hardware and software updates conducted by CCG personnel according to instructions from Ross Engineering - Partial training (mid-January) from Ross Engineering (L. Simpson) stopped because of erratic functioning of system - Necessary correction to cavities systems (Lauzon) - Reduction in output power of Ross transmitters and addition of exterior amplifiers (Lauzon and Trois-Rivières) - Installation of first version of software capable of fast reporting (Rec. 825) - Hardware and software updating (end of February) at sites and mobile stations by Ross Engineering technician - Corrections made by CCG personnel to INIT files at the sites after visit by Ross Engineering technician - Replacement of Ross modems (dial-up lines) by CCG multiplexers (dedicated digital lines) (Sorel and Trois-Rivières)
April - July 96	- Sub-standard functioning of system - Weak radio sensitivity (-55 dBm) - Conflict in vessel assignment versus assignment tables; system sensitive to operator keying (log in/log out) and causing assignment conflicts¹ - Replacement of Ross modems (dial-up lines) by CCG multiplexers (dedicated digital lines) (Lauzon)
August 96	Major updating of hardware and software by Ross Engineering technician to install new functional version in accordance with the latest version of modified Rec. ITU-R M.825 with fast reporting and transmission of ASCII-coded messages
Sept. - Dec. 96	- Functional within a single zone controlled by the same shorebased site - Erratic functioning when changing areas and working frequency - Replacement of Ross modem (dedicated line) by CCG Motorola (dedicated analog line) (Ile Charon)² - Modification (Nov. 96) of parameters for transmission interval of 'all ship call' (2 to 5 minutes) - System functional over several adjacent sites (Dec. 96)

¹ See detailed description of problems in Appendix E

² See detailed description of problems in Appendix E

5.4.2. GP&C/Norcontrol

Installation and activation of the GP&C system, and the first site at Quebec, was completed in two weeks in the fall of 1995, and the system was functional as soon as it was activated. The company provided very good support during set-up and acceptance. Good training was also provided during this period. A second site at Sorel, controlled from the MCTS centre at Longueuil was installed afterwards and was activated by CCG personnel in the spring of 1996.

The system currently operates on the aviation VHF band (118-142 MHz) and presents little or no risk of interference at our sites. However, use of this band has only been authorized for the duration of our trials. A VHF frequency in the marine band would have to be requested at the international level, in order to get licensing approval for marine operations.

We also noted interference on a vessel when the (AIS) system VHF antenna was too close to the television reception antenna which was a wide-band variety. The problem was corrected by adding adequate filtration on the television antenna. Table V shows the various changes and installation stages involved for the GP&C/Norcontrol system during the evaluation period:

Table V
Changes and Installation Stages
(GP&C/Norcontrol (AIS)-Broadcast system)

Period	GP&C/Norcontrol (AIS)-Broadcast System Stage/Activity
Sept. - Oct. 95	Installation and activation of control station and Quebec site at 101 Champlain on a temporary radio frequency
December 95	Relocation of remote site to Mont-Bélair Use of a new radio frequency (142.255 MHz) authorized by Industry Canada for the duration of the trials
April 96	Installation of a second site at Sorel and control station at MCTS Longueuil

6. EVALUATION METHODOLOGY (TESTING PROCEDURES)

6.1. LEVEL OF EVALUATION

Evaluation of the (AIS) systems under consideration can be divided into 3 different levels:

1. Comparative study and analysis of the two (2) technologies being used - (AIS)-DSC (Ross Engineering) and GP&C (AIS)-Broadcast (Norcontrol/SSC); this first level of evaluation was conducted mainly at the technical level but also at the operational level, particularly with regard to the user interface.
2. Evaluation of (AIS) system, regardless of technology being used, as compared to conventional systems (radar, VHF); this second level of evaluation was addressed primarily through operational evaluation.
3. Evaluation of each system's respective technical specifications and performance; this third level of evaluation was addressed at the technical level and involved checking the adequate functioning of each of the systems as well as their performance characteristics.

The respective approaches of these three levels helped to compare two different technologies and assess the characteristics and the advantages and disadvantages of each. The first level of evaluation was addressed first because it served to present the architecture and the principle of operation of the systems under consideration. The second level of evaluation dealt more particularly with the operational requirements for using (AIS) systems, regardless of the technology. The third, and last, level of evaluation was more of a technical verification of the characteristics and performance of each of the two systems being evaluated based on the specifications guaranteed by the respective manufacturers.

In order to meet both the operational and technical objectives set out for the project, several test modules, evaluation scenarios and observation checklists were developed. (See Appendix A).

Evaluation of the (AIS) systems under consideration was conducted as follows:

- Use and observation of control and display systems by MCTS operators
- Use and observation of display laptops by officers on board equipped CCG and commercial vessels
- Evaluation and presentation to pilots during transit between Quebec and Montreal aboard *Le Brave*
- Performance measurement and technical evaluation of the two (2) technologies both in the shop and on an equipped vehicle
- Theoretical and analytical assessment of the two systems being evaluated (architecture, protocol, etc.)

6.2. COMPARATIVE STUDY AND ANALYSIS OF THE 2 TECHNOLOGIES

We evaluated and compared the definitions and architectures promoted by each of the two (2) systems under evaluation, bearing in mind the specific requirements of an (AIS) system along a waterway such as the St. Lawrence River. We therefore evaluated the type of infrastructure that would be necessary to support both the needs of vessel traffic services (position reports) and the principal requirements of mariners (vessel traffic reports, information and collision avoidance system).

We therefore paid particular attention to:

- the definition and infrastructure deployment that would be necessary for river applications versus port applications;
- installation requirements for shorebased communication sites;
- the infrastructure required to ensure ship-to-shore, shore-to-ship and ship-to-ship communications.

6.3. OPERATIONAL EVALUATION OF (AIS) SYSTEM

The (AIS) systems' functional capabilities were evaluated by various users, primarily MCTS operators who compared and commented on the use of (AIS) in vessel traffic services. Comments were also provided by CCG and commercial vessel crew members and some pilots who used the laptop electronic chart systems (ECS) linked to the (AIS) transponders.

6.3.1. Use/Observation Under Operating Conditions by MCTS Centres

Operational evaluation took place by using and observing control and display stations installed at MCTS centres. It is important to emphasize that the operational evaluation was therefore partially focused on the user interface, even though the user is to a certain extent independent of the system technologies under consideration (AIS-Broadcast vs. AIS-DSC).

MCTS operators evaluated the operational performance of the (AIS) systems based on their traffic regulation needs, i.e., position report, traffic surveillance, accuracy of (AIS) vs. radar, communication, etc.

6.3.2. Use in Ship Operations

The Norcontrol system was installed and used on the commercial vessels *Le Brave* and *Emerald Star*. Two (2) systems were also shared among CCG vessels *Radisson*, *Desgroseillers*, *Laurier* and *F.G. Smith*. Two laptops for displaying the Ross system were also installed on CCG vessels *Laurier* and *Tracy*.

Officers aboard the participating ships evaluated the (AIS) system's functional capabilities primarily through the use of an installed laptop display which enabled them to see the movements of other vessels also equipped with compatible transponders. Test module TE.18 was used to gather comments regarding on-board use of the system from the CCG's shipboard personnel.

The two commercial vessels equipped with the GP&C system had the advantage of a complete operational system - for mutual display of their own positions and those of equipped CCG vessels. The Norcontrol display system also enabled them to experiment with electronic messaging. One of the two vessels, *Le Brave*, traveled

between Quebec and Montreal an average of 2 to 3 times a week during which time crew members were able to familiarize themselves with and use the system.

6.4. TECHNICAL PERFORMANCE MEASUREMENTS

In order to measure the technical performance of the systems, we developed a series of tests to be conducted on board CCG vessels, commercial vessels, and in the shop (see Appendix F).

Performance measurements conducted during the trials should enable us to address and evaluate the various features that can be classified under the following headings:

1. **Protocol:** Compare the two protocols being used - the DSC protocol adapted for use in vessel traffic services, and the TDMA protocol used by the GP&C system; evaluate the reliability of the communication protocol to determine the likelihood of 'lost' position reports, 'message collisions' or any other effect that might hamper reception of timely ship position reports.
2. **Ship Handling Capacity:** Evaluate the system's ship handling capacity and the ability of the (AIS) system to transmit non-(AIS) reports (ship position and ID) and analyze the assignment of respective communication priorities;
3. **Systems:** Evaluate and compare the overall definition and operating features of the two (2) systems under consideration, with particular emphasis on:
 - transponder operations
 - performance and user-friendliness of control station and shipboard display terminals
 - communication principles and message acknowledgment
 - compliance with standards
 - etc.
1. **Technical functional capabilities:** Compile and compare technical performance data on each of the systems such as:
 - coverage and radio interference
 - reliability of automatic switching of mode and/or communication channel
 - capacity of the system to adopt new ships in the coverage area
 - accuracy of transponder DGPS positions compared to those provided by radar
 - robustness of data transmission system
 - etc.

7. EVALUATION AND ANALYSIS

7.1. COMPARATIVE STUDY AND ANALYSIS OF THE 2 TECHNOLOGIES

7.1.1. Functional Description of the Ross System

The Ross system is based on the operation of a shorebased station that manages and synchronizes ship-to-shore and shore-to-ship communication. The shore station periodically checks for the presence of new vessels in its coverage area (parameterized for every 5 minutes on our network), by sending out an all ship call on Channel 70. New vessels are automatically identified, added to the base station's assignment table and are informed by the station to transfer ship/shore communication to the shore station's working (duplex) channel. This transfer process takes 40 to 50 seconds from the time the ship receives the first all ship call.

We checked the functional capabilities of communicating on Channel 70 and switching to the zone's working channel (Objective 9, TE.12¹). This function works well in a given sector controlled by a single shore station. However, when a ship is moving on the river and changes shore station coverage areas (according to an adjustable parameter that determines a pre-set distance from the shore station beyond which communication is transferred from the duplex channel to Channel 70), the mobile unit automatically returns to Channel 70 and awaits re-initialization on the new zone's working channel. When the next station finally takes over the ship after transmitting an all ship call on Channel 70, it assigns the vessel a new working frequency and ship-to-shore and shore-to-ship communication takes place through the new base station.

The Ross system works with autonomous control and communication sites; when a ship changes zones, it can wait several minutes (approx. 3 to 8) before communicating on the shore site's working frequency; in the meantime it remains on Channel 70. Our trials also showed that a too-frequent all ship call (eg., every 2 minutes) can create problems in handing off vessels to adjacent stations. After a number of trials (this rate can be parameterized for each shore station) a rate of every 5 minutes proved to be functional and adequate.

The Ross system's definition relies on shore sites to rebroadcast vessel traffic information. It does not allow for direct ship-to-ship communication that would enable vessels to exchange position information directly and display it on their respective screens. Two vessels have to be in the same (AIS) coverage area in order for either to receive position information on the other approaching vessel.

Figure 6 shows how the Ross system functions at the outer limit of 2 coverage areas (Objective 4, VTS.9) and the information displayed on the shorebased and shipboard control terminals according to the ship's location and the communication channel in use (70 or duplex). In this example, Ship 1 must first establish communication on Channel 70 before it can be transferred automatically (through a DSC command from the shorebased station) onto the duplex channel. It is via this duplex channel alone that Ship 1 will access information on other vessel traffic.

Therefore, 2 ships at the outer limit of the coverage area of 2 different shore stations will not have access to information on each other because each will be operating on its own duplex channel (the one being used by the shore station in its zone). Unable to see each other on their display systems, these 2 vessels could find themselves heading for a collision!

¹ Appendix A - Specific Objectives - Table 4

Evaluation and Analysis

The Ross system can therefore transmit positions and information from ship-to-shore (vessel traffic service requirement) and from shore-to-ship (traffic information for mariners) within the same coverage area. The Ross system allows for automatic hand-offs between base station coverage areas; it also allows for traffic information display in the sector being transited by a vessel within a single shorebased coverage area, but not at the outer limit of two adjacent coverage areas (i.e., where two vessels heading toward each other are controlled by two different shore stations).

ROSS ENG. SYSTEM COMMUNICATION PROTOCOLE

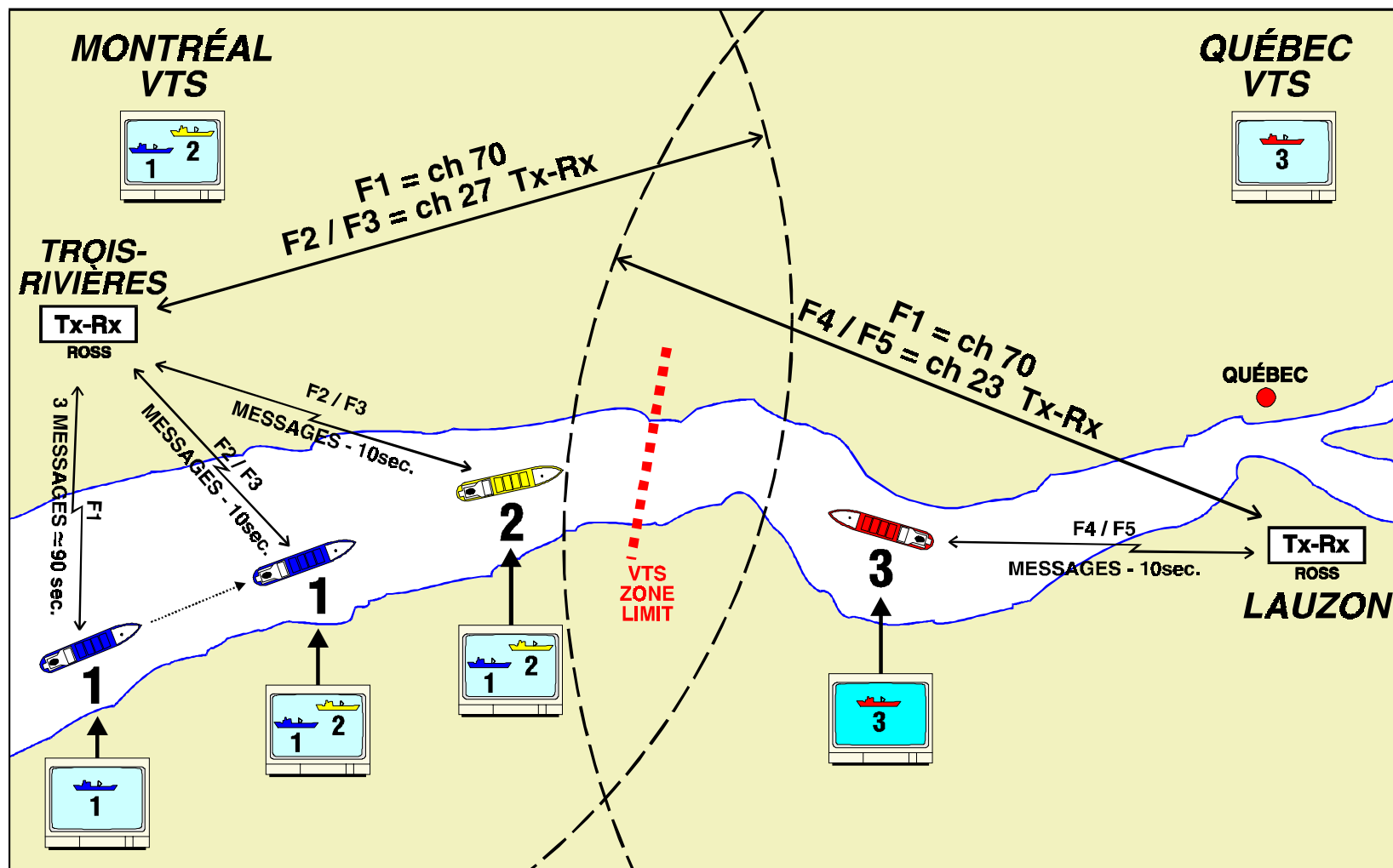


Figure 6 - Ross system operating at the outer limit of 2 coverage areas

7.1.2. Functional Description of the GP&C System

The GP&C (AIS)-Broadcast system definition is relatively simple. When operational, the transponder listens to traffic for three minutes on the system's single radio frequency to determine available time slots and automatically takes over one that is free. Each transponder then automatically and continuously transmits its position and information to all other transponders (ships or shore sites) capable of reception.

Direct communication between vessels is possible and therefore each vessel can display ships within its VHF range. The shore station, which has wider radio coverage, can 'see' a larger traffic sector and can also act as a repeater to rebroadcast traffic information from vessels outside radio range. Figure 7 illustrates the GP&C broadcast system definition.

A ship in the coverage area of a shore station has access to information on the traffic situation for the entirety of that station's coverage area. The ship can also communicate directly with another vessel (single simplex frequency). This also enables the ship to receive the position of another vessel which, although outside the range of the shore station, might still be encountered at the outer limits of the coverage area.

We were able to verify the capacity offered by the GP&C system to allow direct ship to ship communication (without rebroadcast from a shore site) upon the meeting on the river of Le Brave and the NGCC Radisson, then at the mouth of Lac St-Pierre and out of range from Mont-Bélair radio site; the two ships were able to respectively « see » each other on their screen. Then pursuing her course toward Québec, Le Brave later appeared on the Radisson screen, docked at Québec, indicating her position in the Grondines region (between Trois-Rivières and Portneuf); this position was therefore rebroadcast through Mont-Bélair shore station, Grondines being much too far away from Québec (approx. 75 km.) to allow the establishment of a direct ship to ship radio link.

GP & C COMMUNICATION PROTOCOLE

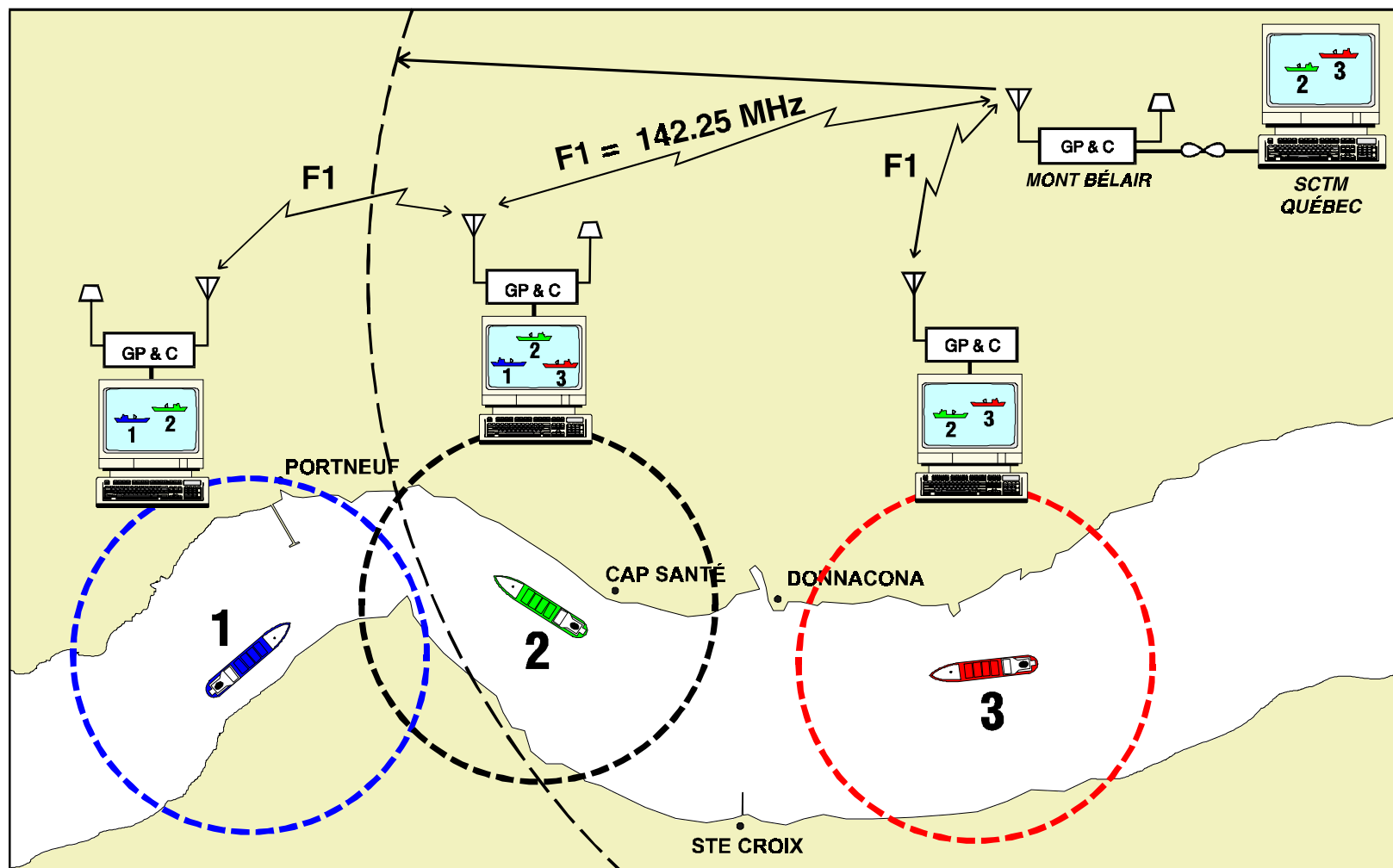


Figure 7 - GP&C Broadcast system definition

7.1.3. Impact of Adjacent Zones (TE.25A)

We evaluated the functional capabilities of the two (AIS) systems for use on the river where several adjacent radio coverage areas (that might overlap) are required in order to provide complete coverage from Quebec to Montreal.

Initially, the Ross Engineering system was not designed to operate automatically with more than one site at a time. The MCTS operator was therefore required to manually log out every vessel as it left the coverage zone of a particular site so that it could be picked up by the next site. With the latest version of the system installed in August 96, the process of switching control sectors was automated and this was confirmed at least once with a CCG vessel crossing 3 successive zones between Quebec and Sorel. When it passed between zones, communication between the site and the vessel was transferred from the original zone's working channel to Channel 70 (common channel) and then to the working channel in the next zone. As there has been rather limited observation of this automatic switching capability, we cannot confirm that the procedure is now completely reliable.

At the beginning of the evaluation period when there was a single GP&C site installed, there were obviously no repercussions related to multiple zones. Once a second GP&C site was added (May 96), no particular problems were observed; at times we were able to observe information exchanges between transponders at two shore sites (by radio waves, where signal propagation made it possible), giving each control and display station access to all traffic on the network.

The TDMA protocol used by the GP&C broadcast system, unlike the DSC protocol used by the Ross system, has a vessel collision avoidance function that does not rely on shore station coverage and therefore operates regardless of where the vessels are located.

Table VI summarizes our observations on both systems:

Table VI
Impact of Adjacent Zones

Systems	Observations
GP&C/Norcontrol	- Two shore sites were installed, each linked and controlled by its own control station set up at Quebec and Longueuil respectively. The GP&C (AIS)-Broadcast system definition, based on use of a single frequency, could cause interference problems for mobile units during information rebroadcasting if shore stations are using the same time slots; - The 2 shore sites are far enough away from each other (Sorel and Mont-Bélair: approx. 150km) to almost always prevent the possibility of communication between the sites; however, on occasion, when signal propagation conditions between the two sites were favourable, we did observe the positions of all vessels throughout the network coming from both shore sites on both MCTS displays. This information was accessible when the radio communication established between the two shore sites allowed each transponder to receive traffic information from the other unit!
Ross Engineering	- Based on the use of a common frequency (Ch. 70) and a separate duplex working frequency in each coverage area - System originally designed to operate with a single shore site covering a surveillance zone - When we began evaluations with the first versions, the system required manual commands (by the MCTS operator) for changing zones, i.e., 'login' and 'logout' operations to activate and deactivate vessels when transferring from one zone to another. - Through adjustments to the parameters, the most recent version of the software allows a boundary to be set for each of the sites (a predetermined distance from the geographical position of the radio site) at which point the frequency will change between Channel 70 and the specific duplex channel for each site; - this functional capability was confirmed between Quebec and Sorel with a vessel successfully transiting 3 separate zones through which automatic frequency switching did take place, as did automatic control transfer ('login' and 'logout') from one MCTS control and display station to the next. However, it does take several minutes (2 to 6) before the transfer is completed; this delay is the result of the automatic interrogation (all ship call) function which enables each station to adopt into its system new vessels arriving in its coverage area.

7.1.4. Architecture

A similar architecture is used with each of the two (2) systems under evaluation. A control and display station at the MCTS centre receives information from a shorebased communication site via a digital telephone line.

With the Ross Engineering system, a control station and a separate telephone line are necessary for each of the shorebased sites; it is not possible (at this point) to link several sites on the network to share vessel traffic information over the entire territory.

The GP&C system is also used in a configuration that links a single communication site per control station; however in its original proposal, Norcontrol suggested using a number of serially-linked radio sites on a digital line to a single control station to ensure traffic tracking over a greater area.

However, transponder communication, based on a single radio frequency, allows radio communication between shorebased sites, as each site is seen as an additional mobile unit by the other site.

Under favourable signal propagation conditions, the MCTS centres at Quebec and Longueuil were each able to see traffic information from the other sector without adding any physical links. This phenomenon could have an impact on ship handling capacity; however, given the small number of ships in our network, we were unable to observe this.

7.1.5. Protocol

The DSC protocol used by Ross is based on existing standards (ITU M.493) or on proposed modifications (ITU-R M.825). Existing standards define use of Channel 70 and message formats. Every vessel that must comply with Global Maritime Distress and Safety System (GMDSS) requirements will be equipped with a VHF-DSC unit identified by its own name and code.

However, the protocol performance does limit ship handling capacity and the addition of a second channel is necessary. This channel then has to use a different format and protocol as defined by the proposal to modify Rec. ITU-R M.825. This communication protocol requires the use and operation of a shore station that acts like the conductor of an orchestra, coordinating the detection and identification of vessels, the selection of channels that will be used, and the formatting of messages. The shore station also rebroadcasts messages to participating and equipped vessels.

The TDMA protocol used by the GP&C system optimizes use of the radio channel, with a single frequency accommodating a maximum of 2250 time slots/minute. However, using a control line that is limited to 9600 bps reduces the number of vessels to 1200. Norcontrol's use of a different protocol between the control station and the transponder also limits the name given to each vessel to 8 characters. The name or code assigned to each of the transponders must be associated with a vessel name table at every control station and display computer. When a transponder is moved from one vessel to another, each display terminal's assignment table has to be updated - which is extremely impractical! Also, the transponder broadcast rate used during our trials was not adjustable and had been set at 1 report/second.

7.1.6. Ship Handling Capacity

7.1.6.1. Number of Vessels

Given the small numbers of vessels equipped with systems and, in particular, able to transmit their positions simultaneously, the ship handling capacity was assessed using a limited number of vessels and by increasing, when necessary, the reporting rate in order to increase the volume of data to simulate a larger number of ships.

With the Norcontrol system it was also possible to observe the level of use of the communication channel (given in %) and to compare this with the number of vessels or land-based mobile units in communication. A ship position simulator was also provided by Norcontrol, but was never activated and could not be used during the trials.

A. GP&C

A vessel reporting every second would therefore use 60 time slots out of a possible 2250 per minute, resulting in channel use of 2.7%. Typical channel use during our evaluation was between 6 and 12%, depending on the number of available vessels (generally 2 to 4).

Objective 3 (TE.8) in Appendix 5 gives an example of how the level of use of the link is calculated.

Extrapolating use of the system with 30 ships for a typical MCTS surveillance sector and a one-second reporting rate yields a radio channel utilization of 80% ((30 ships X 60 rep./min.) / 2,250 rep./min.). If we assume that half of these ships are at wharfside and transmitting a position report only every minute and the other half continue to report every second, utilization decreases to 41% (((15 ships X 60 rep./min.) + (15 ships X 1 rep./min.)) / 2,250 rep./min.).

B. Ross Engineering

The original system was able to handle 40 to 50 reports per minute. Improvements to the system made by the company (August 96 revision) have now increased to 250 reports per minute - or 4 to 5 reports per second.

With 5 vessels operating in the same sector, we monitored the ship handling capacity by adjusting the reporting rate to once every 5 seconds for each vessel, thereby creating the equivalent of 1 report per second.

If we extrapolate use of the system with 30 ships for a typical MCTS surveillance sector, we cannot retain a one-second reporting rate without exceeding the maximum channel capacity; limiting reports to one every 10 seconds will yield a radio channel utilization of 72% ((30 ships X 6 rep./min.) / 250 rep./min.). If we assume that half of these ships are at wharfside and transmitting a position report only every minute and the other half continue to transmit every 10 seconds, utilization decreases to 42% (((15 ships X 6 rep./min.) + (15 ships X 1 rep./min.)) / 250 rep./min.).

7.1.6.2. Messaging (TE.8)

The messaging function provided with each of the two (AIS) systems under evaluation actually allows each vessel to be reached individually.

A. Ross

Messages were sent from the MCTS centre to shipboard mobile units and vice-versa. Messages were also sent between two mobile units; these messages went through the shorebased site and the working channel.

The Ross system provides message receipt acknowledgment. At most, a warning signal at the transmitting station will be generated if the message is not received by the recipient or if the recipient is not available.

The Ross system can cluster several vessels within one group (up to 128 groups); however, it cannot send a message to all vessels in a single group.

B. GP&C

The messaging function of the GP&C system allows for the transmission of short messages (maximum of 40 characters) and works both ways (ship-to-shore and shore-to-ship, as well as ship-to-ship).

The GP&C/Norcontrol system provides an electronic acknowledgment to indicate that the transmitted message has been received by the vessel's transponder. It also supplies a second acknowledgment when the user accesses the message, confirming that the message has indeed been received by the user.

With the GP&C/Norcontrol system, messages can be sent to all vessels which is useful when transmitting general broadcast messages.

7.1.7. System

The two systems being evaluated are made up of transponders or reception equipment installed at communication sites and linked by telephone lines to control and display stations.

Operators much preferred the GP&C/Norcontrol system, particularly with regard to its control and display capabilities which they felt were superior.

7.1.7.1. Ross Engineering

The system supplied by Ross Engineering is made up of sub-systems that are almost entirely developed by the company itself (with the exception of the GPS receivers).

The transponders therefore operate with DSC-500 radios that the company manufactures itself and which are one of its major products. The company purchases GPS display charts that it packages with a DSC-500 radio and control card to create (AIS) transponders.

The control and display systems have also been developed based on commercial computers (programming). The control and display system provided runs under the Windows 3.1 operating system. Several vessels can be displayed at the same time, but information on only one vessel is available at any one time. Ross personnel program the software being used on the shipboard laptops as well as at the shorebased control stations.

7.1.7.2. GP&C

The Norcontrol/GP&C system is the joint product of two companies. The first, GP&C, developed the transponder technology using the TDMA protocol. This company joined forces with Norcontrol, which specializes in radar surveillance systems and control and display systems.

The display system used - the Norcontrol VOW5000 - runs under the Windows NT operating system and can track several vessels at a time, each in a separate window with its information displayed.

7.2. OPERATIONAL EVALUATION

7.2.1. Vessel Traffic Surveillance (VTS.1, 2 and 3)

We reviewed the procedures that currently govern vessel surveillance using an (AIS) system and compared it to current systems such as surveillance radar and VHF radio communication systems.

Table VII summarizes the features of the systems under consideration for each of the following regulation functions:

- Authorization
- Reporting at calling-in points
- Additional reporting
- Information to shipping

Generally, the (AIS) system is valuable in areas where only VHF radio coverage is available. The (AIS) system provides more detailed information on vessel traffic than can be obtained through VHF. In areas covered by radar, (AIS) positions are just as accurate, but radar does have the advantage of providing the vessel's true course (something that the (AIS) system could provide if the transponders were linked to the shipboard gyrocompass, which was not the case during our trials).

Table VII

Features of the Systems Under Consideration According to Regulating Functions

Regulating Function	VHF Communication	(AIS) (Over entire zone)	Radar (Radar zone only)
Authorization	- Decision-making based on ETA - Safety margin has to be greater because of poor position accuracy - Needs more communication	- Decision-making based on vessel's true position - Doesn't give true motion display - Slightly smaller safety margin - Efficient - Zone completely covered	- Decision-making based on vessel's true position (using actual course) - Reduced safety margin - Very efficient - Smaller coverage area
Calling-in Point	Don't know true position	- Ship's position certain - More detailed traffic information can be given (eg.: exact position without requests) - Doesn't give vessel's course	- Ship's position certain - More detailed traffic information can be given (eg.: exact position without requests) - Shows vessel's course
Additional Report (eg.: engine failure)	Lack of information	- Fewer requests - Exact position - Course and speed made good - No vessel course - Detection of vessel in trouble that hasn't yet identified itself as such - Could give indication of vessel negotiating ice or changing pilots through observed speed	- Fewer requests - Exact position - Course and speed made good - Vessel course available
Information to shipping	Voice	- Partial information on traffic - Partial information through messaging function	None supplied

7.2.2. (AIS) vs Radar (VTS. 4, 5 and 14)

In radar coverage areas, (AIS) can detect equipped ships and display (like the radar system) their position on a CRT screen. (AIS), however, offers the advantage of automatically acquiring ship information, including the identity, thereby decreasing oral communication with ships. Once a vessel is targeted, accuracy of the (AIS) system is at least as good (vessel in GPS mode) as radar tracking (+/- 20 metres) and is sometimes even better (when the ship's position is available in DPGS) (+/- 10 metres).

In harbour areas, where there is a great deal of manoeuvring, radar's ability to provide a vessel's true course makes it superior to (AIS) at tracking commercial vessels (large ships). (AIS), however, appears to be better at tracking small units (cruise boats) that could be hidden by larger vessels or other obstacles.

In VHF radio coverage areas, (AIS) is definitely an asset with automatic, continuous display of the position of vessels and the ability to exchange messages with them.

By comparing the (AIS) control and display systems with the one that operates with the current radar system, we were able to determine how important it is for a vessel tracking system to have a warning signal on moving vessels that might collide.

The following functions, which are available with radar, were found by vessel traffic service operators to be essential for their operations and should be available on any potential (AIS) display system or integrated AIS/radar system:

Log - Reference Point - Offset - Target Trace (short and long) - Predictions - Simulation - Target Anchorage and Alarms - Vector / Tag - Info Symbol - Collision surveillance assignment.

7.2.3. Operational Requirements vs (AIS) (VTS.6)

While monitoring and tracking vessels, the MCTS centre collects and broadcasts various information on vessel traffic and on shipping in general (tide forecasting, under-keel clearance, weather, ice conditions, messages regarding pilotage, etc.)

An operational (AIS) system could meet the need for collecting and broadcasting some of this information, particularly regarding vessel traffic.

Broadcasting of some repetitive messages of a general nature could be done using a messaging system such as the one that comes with the (AIS). However, other, more sporadic information that requires interaction with the shipboard operator (eg. pilot) is better communicated over conventional VHF radio.

Table VIII summarizes information that is actually managed and broadcast to mariners by MCTS centres and which needs to be taken into consideration for operational requirements:

Table VIII
Information managed and broadcast to mariners by MCTS centres

Operational Requirements	Information Broadcast
Vessel Traffic	• vessels approaching • ETA of vessels at CIP in poor weather conditions - deep-draught ships - ship with tow • vessel being overtaken • overtaking vessel • manoeuvring under control • at anchor • in difficulty • special operations such as laying buoys - dredging - sounding, etc. • Under-keel clearance standard
Shipping Information	• NOTSHIP • Deep-draught restrictions • Temporary speed reduction for activities such as: diving - seaplane operations - other • Weather conditions - visibility - gale warnings • Ice conditions and shipping restrictions • Mooring instructions • Unusual tide conditions • Water level monitoring - tidal predictions • Draught - pre-clearance for deep-draught vessels • Vessel height - monitoring of vertical clearance • Messages regarding pilotage or other agencies (Harbourmaster, Investigators - Ship Safety - Immigration - Customs - RCMP - etc.) • Federal Court Orders

7.2.4. Electronic Navigation

Operational evaluation of the onboard (AIS) system by ships' officers (CCG and commercial vessels) and by pilots was limited to those who used the GP&C/ Norcontrol display system. This was the only system that was sufficiently operational during the evaluation period to display participating vessel traffic - which is the primary function of the (AIS).

However, use of the shipboard system was variable, depending on crew members and how much they knew about or were interested in the system. We were able to judge the impact of the GP&C broadcast system during a two-day voyage on board *Le Brave* on April 24 and 25, 1996. During this round-trip voyage between Quebec and Montreal, we collected comments and observations from ship's officers and various pilots (4) on duty and were able to evaluate and discuss with them the use and functions of the Norcontrol/GP&C (AIS) system.

The pilots used the system very little themselves, merely answering our questions and leaving it up to the officer of the watch to operate the set to display vessel traffic and send messages. We should emphasize that the small number of vessels equipped with (AIS) transponders limited the amount of available traffic, so the laptop displays were therefore only being used as a stand-alone navigation tool like any other electronic chart system.

Comprehensive evaluation of the display system supplied by Ross Engineering was not possible because of reliability problems with the transponder (Ross 12500). Displayed and broadcast positions kept jumping by several dozen kilometres (problem with transponder's DGPS interface resulted in return of the set to the company for repairs). In particular, evaluation was not possible because of the marginal operation (until August 1996) of the rebroadcasting of vessel positions from shore network sites.

Further, the Ross Engineering mobile units installed on CSA commercial vessels were not really evaluated by navigational personnel, because the units could not be connected satisfactorily to a display system or the ship's ECDIS. In fact, the erratic operation (until August 96) of the transponders, coupled with some decline in interest by the CSA, forced OSL to work with Ross Engineering to adapt its ECDIS system to (AIS). These are the main reasons why this evaluation was not carried out.

7.2.4.1. Vessel Traffic Display System

Comments regarding the traffic display function as experienced on the Norcontrol system were positive. CCG officers recognized the system's usefulness while recommending that it be integrated into the onboard ECDIS/ECS system.

It was suggested (by a CCG officer) that the size of the information window for other vessels (targets) be reduced. It currently takes up a large portion of the laptop screen.

Also, when the system is used with a small-scale chart (1 to 5 nm) other vessels cannot be displayed (not yet visible). It was suggested that an icon appear to indicate that another vessel is now within coverage range. The current system requires ship personnel to consult the list of targets regularly in order to know whether new ships are in the vicinity.

The remarks and comments of the officer on board the participating vessel *Radisson* are provided in Appendix 4.

7.2.4.2. Position/Distance Fix

Distance fixes on known fixed points (end of a wharf, leading lights, shoreline, etc.) were taken from the vessel *Le Brave* using the fix function of the (AIS) display system, and the results were compared to radar. The differences were between .01 and .02 nm (18 to 36 metres) which is comparable to radar resolution. The (AIS) system on the *Le Brave* operated in GPS mode only (30 to 100 metres @95%), explaining the limited accuracy.

Using GPS without differential correction results in a significant lack of accuracy (10 to 20 metres) when the heading followed is compared with the course provided by the leading lights. The increased accuracy of DGPS is therefore necessary for greater accuracy (<5 metres), particularly when approaching another vessel or when vessels are required to stay on their own side of a channel.

7.2.4.3. Navigation System (ECDIS/DGPS)

All the comments received were unanimous in stipulating that any display for a future (AIS) system must be integrated into the on-board navigation system (ECS or ECDIS) so as to reduce the number of information screens that need to be consulted.

Some pilots found that the laptop computer monitor (Toshiba T4900) was too small. They also expressed a desire to see better integration of navigation systems using equipment with larger screens.

For pilots in particular, a navigational tool of this sort should above all provide information on the course to be followed by the vessel, so that appropriate instructions can be given to the helmsman.

7.2.5. Messaging System (VTS.6 and 11)

Generally, communication between MCTS centres and vessels is on an individual basis (with each targeted vessel) and requires an acknowledgment from the vessel (which is obvious with voice communication via VHF).

Onboard messaging functions were evaluated for the GP&C/Norcontrol system only as the Ross system was not functioning for the greater part of the evaluation period. The Ross messaging system did, however, undergo technical evaluation (Section 7.3.2.2).

The electronic messaging functions were used and tested by the various ships for transmitting short requests to MCTS (tide, weather, etc.) or for transmitting ETAs. The vessels equipped with this feature also used it to communicate amongst themselves.

The limit on the number of characters that can be transmitted at one time (40) does restrict message content. This current limit on the GP&C system has been established solely to ensure that the communication channel does not become overloaded with messaging, thus blocking vessel identification and position reports. Depending on communication needs, and especially on the amount of vessel traffic, this restriction could be revised, and the number of consecutive time slots reserved for messaging increased.

Pilots were not particularly interested in having to use a keyboard to request information from or provide information to MCTS. They feel that the current VHF communication system is fast and well suited to the type of information to be obtained or transmitted. Some pilots did, however, recognize the advantages of a system for transmitting navigation information digitally that would require little or no keyboard use and that would be integrated into the other display systems currently in use (i.e., ECDIS). The information could appear in a display window or as a line of information at the bottom of the screen when this information is necessary for the vessel, depending on its requirements of shipping zone.

7.3. TECHNICAL PERFORMANCE

The evaluation was conducted using a number of precise test modules which dealt primarily with radio coverage, system capacity regarding the number of position reports and/or messages that can be transmitted, and equipment accuracy and reliability. The various tests were conducted in the shop, on board ships and using a vehicle equipped with the 2 systems. All the technical data and observations gathered during the various trials were used to create the technical evaluation reports in Appendix 5.

7.3.1. Radio Performance

7.3.1.1. Sensitivity and Coverage (TE.5)

The results of these trials are part of Objective 9, TE.5¹ which sought to accumulate data on the technical performance of the systems.

Sensitivity was first evaluated in the shop using a variable attenuator in line with the antenna to simulate a progressive signal reduction at the receiver input. We then observed how the (AIS) system received position reports until it was no longer functional owing to the weakness of the signal. We then measured the minimum signal level necessary for the system to become functional again. This simulation helped to determine the functional sensitivity of each system.

The data were then all checked in operational mode by driving a vehicle to the limit of function sensitivity. In this way we obtained the maximum distance (coverage) that could be reached with the minimum signal required. This test allowed us to establish the actual coverage possible.

A. Ross Engineering

The sensitivity of the Ross receiver was measured at -119 dBm, the level at which the system no longer receives messages. The transmitter's power is 25 watts on Channel 70 (except at Sorel at 55W) and 7.5 watts on the working channel (except Lauzon at 55 W). At this level, coverage fluctuates between 60 and 115 km depending on the site being used and antenna height.

¹ Appendix A - Specific Objectives - Table 4

B. GP&C

The sensitivity of the GP&C system was measured at -100 dBm, the level at which the system no longer received messages, and at -105 dBm, the level at which there were no more position reports. The transmitter's power is 10 watts and combined losses due to cavities and antenna systems equal 2.5 dB. This level gave us a coverage of 150 km from the Mont-Bélair site where the shore station was installed.

Coverage from the Sorel site extends approximately 35 km.

Table IX summarizes the data taken for each of the installed systems at the time of their acceptance (April 96) following network installation (and revised in August, following corrections made to the Ross system).

Table IX
(AIS) SYSTEM ACCEPTANCE

April 96 (revised August 96)

EQUIPMENT DETAILS

Site Name	Power/Sensitivity	Loss in Cavities	Antenna Gain	Comments
Lauzon 70 Tx-RX	25 watts 0.25 μ V for 12 dB SINAD	2.2 dB	9 dB	
Lauzon TX-23	55 watts	1.6 dB	9 dB	
Lauzon RX-23	0.25 μ V for 12 dB SINAD	2.2 dB		
Mont-Bélair 142.25 MHz TX / RX	10 watts 0.5 μ V / 20dB S/S+N	3.2 dB	0.7 dB	
Trois-Rivières Channel 70	25 watts 0.25 μ V for 12 dB SINAD	3.0 dB	9 dB	
Trois-Rivières Channel 27	7.5 watts 0.25 μ V for 12 dB SINAD	3.5 dB 2.0 dB	9 dB	
Sorel Channel 70	55 watts 0.25 μ V for 12 dB SINAD	4.5 dB	9 dB	
Sorel Channel 87	7.5 watts 0.25 μ V for 12 dB SINAD	3.0 dB 2.0 dB		
Île Charron Channel 70	25 watts 0.25 μ V for 12 dB SINAD	1.5 dB	3 dB	
Île Charron Channel 27	7.5 watts 0.25 μ V for 12 dB SINAD	2.0 dB	3 dB	

To conduct these trials, antennas were installed on a vehicle with the communication and trial equipment.

Equipment	Function	Ancillaries	Comments
ROSS transponder model 12500 with computer	Communication with Lauzon site and user interface	GPS, VHF and DGPS (LF) antenna	Equipment from Tracy
GP&C broadcast transponder with Toshiba computer	Communication with Bélair and user interface	GPS and VHF antenna	Spare equipment from Radisson

FINDINGS

System	Necessary signal for normal operation	Coverage	Comments
ROSS	-119 dB	Ste-Croix (south shore) Portneuf (north shore)	DSC-500 sensitivity was greatly increased with the revision of late August
Swedish Space/ Norcontrol	-100 dB (-105 dB for operations without messaging)	Reliable and constant signal to the middle of Lac St-Pierre (except at Trois-Rivières bridge)	

7.3.1.2. Radio Interference (TE.23)

We assessed the potential interference to currently operating systems resulting from the addition of the (AIS) systems both at CCG communication sites and on ships.

Generally, adequate filtration is necessary and sufficient as long as operational systems use receivers and antennas in the same band as the (AIS) systems being evaluated. Table X summarizes our observations.

In addition to good filtration on radio frequencies, the system must also be fully functional. When the Ross system was first installed, we planned on using Channel 70 only at the Trois-Rivières site, with no transferring to a duplex channel, on the assumption that the limited capacity of this channel would be adequate for this zone.

Interference was noted when the shipboard Ross transponders were stuck on a duplex frequency also being used for radio communication. The interference problem arose when ships arrived in the Quebec sector with their transponders set to Sorel - Channel 87. The system had failed to return automatically to Channel 70 or switch to a new duplex channel for the new VTS zone. Channel 87 therefore interfered with the Mont-Bélair channel being used for radio operations.

A duplex channel was then added at the Trois-Rivières site. The automatic transfer function from Channel 70 to the duplex channel (August 96 version) also eliminated this potential for interference.

Table X
Radio Interference

System	Observations
GP&C/ Norcontrol	- interference in television reception on board F.G. Smith; TV antenna is wide-band variety and is also affected by ship's VHF communication; however, periodic transmission (i.e., 1 per second) of the (AIS) transponder signal (142.25 MHz) did regularly interfere with television reception; a filter was added to the TV antenna circuit and the interference problem disappeared - no interference on larger vessels (1100 and 1200 class) where the antennas are farther apart
Ross Engineering	- when using marine band frequencies (156 - 162 MHz) adequate filtration at CCG communication sites is needed so that the marine frequencies can coexist with existing frequencies being used for normal MCTS operations - the Ross system transponder caused interference in the radar and intercom systems of one ferry; the DSC-500 was supposed to function on low power (1 watt) when close to the control station (<10 nm); this function (low power) was inadequate in the first versions of the system and the unit kept returning to high power (25 watts) and provoking interference with the ship's equipment; an external attenuator had to be added; the new version now effectively handles the transponder power change as triggered by the ship's distance from the communication site

7.3.2. Ship Handling Capacity

7.3.2.1. Number of Vessels

The GP&C broadcast system is capable of 2250 reports/minute. This is enough capacity, for example, to track at least 30 vessels with a reporting rate of once per second, or $1800 (30 \text{ vessels} \times 6 \text{ rep./min.}) / 2250 \text{ reports} = 80\%$ utilization.

For the same number of vessels (30), the Ross system would be limited to a reporting rate of every 10 seconds, or $180 (30 \text{ vessels} \times 6 \text{ rep./min.}) / 250 = 72\%$ utilization.

In the case of vessels traveling at an average speed of 6 metres/second (12 knots), a delay of 10 seconds between reports introduces a discrepancy of at least 60 metres (not including rebroadcasting delays) in received positions, which could be increased in a heavy traffic situation or where vessels are closing in on each other or are in convoy.

7.3.2.2. Messaging Function

A. GP&C

With the GP&C/Norcontrol broadcast system, messages can be a maximum of 40 characters long, which limits the amount of information that can be transmitted in a single message. It is possible, however, to use several consecutive messages, if necessary.

Ross Engineering

The Ross system can send long messages (estimated at up to 5000 bytes) that are automatically divided up into bundles of 256 bytes and transmitted as several consecutive messages. The message is automatically reconstructed by the receiver without the user being aware of the process. Transmission time, is, however, directly related to message length: i.e., a message of 5000 bytes could take 8 to 10 minutes to be received.

The Ross messaging function is capable of transmitting messages that are several tens of thousands of characters long. With the new protocol being used (M.825) text messages are divided up into multiple messages of no more than 256 characters which are then sent as successive messages. Our trials showed how the function works and revealed the direct link between the length of the message and the time required to send and reconstruct the complete message. Tests were conducted by sending messages of 250, 1000 and 5000 characters. The transmission time rose from 20 sec. to 8.5 minutes between the 250 character and the 5000 character messages.

With the Ross Engineering system, it is also possible to cluster mobile units into a separate group (up to 128 possible groups) and then send messages to a specific group.

7.3.3. Reliability (TE.6 and 24)

Evaluation of the systems' reliability was based on the functioning and performance of each of the systems throughout the trial period. Breakdowns in each system demonstrated their respective overall level of reliability.

In general, the GP&C/Norcontrol broadcast system was a good deal more reliable than the Ross system. The GP&C/Norcontrol broadcast system was operational as soon as it was installed in the fall of 1995, and some communication problems with the Mont-Bélair shore site were the only ones affecting operation of the MCTS control and display station. The system required no changes or modifications over the course of our evaluation.

The Ross Engineering system required several changes, improvements and updates (hardware and software) between the initial installation (July 1995) and August 1996 which was the greater part of the trial period. Over this time, reliability was very low and difficult to assess. Since the last update, reliability has been better, although there is still room for improvement:

GP&C/Norcontrol Broadcast System

- Technical Reliability:

There were some communication problems between the shorebased transponder (Mont-Bélair) and the MCTS control station which affected traffic information reception; at times, this problem resolved itself or, when the screen was frozen too long, the MCTS control terminal had to be reset.

With the occasional failures that affected MCTS operations, the system was assessed as having 90% overall reliability.

Ross Engineering System

- Technical Reliability:

Various Ross system components experienced a number of failures, primarily during the first months of operation (until August 1996). There was a problem with the GPS receiver in the 12500 units where positions sometimes jumped (vessels were ‘virtually’ cruising down Highway 20 and 40 as well as in South Africa!). The DSC-500 radios had problems with weak sensitivity which significantly reduced the system’s functional coverage.

- Reliability of Communication Protocol:

Implementation of a new protocol (ITU-R M.825 revised) to increase ship handling capacity had an impact on overall reliability of the system as of January 1996 until August when a sufficiently functional version of the software was finally available; until that time, operations were somewhat erratic, which prevented us from making an in-depth evaluation of the system.

Given the many failures and general weakness of the system, we assessed its overall reliability at 50% to August 1996 and then at 75% since then. The latest changes to the system contributed to increasing functional capability and reliability.

7.3.4. Display System (TE.18)

The display systems provided with each of the systems being evaluated and used on board commercial vessels were not originally designed to meet ECIDS standards, particularly with regard to screen size - which was in fact one of the first comments made by one of the pilots involved.

The laptops are used to display (AIS) information such as positions and vessel characteristics, some navigation functions such as distance plotting and some message exchanges between MCTS and vessels. Table XI summarizes the characteristics we observed with each of the supplied display systems.

Figures 8 and 9 are examples of display screens from each of the (AIS) systems under evaluation.

7.3.4.1. Interface with ECDIS

We took advantage of a new ECDIS system currently being developed by Qmar to assess the functional capability of their system to mesh with one of the (AIS) systems.

The GP&C (AIS)-Broadcast system was evaluated on board the CCG survey vessel *F.G. Smith*. The demonstration took place during Qmar’s development of the Marine Navigation System (MNS), an initiative sponsored by the TDC and the Innovatech company of greater Montreal. The new system has been required to have an (AIS) function.

A demonstration was conducted of Sailsafe displaying (AIS) targets, and the results were conclusive; a distinctive symbol, a triangular target (in keeping with IMO standards), was used to identify (AIS) equipped vessels; an information window also supplied the pertinent information (name, position, bearing and range) for each target on the screen.

In this trial we were able to see how an electronic navigation system other than the ones provided by the participating companies (Ross and Norcontrol) would operate, and, in particular, to confirm the communication compatibility between the (AIS) transponder and an ECDIS system that complies with IMO standards. This was the only trial where we were able to check (AIS) information display on an ECDIS. Trials that were supposed to be conducted on commercial vessel ECDIS systems did not take place.

The Qmar Sailsafe system is the first and only ECDIS system meeting international standards (S52/57) to demonstrate the (AIS) display function, including compatibility with one of the (AIS) systems under evaluation.

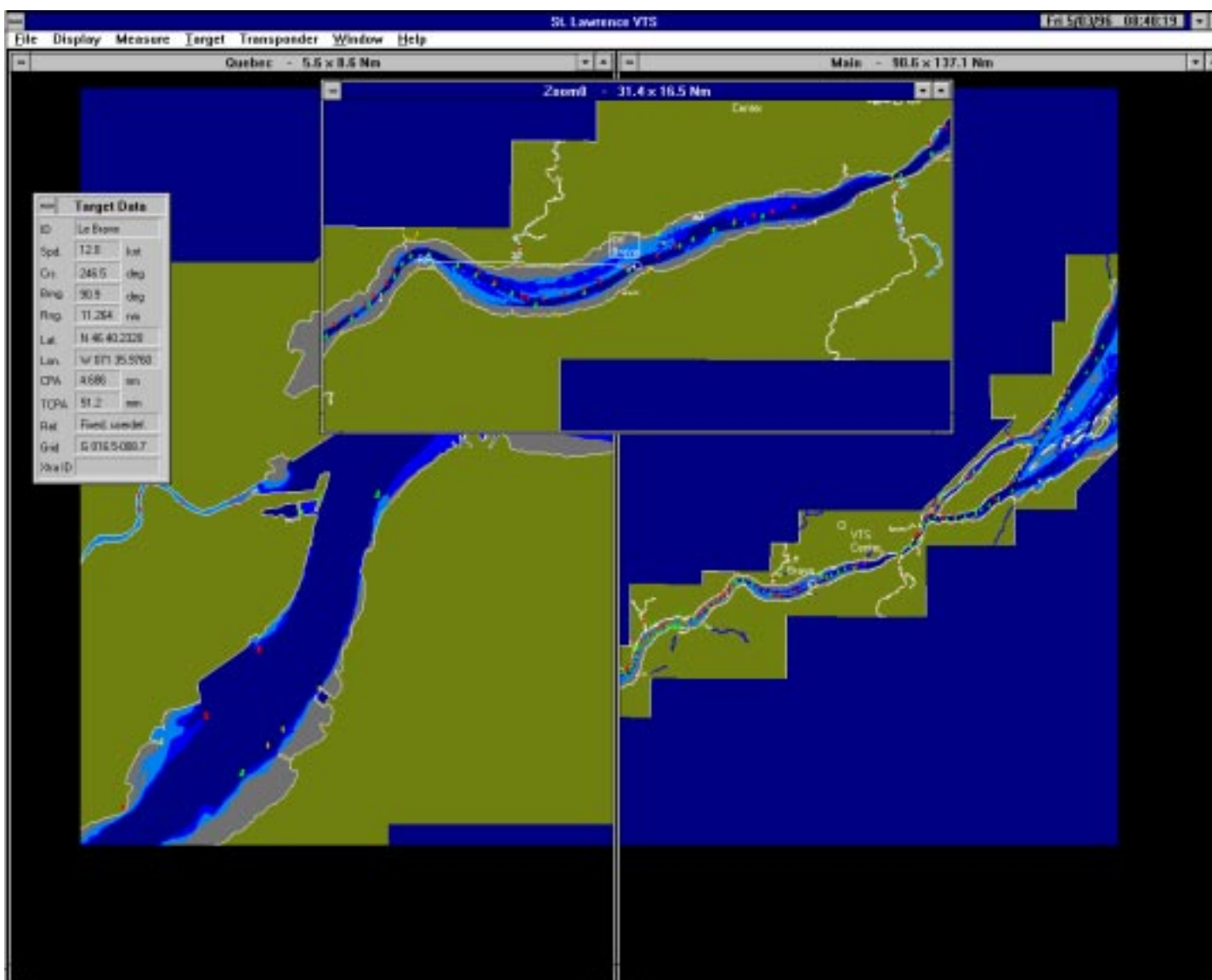


Figure 8 - GP&C\NorControl (AIS) display screen

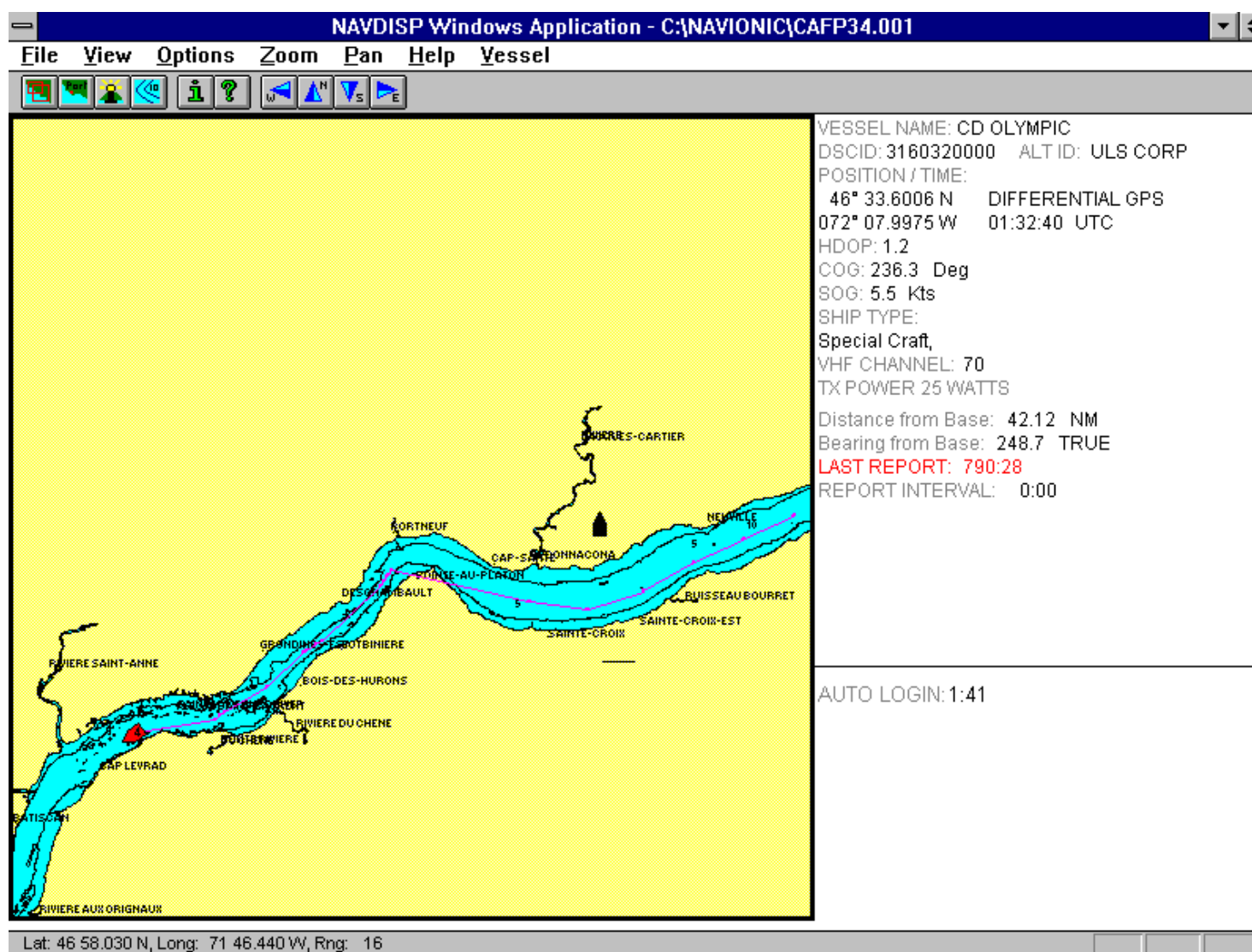


Figure 9 - Ross Engineering (AIS) display screen

Table XI

Display Systems

System	Features	Observations
GP&C/ Norcontrol	Display	• System runs on Pentium laptop under Windows NT; • Vectorized digital colour charts are supplied by Cmap; • The small screen size makes it difficult to use for navigation - users practically have to plaster their noses against the screen, which is impractical for officers and/or pilots.
GP&C/ Norcontrol	Vessel Traffic Display	• Information from other vessels supplied by the GP&C (AIS) transponder is received on board as soon as both vessels are within each other's respective radio coverage area (the vessels don't necessarily see each other at the same time, depending on the emitted signal strength, antenna height, VTS zone, etc.); • once information from another vessel is received, it is automatically displayed on the screen, as long as the chart scale is adjusted appropriately; • the list of available targets can be consulted to see if a ship is available and to select it; • a monitoring mode allows users to see all messages transmitted and received on the communication channel; if a new vessel enters the system, new messages will appear on the list with the ships' individual header; • to display a vessel's characteristics (own or another) the target function is used to bring up a window with: name, ID, speed... (to be finalized) • a beep indicates that a message has been received from another transponder (vessel to MCTS)
Ross Engineering	Display	• System runs on a Pentium laptop under Windows 3.1; • Vectorized digital charts are supplied by Navionic • X 480 resolution
Ross Engineering	Vessel Traffic Display	• Other vessels in the vicinity are displayed on the screen when their information (position, ID, etc.) is rebroadcast from one of the shore stations that receives it; • When a displayed vessel is selected, its associated information appears on the right side of the screen (information can be displayed on only one vessel at a time)

7.3.5. (AIS) vs. Radar (TE.22)

We compared and evaluated the use and performance of onboard (AIS) and radar systems to determine the ship's distance from various fixed or mobile reference points. Primarily, these trials compared the accuracy of the (AIS) transponder's GPS (or DGPS) as compared to radar. During the trials we were also able to check the distance measuring functions provided with the onboard laptop display systems.

Table XII summarizes observations on each of the systems:

Table XII
(AIS) vs. Radar

System	Observations
GP&C / Norcontrol	• The GP&C broadcast transponder uses only one 6-channel GPS receiver. • Identification of fixed targets is possible with the Norcontrol display system (buoy or end of wharf) and so are mobile targets (other vessel equipped with a GP&C broadcast transponder and accepted in our system); the system then makes continuous calculations (every second) and displays the distance and bearing of the target in relation to the vessel; • comparisons with onboard radar showed differences of about .01 to .02 nm (18 to 36 metres), which is very good considering the radar system's resolution (approx. .01 nm) and the fact that the (AIS) system in the trial was only equipped with a GPS receiver (30 to 100 metre error @ 95%)
Ross Engineering	• The Ross Engineering transponder includes a 12-channel DGPS receiver which should be accurate to within 5 metres). • Measurements taken at the wharf displayed a level of accuracy comparable to - at least as good as - the Leica MX-200 DGPS receiver used for navigation. • The Ross 12500 transponder had reliability problems (jumping position) affecting the reported position by dozens of kilometres which is unacceptable for this type of system; the equipment was corrected with the latest version delivered in August

7.3.6. Transferring from Channel 70 to the Working Channel (Ross System) (TE.12)

Within a given coverage area, we evaluated the ability of the Ross Engineering system to, first, accept new ships on the call Channel 70 and, second, to transfer them to the zone's duplex working frequency. We also evaluated the system's ability to transfer vessels from one zone to another, going first from the duplex working channel of the zone being exited to Channel 70 and then to the duplex working channel of the next zone.

With the first versions of the system (until the one delivered in August 1996) MCTS operators had to manually log a vessel in and out of the control and display station as it passed through successive zones.

Since the latest version was operational (August 1996) vessels are automatically logged in and out. This function was verified while *Tracy* was transiting from Quebec to Sorel and passing through 3 separate and successive coverage areas. Table XIII summarizes our observations:

Table XIII
Transferring from Channel 70 to the Working Channel
(Ross Engineering (AIS)-DSC System)

System	Observations
GP&C/ Norcontrol	N/A
Ross Engineering	- When a new vessel arrives (or its transponder is activated) within a site's coverage area, it is first contacted on Channel 70 during an all ship call; the frequency of all ship calls can be adjusted through a parameter which for our trials was set at 5 minutes (the ship's transponder has to be tuned to this frequency); after three messages are exchanged between the ship and the control station, communication is transferred to the zone's duplex working frequency and continues on this channel according to a refresh rate set by the control station (between 2 seconds and 90 minutes); - the system now (since the August 96 version) automatically changes communication channels as a ship passes into another coverage area (with previous versions, the transfer had to be done manually by the MCTS operator at the control station); - when the vessel Tracy traveled between Quebec and Sorel, we confirmed that the automatic frequency transfer was taking place properly between the various zones in with accordance coverage boundaries set for each of the shorebased sites (parameters); Tracy therefore used Channels 23, 70, 27, 70 and 87 in succession. - when a vessel leaves a coverage area, the transponder switches to Channel 70; the ship is still displayed at the MCTS station in the zone the ship is leaving and has to be removed manually - logged out - by the operator; - entering a new coverage area reactivates the process of acceptance and transfer to the new duplex working frequency - with the first versions of the Ross system (before August 1996), the transponder did not always automatically switch back to common Channel 70 when leaving a control zone; it sometimes stayed on the duplex working frequency of the first zone and so was never able to receive all ship calls in subsequent zones; the new version appears to have corrected this problem, particularly since being used with all ship calls transmitted every 5 minutes - We tried to increase the all ship call transmission rate to every 2 minutes, but this created problems in that the transponders stayed on the first duplex frequency identified after the original all ship call and never switched to the new frequency in the next zone

7.3.7. List of Supported Functions and Suggested Improvements (TE.4)

For each of the systems being evaluated we have drawn up a list of features or functions that could be improved, modified or better implemented. Table XIV includes a list of observations for each of the systems being considered:

Table XIV
Supported Functions and Suggested Improvements

System	Function	Observations
Ross	Transponders	• DGPS positions with the 12500 units are not reliable and jump regularly • Option of plugging into onboard gyro to obtain true bearing • Provide transponder that can be plugged into onboard GPS to reduce costs for vessels that already have this type of receiver
	Messaging	• Add acknowledgment that message has been received; currently there is no indication that a transmitted message has actually been received; at most, a warning message indicates if a message hasn't been received
	Display and Control	• Possibility of displaying information on more than one ship at a time; in the current version, the display system provides digital information (ID, position, etc.) on only one ship at a time - the ship that has been selected • a communication link (dedicated telephone lines) should be set up between adjacent control stations to ensure that information from the ship data bank is shared so that vessels will be automatically transferred between coverage areas (VTS sectors)
GP&C	Transponders	• it is difficult to adjust the unit's reporting rate (configured at installation) and only 2 modes are currently available: • normal mode: can be parameterized between 1/second and 1/minute • 'sleeping' mode: slower reporting rate when vessel speed is reduced below a pre-set value (eg., 2 knots, to simulate a ship at anchor) • available targets in the system have to be identified manually in each display system, which is very impractical when a new vessel appears for the first time in a coverage area (the company states that an automatic initialization process for new ships would be offered with an operational system) • Option of plugging into onboard gyro to obtain true bearing • Provide transponder that can be plugged into onboard GPS to reduce costs for vessels that already have this type of receiver
	Messaging	• The allowable message length (40 characters) is too short for messages with greater content and could surely be increased by using several time slots allotted by the protocol (while ensuring that position time slots have transmission priority over those of messages)

Also, information transmitted by vessels varies depending on the system. Table XV shows the information received by each of the technologies.

Table XV
Information Received at MCTS Centre

System	Transmitted and Displayed Information
Ross	• Information (target) displayed about a selected ship: * Vessel Name: Le Brave * DSC ID: 366XXXXXX ALT ID: ABCD * Position / time ⇒ Latitude: XX XX.XXXX N ⇒ Longitude: XX XX.XXXX W * HDOP: X.X * COG: XX deg. * SOG: XX knots * Length: XX meters * Draught: X.X metres * Next port: Montreal * Ship type: Tanker * VHF channel: 23 * Last report: XX sec. * Report interval: XX sec.
GP&C	• Information (target) displayed about a selected ship: * Le Brave * Speed: XX.X knots * Course: XXX deg. * Bearing: XXX deg. * Latitude: XX XX.XXXXN * Longitude: XX XX.XXXXW * CPA: X NM note: Closest Point of Approach * TCPA: XX.X min. note: Time to CPA * Ref.: ABCD * Grid: * XTRA ID:

8. COST BENEFIT ANALYSIS

We assessed the implementation costs for both (AIS) systems being evaluated in this project. We then identified and quantified the possible benefits (both monetary and social) to the CCG, the marine industry and the environment.

8.1. CCG INFRASTRUCTURE COSTS

The infrastructure costs involved in implementing an (AIS) system were assessed for each of the 2 systems being evaluated. Three (3) scenarios were considered - Implementing (AIS):

- a) in current MCTS radar surveillance zones,
- b) over the whole river from Montreal to Les Escoumins, and finally
- c) over the territory from Montreal to Sept-Iles (66 degrees West).

The costs used in our estimates were verified with Ross Engineering and Norcontrol (authorized distributor of the GP&C system). The primary cost differences were due to the number of sites necessary - 3, 4 or 5, depending on the scenario.

The shore infrastructures costs, based on one or the other of the 2 evaluated systems, Ross Eng. or GP&C / Norcontrol, are equivalent, give or take a few thousand dollars. The onboard equipment is, however, more expensive for a comprehensive Ross system (transponder with DGPS and laptop display system) at \$45.1K as compared to \$29K for the GP&C/Norcontrol broadcast system. However, Ross is the only supplier that can offer a minimum transponder system with full DSC capabilities for VTS without DGPS and that can be hooked up to onboard equipment (DGPS and ECDIS) for a cost of \$6.7K.

Tables XVI and XVII compare and summarize (AIS) infrastructure costs for both the shore network and onboard equipment for each of the scenarios we considered. The specific costs for each of the scenarios are provided in Appendix 7.

Table XVI
Network Infrastructure Costs

	Ross Engineering	Norcontrol/GP&C
Radio sites	\$ 24.7K	\$ 25K
Control & display station	\$ 30.8K	\$ 31K
Sub-total	\$ 55.5K	\$ 56K
Engineering, installation and training	37.8%	37.8%
a) 3- site scenario	\$ 229.3K	\$ 231.5K
b) 4-site scenario	\$ 305.7K	\$ 308.7K
c) 5-site scenario	\$ 382.2K	\$ 385.8K

Table XVII
Onboard Equipment

	Ross Engineering	Norcontrol/GP&C
Complete transponder (incl. (AIS), DGPS and ECS)	\$ 41.5K	\$ 29K
20-vessel fleet	\$ 830K	\$ 580K
100-vessel fleet	\$ 4,150K	\$ 2,900K
Basic transponder (AIS) only	\$ 6.7K	N/A
20-vessel fleet	\$ 134K	N/A
100-vessel fleet	\$ 670K	N/A

8.2. ADVANTAGES FOR CCG

The potential advantages to the CCG of implementing an (AIS) were assessed from two perspectives - the monetary advantages related to reduction or replacement of equipment currently being used for MCTS operations, and the monetary advantages derived from increased efficiency of MCTS operations and the advantages for CCG navigators.

8.2.1. Replacement or Reduction of Radar Surveillance Systems Currently in Use

The CCG currently operates several MCTS centres equipped with surveillance radar. The product life cycle of these systems would indicate that equipment modifications or replacement can be expected within the next few years. Implementation of an (AIS) system would mean that requirements relating to radar performance would decrease, which could lead to significant annual savings.

8.2.2. Impact on Operations (Increased Efficiency)

An (AIS) system that would automatically display vessel traffic and rebroadcast that information to the entire marine industry fleet would optimize the work currently being done by MCTS operators. An MCTS operator could potentially spend less time in voice communication with every vessel - obtaining and broadcasting vessel traffic information - and could instead broadcast (orally or via computer) other pertinent information to mariners.

This change could result in savings. However, to get a realistic and comprehensive idea of how great the savings would be, every region would have to assess the operational impact and possible savings. In addition, savings could only be realized once the entire fleet was equipped; if all vessels were not equipped, MCTS personnel would be required to continue using current equipment and, more importantly, to continue following current procedures for certain vessels only. International or even national regulations covering (AIS) must be put in place before we can capitalize on its operational advantages.

8.2.3. Impact on CCG Navigators

Using an (AIS) system on CCG and participating commercial ships may prove advantageous for icebreaking and escort operations. The system will allow CCG ships to have continuous, more accurate knowledge of the position of ships transiting ice areas and thus to optimize any movements necessary for their icebreaking or escort missions.

For SAR operations, as well, CCG ships will be able to use the display of vessel traffic to optimize the necessary movements and to facilitate communications between the various parties ashore and at sea.

Thus, in addition to contributing to enhanced safety through the availability of greater traffic information, (AIS) will allow substantial savings on ship movement and transit costs.

8.3. ENVIRONMENTAL IMPACT OF (AIS)

Installation and commissioning of (AIS) on the St Lawrence River could definitely have a positive impact on the coastal and marine environment.

Ships traveling at higher speeds have a direct impact on the environment, particularly through damage to the ship channel, shoreline, docks, winter ice cover, etc. Annually, the necessary repairs result in overhead costs that are not covered by the CCG but which are still paid for by society. The cost of these repairs can reach into the hundreds of thousands of dollars per year.

We believe that with (AIS) implemented throughout the fleet, the CCG could more easily track the speed of these vessels and would then be in a position to reduce the negative environmental impacts. We estimate that overhead costs could be reduced by some tens of thousands of dollars annually.

8.4. ADVANTAGES FOR THE MARINE INDUSTRY

Advantages for the marine industry can be found in the increase of onboard safety and the availability of better information on vessel traffic. This second advantage would affect shipping agencies but would require outside access to vessel traffic information provided through the (AIS).

8.4.1. Increase in Shipping Safety (Collision Avoidance)

Avoiding a major marine incident every five years could result in annual savings of 'several hundreds of thousands of dollars'.

8.4.2. Improved Fleet Management

We believe that improved fleet management would enable the marine industry to optimize use of their resources (ships, pilots, longshoremen, etc.) and thereby save 'several tens of thousands of dollars' per year.

9. RESULTS

This section presents a summary of the evaluation results and analysis of the (AIS) systems at an operational, technical and economic level.

9.1. COMPARATIVE ANALYSIS

9.1.1. Definition

The Ross Engineering system operates with the DSC protocol, adapted for vessel traffic management and is based on the use of active shorebased communication sites that provide radio coverage for a particular area. The shore site is essential for system operations, vessel tracking and rebroadcasting information.

Communication takes place initially on Channel 70 in accordance with DSC protocol (ITU-R M.825¹) and then on an additional duplex frequency which is different from one site to the next where the radio coverage of these sites overlaps. Therefore continuous coverage along a waterway requires, in addition to Channel 70, two alternating duplex channels used at successive sites. The system allows ship-to-shore, shore-to-ship, and ship-to-ship communication, although communication between vessels goes through the shore station (ship-to-shore-to-ship) thereby limiting communication within the coverage area of a shore site.

The GP&C system is based on the TDMA protocol and was used in slave mode (master mode was not available) with a single communication frequency.² In this operational mode, each transponder individually selects an available time slot (maximum of 2250 time slots/minute) that it secures and on which it broadcasts its information. All other listening transponders can receive the messages being broadcast either from other mobile units or from shore sites.

With the GP&C broadcast system, shorebased sites are not necessary for ships to communicate among themselves; fixed transponders installed at shore sites act as mobile units and received information is transmitted to the MCTS centre; fixed sites also serve as passive repeater stations to rebroadcast vessel traffic information received over a greater coverage area.

9.1.2. Architecture

Both systems we evaluated use a similar architecture. A control and display station at the MCTS centre receives information from a shorebased communication site via a digital telephone line. There is no physical link between shore sites to enable sharing of vessel traffic information among centres.

The GP&C's use of a single radio frequency did however provide a number of occasions (under favourable signal propagation conditions) where there was communication between the 2 shore stations which allowed both control stations to display traffic from both coverage areas without any apparent communication conflict.

¹ Recommendation presented to the IMO and pending approval

² Protocol presented to the IMO and pending approval

9.1.3. Protocol and Standard

The Ross Engineering system uses the VHF-DSC protocol modified according to ITU-R Recommendation 825 for marine traffic systems. The original DSC protocol was developed a number of years ago and is recognized primarily for its robustness rather than its transmission speed performance. It is, however, recognized internationally and already includes a number of messages defined for MCTS applications.

The TDMA protocol used by the GP&C system is already in use in some northern European countries (Sweden) for air traffic control and also for some marine applications. It performs much better, but no frequency has yet been adopted internationally for marine use. There are other systems elsewhere in the world using a TDMA-type protocol, which might make it difficult to standardize a single protocol.

9.1.4. Ship Handling Capacity

The Ross system has a lesser ship handling capacity, proportional to the protocol rate being used (1200 bps vs 9600 bps) or a maximum capacity of 250 vs 2250 reports/minute. The impact of this capacity will depend on the number of vessels being tracked. To monitor approximately 30 vessels, the Ross system would be limited to a reporting rate of every 10 seconds ($180/250$ vessels/min. = 72%) while the GP&C broadcast system would allow reporting every second for the same number of vessels for a similar utilization rate of the radio channel ($1800/2250$ vessels/min. = 80%).

A lesser capacity will have some impact on traffic surveillance (depending on the number of equipped vessels) but could have a greater impact when ship positions are being rebroadcast in a situation where two vessels are approaching each other at 6 metres/sec. (12 knots). At that speed, a 10-second delay represents a distance of 60 metres!

Both systems are capable of sending text messages. The Ross system can send messages that are thousands of characters long. Messages are broken up and transmitted in several successive blocks of 256 characters so that the radio link needed for position reports isn't monopolized by messages. A message of 5000 characters ($1\frac{1}{2}$ pages of text) took 8 to 10 minutes to be transmitted from the MCTS centre to the vessel.

Messages sent by the GP&C broadcast system evaluated during our trials were limited to 40 characters at a time, which is relatively little and was used mostly to evaluate its functional capabilities. The GP&C broadcast system was the only one to provide a double acknowledgment which indicates first to the sender of the message that it has been received by the receiving vessel's transponder and then that it has been read by the user on board.

9.1.5. System

Ross develops and manufactures its (AIS) transponders and display and control terminals itself. First and foremost, Ross is a radio manufacturer that is familiar with the potential of the DSC protocol and uses it effectively. The operating system used for the display terminal (Windows 3.1), limits the system's performance, particularly for tracking a number of vessels when information on only one ship at a time can be displayed.

The GP&C/Norcontrol system provides a display and vessel tracking system that offers better performance including the ability to have several windows open on different vessels and track them with their respective information. Windows NT makes this flexibility possible. Integration of the GP&C broadcast transponder with the Norcontrol display system could be improved upon however, particularly where operators have to manually align the vessel name assignment table with the table containing their 8-character ID transponder codes. The user has to know in advance the transponder codes of vessels likely to come into the vicinity.

9.2. OPERATIONAL EVALUATION

MCTS operators contributed the most to operational evaluation of the systems. Their evaluation was, however, somewhat limited (to the MCTS at Longueuil) because of the many failures of the Ross system and especially because of the small number of transponder-equipped commercial vessels that were available.

The evaluation focused mainly on:

- A. functions offered by the system, including messaging
- B. (AIS) performance vs current radar system, including coverage
- C. impact on operations, particularly on position reports and calculating estimated time of arrival (ETA)
- D. use for mariners

9.2.1. System Functions

(AIS) operations are useful in monitoring traffic in zones that only have a VHF communication system (without radar surveillance). (AIS) provides an accurate ship position, which reduces the amount of information that needs to be exchanged with the vessel, increases communication efficiency, facilitates decision-making and allows for a reduction in the safety margin.

In radar surveillance areas, position information provided by the (AIS) is just as accurate as the same information provided by radar, but radar also provides a true bearing, which is useful information, particularly in ports. To provide a true bearing, an (AIS) transponder would have to be hooked up to the shipboard gyro, which was not the case during our trials.¹

9.2.1.1. Messaging

The messaging function could be used for information requests that are not urgent, are more confidential in nature or are more difficult to understand when spoken (eg., foreign names, etc.).

Using the shipboard keyboard could be more difficult, particularly at night.

9.2.2. (AIS) Performance vs. Radar

Position accuracy using the (AIS) system is at least as good as with radar (+/- 20 metres) even for vessels that are only equipped with GPS receivers, while vessels that are DGPS-equipped transmit an even more accurate position.

¹ Ross now includes a magnetic compass with its 12500 transponder to provide the true bearing

9.2.2.1. Radio Coverage

Radio coverage varied depending on the ships and their set-up (antenna height for example). With the Ross system at the Lauzon site, which was operated from the MCTS centre at Quebec, we observed average coverage from Cap Santé to Montmagny - substantially the same coverage as with radio communication using the same site.

The GP&C broadcast system installed at Mont-Bélair provides solid coverage from Quebec to Trois-Rivières. Vessels are also received to the west up to the middle of Lac St-Pierre but with signal interruptions between the bridge at Trois-Rivières and the eastern end of Lac St-Pierre. The Sorel site provides coverage west from Pointe-aux-Trembles to the middle of Lac St-Pierre.

9.2.3. Impact on Operations

Overall, MCTS believes that an (AIS) would be very effective for monitoring vessel traffic, as long as all vessels are equipped.

Information transmitted from MCTS centres to mariners usually results in an exchange of information between stations (other requests or questions) and it can be expected that voice communication over the VHF will remain a necessity.

Repetitive information (i.e., NOTSHIP) could be transmitted using a messaging function. The current systems cannot transmit repeated messages. Other sporadic information would have to be provided by VHF (more user-friendly). Information transmitted to users could therefore come from two different systems.

9.2.4. Minimum MCTS Specifications

Minimum MCTS requirements for an (AIS) system are the following:

- position reporting rate of every 1 to 2 seconds in high traffic ports and of at least every 10 seconds in VHF only coverage areas;
- system integrating (AIS) control and display and radar;
- ability to track and display tags of several vessels simultaneously;
- ability of control and display system to record and do simulation.

9.2.5. Use by Mariners

Operational evaluation of the (AIS) system on board vessels was only possible with the GP&C/Norcontrol display system. This was the only system that was sufficiently operational during the evaluation period to display participating vessel traffic.

Operational evaluation of the Ross system on board commercial vessels was not possible because the Ross transponders could not be interfaced with the ECDIS systems of participating vessels. The Ross system has since been modified to provide messages in accordance with the ECPINS protocol of Offshore System Ltd. However, to date, no operational shipboard ECPINS-Ross interface has been implemented for the purposes of testing its serviceability.

9.2.5.1. *Display*

The display systems (laptops) that we evaluated were found to be too small by some pilots and should have been integrated into the onboard ECDIS systems used for electronic navigation. For pilots, a system of this sort should above all provide information for steering the vessel - so that orders can be given to the helmsman.

9.2.5.2. *Messaging*

The messaging feature was used with some commercial vessels to send information about weather, ETAs, etc. Pilots found this feature, which requires use of the keyboard, inappropriate for navigation and still prefer voice communication over the VHF. The pilots we spoke with were, however, interested in the possibility of a system that would display on their screens general shipping information without them having to work specifically with the keyboard.

9.3. TECHNICAL PERFORMANCE

Table XVIII summarizes technical performance for each of the (AIS) systems under evaluation:

Table XVIII
Technical Performance

Criteria	GP&C/Norcontrol	Ross Engineering
Operational sensitivity	- 105 dBm (1.25 μ V)	- 119 dBm (0.25 μ V)
Coverage	Sorel: 35 km Mt-Bélair: 150 km	Ile Charron: 60 km Sorel: 45 km Trois-Rivières: 115 km Lauzon: 100 km
Reporting capacity	2250/minute	250/minute
Messaging capacity	40 characters	< 5000 characters
Communication speed	9600 bps	1200 bps
Transfer speed	9600 bps	9600 bps
Reporting rate	fixed: from 1 second up	adjustable from one sec. up
International standard	not yet approved	DSC/ITU-R.493: approved DSC/ITU-R M.825, not yet approved
Control & Display System	Windows NT	Windows 3.1
Reliability	Good (approx. 90%)	Average (approx. 75%)

Overall reliability of the GP&C/Norcontrol system was better. The Ross system (modems, radio, transponders and software) had a number of failures, modifications and updates over the evaluation period which brought its reliability rate down to about 50% up until August 1996. Since the last version was implemented at that time, the level has increased to approximately 75% (3 out of 4 sites are operational).

9.4. COST EFFECTIVENESS

Shipboard equipment costs vary widely, depending on the type of equipment and configuration. The (AIS)-DSC system now offers the least expensive solution (although not available during our evaluation) which is an (AIS)-DSC transponder without GPS receiver, which can be plugged into onboard GPS and ECDIS systems for \$6.7K. The GP&C transponder which includes the GPS receiver is \$15K.

The costs involved in deploying the (AIS) infrastructures varied according to the extent of the territory to be covered. These costs vary from \$229K to \$386K according to the technology and above all the number of sites to be implemented. Costs include shorebased sites and one control and display station per site. These costs vary from \$229K to \$386K according to the technology and above all the number of sites to be implemented. Costs include shorebased sites and one control and display station per site. These estimates are based on full (AIS) coverage for each area considered in addition to the existing VHF and radar infrastructure. A national study should therefore be carried out to evaluate the requirements, and this means:

- implementing (AIS) coverage in an area currently covered by VHF only; and
- removing/modifying/retaining the radar infrastructure in each of the areas currently covered in keeping with the availability of (AIS) technology.

In some areas (depending on requirements, traffic and so on), it is conceivable that the (AIS) technology may duly replace the radar system while, in other areas, the radar will have to be retained. Only a detailed analysis by area will make it possible to make a decision and develop recommendations in this regard.

Installation of an (AIS) system could result in direct benefits for operations. However, no benefits can be realized until all commercial vessels are equipped in compliance with some future regulations. These possible advantages were not quantified during our project.

10. CONCLUSIONS

10.1. OPERATIONAL EVALUATION

The availability and utilization of an (AIS) system in VHF coverage areas would prove an advantage in that exchanges of information with vessels could be reduced and radio communications optimized. In radar coverage areas, position reporting with the (AIS) system is at least as accurate (even for vessels that only have GPS), but (AIS) does not yet provide true bearing (available with radar image) which is essential for tracking vessels in high traffic ports or near obstacles such as bridges and docks. (AIS) complements radar surveillance in that it automatically identifies targets and provides that information to the radar system. It could eventually replace radar, but the system would have to be more reliable and used only in situations where all vessels are equipped with (AIS) transponders. The (AIS) information reporting rate would have to be fast enough (1 to 2 seconds) in current radar surveillance zones. In areas covered by radio only, the targeted reporting rate is every 10 seconds to 1 minute, depending on traffic.

(AIS) makes it possible to transmit shipping information through a messaging system. This function was also found to be useful for transmitting non-priority or more confidential requests through selectively transmitting messages to the targeted vessel only. (AIS) messaging, however, is not efficient enough to replace all VHF radio communication which is also used for brief and rapid exchanges between MCTS operators and shipboard personnel (pilots, officers, etc.).

Having (AIS) information available on board vessels has the additional advantage of assisting the decision-making process. Information provided by the (AIS) on vessel traffic should be integrated into the shipboard ECDIS to minimize the number of screens and information sources. There was no integration of (AIS) and ECDIS on board the commercial vessels selected by the marine industry for our trial period. The objective of increased efficiency - primarily advocated by the CSA - changed during the project, and the CSA decided to make their priority the development of a new, satellite-base communication and positioning system.

Pilots prefer to work with the larger ECDIS screens (21 inches) rather than with the laptops (approx. 10 inches) used in our trials. If, in the future, regulations require vessels to have (AIS), there does have to be a portable system for foreign vessels that may not be equipped with a permanent system. Pilots want to see traffic in the vicinity (approx. 15 km above and below the vessel). Generally, this type of navigational aid should assist pilots in determining what to tell the helmsman about how the ship should be manoeuvred and the course to be steered. For their own requirements, pilots prefer to use VHF radio communication rather than a keyboard for answering or making information requests. They would, however, appreciate a system that would regularly post shipping information (weather, vessel traffic, etc.) on a screen, as long as the system did not require excessive keyboard use.

10.2. COMPARATIVE ANALYSIS

Definition and Architecture:

The broadcast system definition relies on a simpler shorebased infrastructure to ensure shore-to-ship communication than the DSC system. This is particularly true along a waterway that requires radio coverage from a number of adjacent sites. The GP&C broadcast system can also receive data transmitted from vessels (as with the DSC system). However, rebroadcasting of data to vessels and communication amongst ships is much simpler through the use of a single frequency. The broadcast system can, in addition, meet one of the CCG requirements which is to receive the positions of transponder equipped vessels taking part in its ice-breaker convoy missions - even in areas that are not covered by the shorebased rebroadcast infrastructures (eg., Arctic). The (AIS) is the only system to offer a true collision avoidance function which requires direct ship-to-ship communication without going through a shore site.

The DSC-protocol-based system (Ross Engineering) is suitably adapted for receiving position data transmitted to an MCTS centre. However, this architecture is based on the use of shore sites with different duplex frequencies and is less efficient for rebroadcasting information to vessels, and is especially inefficient for ship-to-ship communication. Tracking vessels with the DSC system over a number of successive coverage areas is tricky and requires adequate parameterization and overall synchronization of the system, which was difficult to adjust in this project.

The architectures of the two systems were comparable in their use of a control and display station at each of the shorebased communication sites. In both instances, there needs to be an integration of information coming from several shore sites on one display screen. GP&C's system demonstrated that it was possible to receive information from an adjacent site on the radio channel, so that information from two shore sites was displayed at one station.

Protocol and Standard:

The (AIS)-DSC system is based on a robust and proven protocol that has already been adopted by the IMO (ITU-R. 493) as the message format for Channel 70 (marine frequency). The system we evaluated is also based on modifications proposed to the IMO (ITU-R M.825) to increase (AIS)-DSC ship handling capacity, specifically through use of marine duplex VHF channels. The TDMA protocol used by the broadcast system is already used for air traffic control, but no radio frequency has yet been identified and approved for marine use. The protocol performs better than DSC and takes advantage of new digital modulation techniques that make better use of the radio spectrum. The protocol used by the GP&C broadcast system we evaluated is currently being presented to the IMO in an effort to secure international approval for marine use.

Ship Handling Capacity:

The ship handling capacity of the broadcast system is much greater - approx. 10 times greater - than the capacity of the (AIS)-DSC system. This is primarily due to a higher available gross rate on the radio channel (9600 vs 1200 bps). The higher capacity of the broadcast system is the only one that can track several dozen ships at a reporting rate of once every 1 or 2 seconds, which is one of the MCTS requirements (for possible replacement of the radar surveillance system) in ports and one of the requirements for vessels that are approaching or following each other (convoy).

The more limited capacity of the (AIS)-DSC system - i.e., 4 to 5 reports per second - restricts its use to a supplement to the current radar surveillance system for automatically identifying targets. The (AIS)-DSC system alone could not meet the required reporting rate for high traffic port areas.

The capacity of the (AIS)-DSC system to send messages is higher than for the broadcast system we evaluated. The Ross system can handle the transmission of long messages (estimated at up to 5000 characters) that are automatically divided up into batches of 256 characters while ASCII messages transmitted by the GP&C broadcast system are limited to 40 characters long.

System:

The (AIS)-DSC system we evaluated was developed and assembled entirely by Ross Engineering - both the radio and the control and display terminals. The display system, running under Windows 3.1, limited the system's performance and prevents it from meeting one of the MCTS requirements which is to simultaneously track several vessels, each with its own tag.

The (AIS) broadcast system we evaluated - which is based on the radio developed by GP&C and Norcontrol's display system - runs under Windows NT and offers better performance in that it can display and track several vessels simultaneously. However, the system we used did not automatically identify new vessels or transponders that had been reassigned to other vessels. An officer (or technician) was required to manually update the vessel assignment table for all display stations, both on ship and shore.

10.3. TECHNICAL PERFORMANCE

The (AIS) broadcast system was closer than the (AIS)-DSC system to meeting its specifications for technical performance. The (AIS)-DSC needed a significant number of modifications over the course of the evaluation and it had a lower level of overall reliability (approx. 75%) as compared to the broadcast system (approx. 90%).

Radio sensitivity in the DSC equipment was better (0.25 μ V vs. 1.25 μ V) than the sensitivity of the GP&C broadcast transponders, but radio coverage with the GP&C was superior, due mostly to use of the higher site at Mont-Bélair (> 1000 ft. high).

We were able to use 2 VHF channels (70 plus a duplex channel) at each of the CCG sites by adding antennas and cavities for filtration. With the broadcast system, it was necessary to add an attenuation filter in the onboard television reception antenna line in order to eliminate transponder interference.

It was a long time before the ability to switch automatically from Channel 70 to a duplex channel - which is necessary for the (AIS)-DSC system - was operational. This function is contained in the recommendations for improvements to the protocol (ITU-R M.825) being presented to the IMO and which are still under consideration. The system's ability to switch frequencies was only demonstrated at the end of the evaluation period and for one vessel only.

The (AIS) transponder was interfaced with an ECDIS using a system supplied by Qmar. A demonstration of the interface was made to the CCG using the GP&C broadcast system on the vessel *F.G.Smith*. No other (AIS)-ECDIS interface was possible on the commercial vessels during our evaluation period. Ross Engineering did modify its transponder by adding an NMEA outlet compatible with OSL's ECDIS, but no real trials were conducted.

10.4. COST BENEFIT ANALYSIS

Shipboard equipment is less expensive for the Ross Engineering (AIS)-DSC which in one configuration costs \$6.7K for a DSC unit and (AIS) interface that can be linked to the ship's GPS and ECDIS. The (AIS) broadcast transponder includes a GPS and sells for \$15K - more than double the (AIS)-DSC option.

Conclusions

The cost of a shorebased infrastructure to receive, display (at MCTS centre) and rebroadcast (AIS) information is proportional to the desired coverage and the number of sites required. Costs vary between \$229K and \$386K depending on the technology and the number of sites being considered (3 to 5 sites) for an average of approximately \$77K per site. The costs involved in implementing an (AIS) system in areas currently covered by radar would be in the order of \$230K, depending on the technology, and on the order of \$385K for the entire territory (Montreal to Sept-Iles).

As implementation of (AIS) necessitates additional infrastructure, the pertinence of doing so in each area now covered by VHF only or by radar and VHF should be assessed. A detailed national analysis will have to be carried out by area and will help to make a decision and develop recommendations in this regard.

Direct benefits to the CCG from implementation of an (AIS) system were not quantitatively assessed. Such benefits, however, could only be realized if all commercial vessels were transponder-equipped.

11. RECOMMENDATIONS

1. Support IMO development of a performance standard for an (AIS)-Broadcast system and adoption of international standards for marine use;
2. Study at the national level the advisability and feasibility of using and implementing (AIS) according to the existing CCG radar or VHF coverage areas .
3. In conjunction with involved parties, complete a detailed evaluation of the potential real benefits of using an (AIS) system for the CCG and the environment as well as for the shipping industry;
4. In conjunction with the GCC-RL Marine Programs Branch evaluate the possibility of optimizing our (AIS) infrastructure and equipment that are in use in our region, particularly for traffic tracking, ice-breaking, search and rescue, and dredging surveillance operations;
5. Evaluate the feasibility of using an (AIS) satellite system in areas that are not covered by shore sites (Gulf and Arctic);
6. Continue working toward integration of (AIS) with onboard ECDIS and the CCG's INNAV system.

APPENDIX A

SPECIFIC OBJECTIVES

Four (4) participants in the project - two (2) representatives from the marine industry (CSA and Shipping Federation) and two (2) groups from within the CCG (MCTS and Technical Services) - took part in developing the project's specific objectives.

These objectives were analyzed and divided into 14 test modules containing similar goals. Tables 1 to 4 contain the specific objectives applicable to this project as well as the participant(s) responsible for their evaluation or completion. Table 1 also indicates the actual level of completion achieved by the participants responsible for each of the objectives.

- Objective not achieved or not addressed: 0%
- Objective partially achieved or no conclusive decision made: 50%
- Objective fully achieved: 100%

Of the 47 specific objectives (Table I), 11 were fully achieved and 22 were partially achieved. The 14 other objectives were either not completed or simply were not evaluated. Tables 2 to 4 contain objectives relating to each of the participating groups.

Table 1

Test Modules	Objectives	Responsible			% Achieved
		Industry	MCTS	Tech.Serv.	
1. Traffic Monitoring	SF.6A	X	X		0
	VTS.2		X		50
	VTS.3		X		50
	VTS.14		X		0
2. ECDIS Display	CSA.2A	X		X	50
	SF.1	X		X	100
	TE.18	X		X	50
3. Operational Requirements	VTS.6		X		0
	VTS.10		X	X	0
	TE.8			X	50
	TE.9		X	X	50
4. Impact of adjacent zones	TE.25A			X	100
	VTS.9		X		100
5. Compatibility with SL Seaway	TE.17	X		X	0
	TE.29	X		X	100
6. Compatibility with Inmarsat-B Service	TE.28			X	0
7. (AIS) vs radar	VTS.4		X		100
	VTS.5		X		100
	TE.7			X	100
	TE.22			X	100
8. Increased communication efficiency	CSA.3A	X			50
	SF.7A		X		100
	VTS.11		X		50
	TE.8			X	50
9. Impact on operations and frequencies	VTS.1		X		0
	VTS.6		X		0
	VTS.7		X		0
	VTS.8		X		50
	TE.1			X	100
	TE.4			X	50
	TE.5			X	50
	TE.11			X	0
	TE.12			X	100
	TE.21	Pilots		X	50
	TE.23			X	50
10. Reliability	SF.13	X			50
	VTS.15		X		0
	TE.6			X	50
	TE.24			X	50
11. Impact on safety	SF.14	X		.	0
	SF.15	X		.	0
	VTS.13		X		50
12. Compatibility with international standards	TE.26			X	50
	TE.27			X	0
13. Opportunity study/14. Feasibility study	SF.9	X	X	X	50
	TE.2			X	50
	TE.20			X	50

Table 2
Objectives
Marine industry

CSA.2A:	Increase usefulness of ECDIS systems in operation through automatic display of the position of ships in the vicinity; (Capacity) (Objective 2)
CSA.3A:	Establish a system that enables ships to use "voiceless" communication with other ships and with shore-based stations; (Op. Funct.) (Objective 8)
SF.1:	View identification and position information received from other vessels or shore-based sites on a display system or ECDIS; (Capacity) (Objective 2)
SF.6A:	MCTS monitoring of vessel traffic will be made easier by a decrease in the need to log and broadcast traffic information verbally; one operator will be able to monitor a larger area; (Capacity) (Objective 1)
SF.7A:	Evaluate transmission capabilities for other messages (other than AIS), such as pilot orders, water level information, etc; (Op. Funct.) (Objective 8)
SF.9:	Compare the technical and operational advantages and disadvantages of each of the systems being assessed; (System) (Objective 13)
SF.13:	Assess the reliability and continuous monitoring of the system's functioning; (Op. Funct.) (Objective 10)
SF.14:	Increase safety; (System) (Objective 11)
SF.15:	Increase efficiency of waterways. (System) (Objective 11)

Table 3
Objectives
Marine Communications And Traffic Services (MCTS)

VTS.1:	Identify impacts of (AIS) system on procedures currently being used to regulate vessel traffic; (Op. Funct.) (Objective 9)
VTS.2:	Compare (AIS) reporting method with method traditionally used by MCTS centres; identify possible reductions in current number of calling-in points; (Op. Funct.) (Objective 1) • comment on the potential impact on marine safety using concrete examples; • comment on the possibility of allowing some clients to use equivalent procedures under certain conditions, once (AIS) is introduced;
VTS.3:	Evaluate and comment on the operational impact on traffic regulation of having both (AIS) equipped and non-AIS equipped ships in the same zone. (Op. Funct.) (Objective 1) • comment on the possible impact on marine safety, using concrete examples • make recommendations for reducing these impacts (Ref. 2.3.1) • extrapolate for a situation where all vessels are equipped.
VTS.4:	Compare and comment on the target detection performance of (AIS) vs radar: (Op. Funct.) (Objective 7)
VTS.5:	Check the reliability of the following (AIS) data as compared to radar: (Op. Funct.) (Objective 7) • name, speed, bearing
VTS.6:	Identify the minimum operational requirements for establishing an (AIS) service such as: (Capacity) (Objective 3) (Op. Funct.) (Objective 9) • broadcasting of data messages and additional messages, rebroadcasting, polling intervals • user-friendliness of systems, etc
VTS.7:	Evaluate and comment on the two operation modes, automatic and manual: assess the impact of each on the system's capacity. (Tech.) (Objective 9)
VTS.8:	Evaluate and comment on the use of frequencies to determine whether there is any impact on routine operations. (Op. Funct.) (Tech.)
VTS.9:	Evaluate and comment on using (AIS) when areas overlap: interference, jamming, notices, hand-offs, etc. (Op. Funct.) (Tech.)
VTS.10:	Determine the operational requirements for a shorebased (AIS) and the interfaces necessary to display and broadcast information when integrated into current or future systems MCTS monitoring units (e.g. INNAV). (Architecture) (Objective 3)
VTS.11:	Comment on possible improvements to communications between ships and shore stations, owners, agents and other people or organizations that may be involved. (Op. Funct.) (Objective 8)
VTS.13:	Assess the advantages and disadvantages of (AIS) in terms of marine safety. Comment on the impact on safety; take into consideration vessels that are participating and those that are not. (System) (Objective 11)
VTS.14:	Evaluate and comment on the use of radar and radio communication vs (AIS) for traffic regulation. Assess the advantages and disadvantages of each system in terms of efficiency. (System) (Objective 1)
VTS.15:	Evaluate reliability and level of service required. (Op. Funct.) (Objective 10)

Table 4

Objectives - Technical Services

TE.1:	Investigate and compare each of the two (AIS) architectures being tested. (Tech.) (Objective 9)
TE.2:	Collect the information necessary to develop technical and operational specifications to be used in a future call for tenders for an (AIS) system. (System) (Objective 14)
TE.4:	Draw up a detailed list of technical and operational functions supported by each technology and the functions that could have been added or could have been better implemented. (Op. Funct.) (Tech.) (Objective 9)
TE.5:	Compile technical performance data on the systems such as: (Tech.) (Objective 9) • coverage, interference problems • ship handling capacity • coexistence of position reports and transmission of text messages • system reliability • capacity of the system to accept new ships in the coverage area
TE.6:	Determine the robustness of the (AIS) data transmission system in a radio environment. (Tech.) (Objective 10)
TE.7:	Evaluate whether the (AIS) architecture results in latency of vessel position reports. (Op. Funct.) (Objective 7) • to MCTS; • to the vessel.
TE.8:	Evaluate the capacity of the communications channel to transmit non-AIS messages (ship positions and ID) and analyse the assignment of respective communication priorities. (Capacity) (Objective 3) (Tech.) (Objective 8)
TE.9:	Evaluate the system's ship handling capacity. (Capacity) (Objective 3)
TE.11:	Evaluate the advantages and disadvantages of the SCC system's autonomous and controlled modes for MCTS operations and for marine information services. (Op. Funct.) (Objective 9)
TE.12:	Evaluate the capability of the Ross System to transfer communication from Channel 70 to the duplex channel. (Tech.) (Objective 9)
TE.17:	Evaluate compatibility of the system used by the St. Lawrence Seaway (ship transmissions only) with the Ross Engineering system. (Architecture) (Objective 5)
TE.18:	Evaluate shipboard (AIS) information display systems as well as their available and desirable features. (Op. Funct.) (Objective 2)
TE.20:	Determine the real costs of an AIS-based marine information system; take into account the necessary costs for managing information in addition to basic (AIS) information. (System) (Objective 14)
TE.21:	Study the adaptability (transportability, cost, etc.) of the (AIS) system to pilotage activities. (System) (Objective 9)
TE.22:	Make a comparative evaluation of the accuracy and resolution obtained for a ship's position through radar and through (AIS) in areas where both systems are in operation. (Tech.) (Objective 7)
TE.23:	Assess current and potential interference problems caused by using digital signals in the marine band frequency ashore and on ships. (Tech.) (Objective 9) • operating modes (autonomous, controlled, DSC/Duplex, etc.) • parameter adjustment (e.g. transmission rate) • querying for additional information

Appendix A

- TE.24: Evaluate operational and technical reliability and the reliability of the message protocol, to determine the likelihood of “lost” position reports, “message collisions” or any other effect that might hamper reception of timely ship position reports. **(System) (Objective 10)**
- TE.25A: Evaluate the operation and exchange of information between adjacent MCTS zones. **(Capacity) (Objective 4)**
- TE.26: Evaluate compatibility of the Ross Engineering system with ITU-R standards defining GMDSS DSC for distress call functions. **(Protocol) (Objective 12)**
- TE.27: Comment on the DSC format defined by AIS. **(Protocol) (Objective 12)**
- TE.28: Evaluate the functionality of the Shipping Federation's GP&C transponder on an Inmarsat-C link. **(Capacity) (Objective 6)**
- TE.29: Evaluate the compatibility of the Ross Engineering system and the VHF-DSC protocol (ITU-R) with the St. Lawrence Seaway system, using manual transmission from the transponder. **(Capacity) (Objective 5)**

APPENDIX B**RESOURCES USED IN THE PROJECT**

This section provides in table form the financial and human resources expended on the project by various participants since the beginning of April 1995.

	CCG	CSA / SHIP.FED	PILOTS	SHC
Management	4 p.m.	2 p.m.	0.25 p.m.	1 p.m.
Engineering (Ross)	4 p.m.			
Engineering (GP&C)	1 p.m.			
Technical (Ross)	4 p.m.	1 p.m.		
Technical (GP&C)	1 p.m.			
Installation	2 p.m.	1 p.m.		
Operation	4 p.m.		0.5 p.m.	
Total	20 p.m.	4 p.m.	0.75 p.m.	1 p.m.
Budget (\$K)	\$375K	\$100K		

APPENDIX C

OPERATIONAL EVALUATION REPORTS - MCTS

(AIS) Final Report

96-09-20

In January 1996 the Ross Eng. and GP & C systems were installed in the Quebec City centre. The Ross system was installed in Montreal in February and the GP & C system in June 1996.

The Ross system was operational in Quebec City and Montreal, but there were software problems. The GP & C system was operational in Quebec City, but there were technical problems that were solved more quickly. Ross Eng. did not install new software until August.

The GP & C system was installed in Sorel, so comparison with the Montreal radar system was not possible.

The major problem encountered was the small number of vessels that were equipped, and especially the presence of enough targets at the same time and in the same place.

The following report is based on observations, mostly at Quebec City for the GP & C system for comparisons with radar. Much of this report consists of extrapolation.

VTs1.: Objective: to compare (AIS) in relation to current regulation procedures

1 - (AIS) IMPACTS ON CURRENT PROCEDURES

We have broken down the current procedures into four formats:

- a- Clearances
- b- Reports to CIPs
- c- Additional reports
- d- Information for shipping

(AIS) Impacts

a - Clearances (see Annex 1)

VHF Communications	(AIS)	Radar
Decision-making in terms of ETAs. Greater safety margin because of lack of precision on the position Requires more communications	Decision-making in terms of the vessel's actual position. Does not give the true course of manoeuvres. Slightly lower safety margin Effective Complete coverage area	Decision-making in terms of the vessel's actual position (manoeuvre of the true course) Reduced safety margin. Very effective Reduced coverage area

b - Reports to CIPs

Actual position not known	Throughout the zone: Sure of vessel's position Traffic information can be given more precisely E.g.: exact position, without asking questions (Course made good) Does not have the vessel course	In radar zone only: Sure of vessel's position Traffic information can be given more precisely E.g.: exact position, without asking questions (Course made good) Gives the vessel course
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c - Additional reports

E.g.: engine breakdown
Lack of information

Throughout the zone:
Fewer questions
Exact position
Course made good and speed
Does not have vessel course

In radar zone only:
Fewer questions
Exact position
Course made good and speed
Vessel's course available

Detection of a vessel that is having problems but has not yet reported.
Could give an indication of the movement of vessels in ice, changes of pilot,
by the speed observed.

d - Information for shipping

Verbal

Partial information on traffic
Partial messaging information

No contributions

VTS.6: Provide the list of information we transmit verbally to the vessels.

2 - MINIMUM OPERATIONAL REQUIREMENTS

The MCTS now provides the following information to vessels:

1 - Traffic

- approaching
- ETAs of vessels to the CIPs in poor weather - deep-draught vessels - towing
- being overtaken
- overtaking
- manoeuvring with intentions
- at anchor
- in difficulty
- special operations such as buoyage, dredging, sounding, and so on
- **Keel clearance standard -**

2 - Information

- NOTSHIP
- Deep draught restrictions
- Temporary speed reduction for: diving work, floatplane exercises, and so on.
- Weather conditions - visibility - gale warning
- Ice conditions and navigation restrictions
- Docking instructions
- Abnormal tide conditions
- Water level monitoring - tide forecasts
- Draught - pre-clearance for deep-draught vessels
- Vertical clearance - monitoring headroom
- Message on pilotage or other subjects
- Harbourmaster - Investigators - Ship Safety - Immigration - Customs - RCMP, etc.
- Federal court orders

All this information gives rise to other requests or questions, so it is likely that VHF communications will still be necessary, to be certain that the vessel has all the traffic information (for example, a vessel with a system failure or one that does not participate in the (AIS) program).

Repetitive information (NOTSHIPS) could be provided by messaging. At present the systems do not permit repetition of these messages. Other sporadic information should be provided by VHF (more user-friendly). That would mean that information would be coming from two different systems.

VTs.14: We must list the necessary functions of radar and comment on the use of radar versus (AIS).

3 - RADAR AND (AIS) RADIOCOMMUNICATIONS

Radar versus (AIS)

- (AIS) coverage is much greater than radar.
- For wide zones and vessels en route, there are no significant differences.
- Radar is superior in port zones where there are many manoeuvres.
- Radar gives the true course of the vessel, enabling MCTSO to make more enlightened decisions, and increases safety and effectiveness.
- (AIS) gives only the position
- (AIS) seems superior for tracking small units which may occasionally be hidden
- Monitoring of vessels at anchor - radar generates an alarm - not available with (AIS)
- CPA - radar generates an alarm - not available with (AIS)

Essential functions used on radar

Log - Reference point - Offset - Target Trace (short and long) Predictions - Simulation- Target Anchorage and Alarms - Vector / Tag - Info-Symbol - Collision Tracking Assignment -

Radiocommunications versus (AIS)

Generally the communications are intended for a single vessel and require an ACKNOWLEDGMENT of receipt

When a message must be given general distribution, that means that it is intended for all shipping, including pleasure boats that will not be equipped with (AIS).

Urgent messages will of course be issued by VHF.

We believe that messaging could be used for **non-priority** information requests, since they are more confidential and harder to understand verbally (foreign names, etc.).

It seems to us that use of the keyboard on board the vessel will be more difficult, particularly at night.

VTS.15: What alternatives do we have if the system fails?

4 - RELIABILITY AND REQUIRED LEVELS OF SERVICE

The ideal and most beneficial system would be one in which all commercial vessels are equipped.

If this were not the case, the conditions would be more dangerous than with the present system. If a breakdown occurred, we would have to operate with the conventional system. Any loss of communications would cause a total loss of information.

The loss of a land station would reduce the precision of restricted channel information, because it would go from DGPS to GPS.

Reduction in service with volunteer participants.

Conclusion

In conclusion, in the long term, with an ideal system (where everyone is equipped), we believe that the (AIS) is a tool that can make a great contribution to the effectiveness of marine navigation because of the very precise positioning of each vessel, the coverage area and the rebroadcasting possibilities. However, an IMO standard will have to be developed to make certain it is used.

We believe it will be possible to use this system within the future INNAV system by using it as INPUT in the same way as RADAR, VHF DF and simulation are used. That would make it possible to continue working in simulation in case of a breakdown.

Messaging could be used for non-priority information requests, since they are more confidential. However, we still have reservations about this messaging service for the following reasons::

- Requires an acknowledgment of receipt;
- VHF is easy to use at any time, in comparison to monitoring (AIS);
- VHF is easy to use in emergencies;
- Exchange of players.

ANNEX 1

MCTS CLEARANCE PROCESS

Including recommendations and directives

Collect and analyse the information
Compliance of vessel - Detention on a vessel
Intentions
Geography - wide or narrow zones
Whether the vessel is using the channel or not
Direction of departure
Currents and tides
Length of vessel
Draught and keel clearance (**restrictions**)
Winds
Equipment and bow thruster
Tugs
Vessel nationality (communications problems and crew)
Port restrictions
Relevant traffic
Duration of manoeuvre

MCTS needs a buffer zone to clear a departure, and that zone is proportional to the type of tool used to evaluate the traffic image at the time of departure and/or the manoeuvres to be done.



Pêches et Océans
Canada
Garde côtière

Fisheries and Oceans
Canada
Coast Guard

Laurentian Region
Marine Communications and
Traffic Services
101, boulevard Champlain
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Notre référence Our file
DMOD 8052-9

May 2, 1996

MEMORANDUM

To: Gilles Ringuette
 DMYCA

From: Denis Massicotte
 DMODA

Subject: (AIS) project preliminary report

As requested, here are our comments on A.I.S. to date. As agreed, the comments are only on the Norcontrol system.

It is important to point out that the tests we did are definitely not exhaustive, mainly because few vessels are equipped with A.I.S. You will understand that for the moment this report has been prepared with the means we had on hand, and that we hope that eventually more vessels will participate.

In general, we believe that A.I.S. will be very effective for detection and traffic monitoring. Of course, if all vessels are equipped, the overall effectiveness will be very high.

Our present concern is with non-participating vessels, because we believe that that may cause a false sense of safety. There again, however, the more we test the system, the better we will be able to identify the safety needs of regulation.

It is interesting to note that A.I.S. can target and track one specific vessel or a group of vessels, at different locations (zoomer), while displaying a general picture of the traffic in the zone of responsibility.

In general it is a reliable system. However, the signal is sometimes lost; this will have to be corrected.

VTs.1

We were not able to measure the impacts, because the traffic volume did not allow for it, and few vessels are equipped.

VTs.2

There is no indication by which we can identify a reduction in calling-in points for the moment. Here again it is premature to comment on this objective, because the number of vessels using A.I.S. is minimal.

VTs.4

- When a vessel is targeted, the precision of A.I.S seems comparable to that of radar.
- There is an occasional loss of signal, which leads to a loss of targets.
- For the moment, the comparison can be done only within the visual limits of the radar in the Port of Quebec City.

VTs.5

Updating of the parameters seems faster than with radar. Reliability is comparable.

VTs.8

It has been impossible to evaluate this to date, because of the small number of participating vessels.

VTs.9

Ross: the transfer is not automatic. We have to log out for vessels that must change responsibility zones. During that period, there are no longer any targets.

VTs.11

- Only 40 characters available.
- Vessel must be within VHF coverage and targeted by A.I.S.

We do not know, and have not been able to verify this objective.

VTS.14

Objective impossible to assess, because of the lack of data.

We hope you can use this document as a basis, and we would ask you not to make any other operational comments in your presentation.

Denis Massicotte
Regional Program Specialist

cc: Pierre Cloutier DMOD
Reynald Lamalice DMOB-Q
Paul Morin DMOB-Q
Jean-Francois Gravel DMOB-L
G rard Buzar  DMOB-L

APPENDIX D**OPERATIONAL EVALUATION GRID - CCG SHIP**Test No.: **TE.18**

CRITERIA	EVALUATION
Presence of the other ships on the screen	Very easy to interpret
Distance to other ships displayed	
Display of the characteristics of the other ships	The icon is a little large; by reducing the number of data items we could reduce the size of the icon. It could be limited to Lat., Rel. Long., Dist., Heading and Speed.
Quality of charts (precision and resolution, etc.)	For the functions this device is expected to perform, the charts are suitable. Good precision and good resolution. However, the coverage should be enlarged, especially for the port of Montreal.
User interface (user-friendliness, audio alarm, display mode, navigation function, etc.)	Fairly easy to operate. At present the audio alarm is too quiet; you have to be right beside the unit to hear it. The number of windows may be confusing. It must be clearly understood that the primary function of this device is not to be a navigation tool; we have DGPS, PINS and two radar units for that purpose.
Signal that another ship is available	There is no such signal. We have to go into the Target menu to find out whether there is a contact with another ship that is not close enough to be displayed on the screen at the scale selected. (One solution might be to have a small icon displayed.)
Usefulness of this function	It is useful, but it should be integrated into the navigation system. It would be more useful if it kept a view of the traffic.
Compatibility with ECDIS standards	

Michel Dufresne
Second Officer
CCGV Pierre Radisson

APPENDIX E

OBSERVATION GRIDS - TECHNICAL OBJECTIVES

This appendix contains the observation sheets completed for each module of the technical tests (TE.n) corresponding to the Technical Services objectives (Appendix A - Table 4)

Each of the technical objectives evaluated is also associated with one of the 14 test modules (4.2.n) described in Appendix A (Table 1).

4.2.2 Display of the other ships' positions on ECDIS

TE.18 Evaluate shipboard (AIS) information display systems as well as their available and desirable features.

Objective

The display systems supplied with each of the systems being evaluated and used on board commercial ships are not designed initially to meet ECDIS standards, particularly for screen size; that was one of the first comments made by one of the pilots we met.

The objective of these laptops is to permit the display of (AIS) information: the positions and characteristics of the ships, some navigation functions such as distance and bearing, and certain message exchange functions with the MCTSs and the ships.

Comments

1. GP&C (Norcontrol) system

Display

- System based on a Pentium laptop operating under Windows NT;
- The digital charts are in colour and are vector-type, supplied by Cmap;
- The small size of the screen makes it difficult to use for navigation: you almost have to have your face right against the screen, which is impractical for officers or pilots.

Presence of other ships on the screen

- The information from the other ships equipped with GP&C (AIS) transponders is received on board as soon as the two ships are within their respective radio coverage areas (the two ships do not necessarily each see the other at the same time; it depends on the strength of the signal transmitted, the antenna height, the work zone, and so on);
- when the information from another ship is received, it is automatically displayed on the screen, if the chart scale is adjusted accordingly;
- it is possible to consult the list of targets available to see whether the ship is available and to select ships;
- there is a monitoring mode that can be used to observe all messages sent and received by the communication channel; if a new ship is received, there will be new messages, with the header for that ship appearing in the list;
- to display the characteristics of a ship (own or another), the Target function is used to display a window indicating: Name, IC, Speed (to be completed);
- an alarm sounds when a message is received from another transponder (ship or MCTS).

2. Ross Eng. System

Display

- System based on a Pentium laptop operating under Windows 3.1;
- Vector-based digital charts supplied by Navionic;
- Resolution 640 x 480.

Presence of other ships on the screen

- The presence of other ships will be displayed on the screen when their information (position, identity and so on) is rebroadcast from a land-based station that receives it;
- When a ship that is displayed is selected, its associated information is displayed on the right side of the screen (only one ship's information can be displayed at a time)

4.2.3 Operational needs and capability

TE.8 Evaluate the capacity of the communications channel to transmit non-(AIS) messages (ship positions and ID) and analyse the assignment of respective communication priorities.

Objective

Evaluate the messaging functions offered by each system both for transmission and reception of messages between ships and for ship-shore communication; evaluate in terms of performance and reliability, and in terms of impact (priority, speed, number of messages, and so on) on the transmission of the other (AIS) data (ship position and identification).

Observations

1. GP&C (Norcontrol) system

- permits sending short messages (up to 40 characters) corresponding to the use of 2 information frames; the GP&C system definition permits the use of 2250 frames per minute, and each frame can be used to transmit navigation information related to the ships (name, position, speed, and so on) or to transmit messages;
- Uses the free frames to send messages;
- The 40-character limit is not enough to transmit very detailed messages, but questions or brief messages can be sent, such as: “Next home port?”; “Weather conditions Quebec?” or “Pilot on board?”
- System capability is evaluated according to the total number of frames used in the coverage area and the number of ships:

⇒ :	3 ships @ 1 report/sec	=	180 frames/minute
	2 units @ 6 reports /minute	=	12 frames/minute
	Total	=	192 frames/minute/2250 frames
		=	9% use

2. Ross Eng. System

- The messaging function was not available in the original implementation; it was added during the evaluation period;
- it permits sending messages of variable length in 256-character blocks;
- works for both shore-to-ship and ship-to-shore;
- also permits management of groups of ships.

4.2.4 Impact of adjacent zones

TE.25A Evaluate the operation and exchange of information between adjacent MCTS zones.

Objective

To evaluate the operation of the (AIS) systems for an application on the river in which several adjacent (and overlapping) radio coverage zones are required to provide total coverage between Quebec City and Montreal.

Observations

1. GP&C (Norcontrol) system

- Two sites were installed on land, one at Quebec City and one at Longueuil, each one connected to and controlled by its own control station; the GP&C operating principle, based on a single frequency, could cause interference problems for the mobile station when information is rebroadcast, if the shore stations use the same frames;
- the fairly great distance between the two shore sites (Sorel and Mont-Bélair), about 150 km, almost always prevents communication between the sites; however, occasionally, when the propagation conditions between the two sites were favourable, we were able to observe the positions of the ships throughout the network on each MCTS display station, received from the two shore sites; this information was accessible when radio communication between the two sites was such that each transponder could receive the traffic information from the other!

2. Ross Eng. System

- Based on the use of a common frequency (Ch. 70) and a separate duplex working frequency in each coverage area;
- the system was originally designed to operate with a single land-based site covering one monitoring area;
- when we began the evaluation with the first versions, the MCTS controller had to manage zone changes manually by logging in and out to activate and deactivate ships passing from one zone to another;
- the latest version of the software enables us to adjust the parameters to specify a limit for each site (distance calculated from the geographical location of the radio site) after which the frequency will be changed from Channel 70 to the duplex channel specific to each site;
- this function was verified between Quebec City and Sorel with a ship that successfully passed through three separate zones: the automatic frequency change was made, as was the automatic transfer of control (login and logout) between each MCTS display and control station; however, it took several minutes (2 to 6) before the transfer was completed; this delay is caused by the automatic query function (all ships call) which enables each station to acquire the new ships appearing in its coverage area.

4.2.7 Performance and comparison of (AIS) to radar

TE.7 Evaluate whether the (AIS) architecture results in latency of vessel position reports:

- a) to MCTS;
- b) to the vessel.

Objective

Left blank intentionally

Observations

Left blank intentionally

4.2.7 Performance and comparison of (AIS) to radar

TE.22 Make a comparative evaluation of the accuracy and resolution obtained for a ship's position through radar and through (AIS) in areas where both systems are in operation.

Objective

A comparative evaluation of the use and performance of radar and the (AIS) system on board a ship to determine the ship's distance from various fixed or moving reference points.

Observations

1. GP&C (Norcontrol) system

- The Norcontrol display system makes it possible to identify targets that are fixed (buoys or wharf corners) or moving (other ships equipped with GP&C transponders and received in our system); the system then continuously calculates (once a second) and displays the distance and bearing of the target in relation to the ship;
- the comparisons made with the ship's radar indicate differences of the order of .01 to .02 NM (18 to 36 metres); this is very good, considering the resolution of the radar system (about .01 NM) and the fact that the (AIS) system being tested was equipped with only a GPS receiver (30 to 100 metres error @ 95%.

2. Ross Eng. System

Left blank intentionally

4.2.9 Impact on operations and frequencies used

TE.12 Evaluate the capability of the Ross system to transfer communication from Channel 70 to the duplex channel.

Objective

To evaluate the system's capability, in a given coverage area, of detecting new ships, first on the call channel (70), then to transfer them to the duplex working frequency for the area; also evaluate the system's capability of transferring ships from one area to another by first changing from the duplex working channel of the area being left to Channel 70, then switching to the duplex working channel of the next area.

Observations

1. Ross Eng. System

- When a new ship appears (or its transponder is activated) in the coverage area of a site, it is first contacted on Channel 70 by an all ship call; a parameter, set at 5 minutes for our tests, can be used to adjust the frequency of all ship calls (the ship's transponder must be tuned to that frequency); after 3 messages have been exchanged between the ship and the control station, communication is transferred to the area's duplex working frequency and continues on that channel according to a refresh rate set by the control station (between 2 seconds and 90 minutes);
- the system now (since the August 1996 version) permits automatic communication channel changes when a ship moves between coverage areas (with the previous versions, the MCTS operator had to make the change manually from the control station);
- when the *Tracy* was transiting between Quebec City and Sorel, we checked that the automatic frequency transfer was actually occurring between areas, according to the coverage limits (parameter) established for each land site; the *Tracy* successively used channels 23, 70, 27, 70 and 87;
- when a ship leaves a coverage area, the transponder switches to the common channel, 70; the ship remains displayed on the MCTS station of the area it has left, and has to be logged out manually by the operator;
- entry into a new coverage area reactivates the process of acquisition and transfer to a new duplex working frequency;
- with the first versions of the Ross system (before the August 1996 system), the transponder did not always return automatically to Channel 70 when the ship left the control area, and it could remain on the duplex working channel of the original area and thus not be able to receive the all ship calls from the following areas; the new version seems to have corrected that deficiency, especially since it is used with all ship calls issued every 5 minutes
- we tried increasing the frequency of all ship calls to every 2 minutes, but that caused problems: the transponders remained on the first duplex frequency identified following the first all ship call, and never shifted to the new frequency for the next area.

4.2.9 Impact on operations and frequencies used

TE.21 Study the adaptability of the (AIS) system to pilotage activities

Objective

To collect the comments of the navigating personnel of commercial ships and pilots on the (AIS) system, on the electronic navigation systems (ECDIS and DGPS) in general and on their needs for information for navigation on the river and for ship pilotage.

Observations

The comments were collected on two voyages between Quebec City and Montreal on board the *Le Brave*, which was equipped with the GP&C (Norcontrol laptop) (AIS) system.

1. Display system:

- The pilots would like a large screen;
- the pilots would like an (AIS) system integrated into the ECDIS/DGPS and ideally with radar, to confirm the validity of the charts and targets;
- the system must also be reliable and precise.

2. Information system

- The pilots would like information on neighbouring traffic (upbound and downbound); that information is currently provided by radio by the regulator;
- information on the presence of large, deep-draught ships is especially important, since they can affect the ship's behaviour in narrow channels when meeting or overtaking;
- information on the speed of other ships (particularly those that may overtake) is important because of the effect that will be felt in the channel;
- the messaging functions are impractical for pilots, since they must type in each one themselves; they consider that impractical during manoeuvres;
- however, the pilots would be interested in receiving messages (broadcast type) that would be displayed automatically (in a separate section at the bottom of the screen, for example) giving such information as the weather, NOTSHIPS, and so on;
- water level information would also be of interest for deep-draught ships; the possibility of having forecasts of water level at points the ship will reach later is of particular interest.

3. Navigation

- The navigation / (AIS) system must above all make it possible to set courses and bearings so that the pilot can give instructions on heading and course changes to the helmsman.

4.2.9 Impact on operations and frequencies used

TE.9 Evaluate the system's ship-handling capacity.

Objective

Left blank intentionally

4.2.9 Impact on operations and frequencies used

TE.23 Assess current and potential interference problems caused by using digital signals in the marine band frequency ashore and on ships.

Objective

Evaluate the interference caused to the existing operational systems, both at CCG communications sites and on the ships, by the addition of the (AIS) systems being assessed.

Observations

1. GP&C (Norcontrol) system

- Interference caused on the *F.G. Smith* television reception system; the TV system antenna is a broad-band type, and it is also affected by the ship's VHF communications; the regular transmission (1/second) of the (AIS) transponder signal (142.25 MHz) interferes with the television reception each time;
- there is no interference on the larger ships (Cl. 1100 and 1200), on which the antennas are farther away.

2. Ross Eng. System

- The use of frequencies in the marine band (156 - 162 MHz) requires adding adequate filtering at the CCG communication sites for cohabitation with the existing frequencies used for normal MCTS operations;
- the Ross system transponder created interference on the radar and the intercom system of one of the ferries; the DSC-500 radio should operate at low power (1 Watt) when at short distances (< 10 NM) from the control station; this function (low power) is deficient, and the unit constantly returns to high power (25 Watts), promoting interference with the ship's equipment; an external attenuator had to be added.

4.2.9 Impact on operations and frequencies used

TE.4 Draw up a detailed list of technical and operational functions supported by each technology and the functions that could have been added or could have been better implemented.

Objective

For each system evaluated, list the characteristics or functions that it would be beneficial to improve, modify or better implement.

Observations

1. GP&C (Norcontrol) system

- The maximum message length (40 characters) is too short to permit sending messages having any substance, and it could certainly be increased by using a number of frames in the protocol (while ensuring transmission priority for positioning frames over message frames);
- it is not easy to change the reporting frequency for the units (configured on installation), and they currently permit only 2 modes:
 - ⇒ normal mode: can be set as either 1/second or 1/minute;
 - ⇒ sleep mode: slower reporting speed when the ship speed drops below a preset value (e.g.: 2 NM, to simulate a ship at anchor);
- the ships available in the system must be identified manually in each display system; this is impractical when a new ship appears for the first time in a coverage area (the company has stated that an automatic new ship initialization process would be offered with an operational system);
- information displayed (target) on a selected ship:
 - * ID: Le Brave
 - * Speed: XX.X knots
 - * Course: XXX deg.
 - * Bearing: XXX deg.
 - * Latitude: XX XX.XXXXXN
 - * Longitude: XX XX.XXXXXW
 - * CPA: X NM
 - * TCPA: XX.X min.
 - * Ref.: ABCD
 - * Grid:
 - * XTRA ID
- permit connection to the ship's gyrocompass to obtain its true azimuth;
- offer transponders that can be connected to the ship's GPS to reduce the costs for those already equipped with such a receiver.

Note: "Closest Point of Approach"

Note: "Time for CPA"

2. Ross Eng.

- A communication link (dedicated telephone lines) should be set up between adjacent control stations to ensure that information in the ship data bank is shared to permit automatic management of ship transfers between coverage areas (work sectors);
- the DGPS position of the 12500 units is not reliable and jumps regularly;
- information displayed (target) on a selected ship:
 - * Ship Name: Le Brave
 - * DSC ID: 366XXXXXX ALT ID: ABCD
 - * Position/time:
 - ⇒ Latitude: XX XX.XXXX N
 - ⇒ Longitude: XX XX.XXXX W
 - * HDOP: X.X
 - * COG: XX knots
 - * SOG: XX knots
 - * Length: XX metres
 - * Draught: X.X Metres
 - * Next port: Montreal
 - * Ship type: Tanker
 - * VHF channel: 23
 - * Last report: XX sec.
 - * Report interval: XX sec.
- permit connection to the ship's gyrocompass to obtain its true azimuth;
- offer transponders that can be connected to the ship's GPS to reduce the costs for those already equipped with such a receiver;
- permit display of information on more than one ship at a time; in its present version, the display system gives the digital information (Identity, position, and so on) for only one ship at a time - the one that is selected;
- add confirmation of messages received; at present there is no indication that a message transmitted has in fact been received; there is only an alarm message indicating when a message has not been received.

4.2.9 Impact on operations and frequencies used

TE.5 Compile technical performance data on the systems.

Objective

Conduct a systematic technical evaluation of the two systems in terms of certain criteria

Observations

1. GP&C (Norcontrol) system

- Receiver sensitivity level: -100 dBm;
- transmission power: 1 to 10 Watts (adjustable);
- radio coverage: approximately 150 km from a site located at Mont-Bélair;
- reliability: 95%;
- capacity of the system to accept new ships in the coverage area:
 - automatically when the ship is in the coverage area;
 - assignment (association with the ship name) must previously have been done manually on the ship's display system;
- Precision of DGPS units:
 - 6 channel Magnavox;
 - precision 3 to 5 metres in DGPS mode.

2. Ross Eng. System

- Receiver sensitivity level: -119 dBm;
- transmission power: 7.5 Watts;
 - possibility of adding external amplifiers (25, 50 or 100 W);
- radio coverage: approximately 60 km from Lauzon and 35 km from Sorel;
- reliability: 50% to 75%;
- capacity of the system to accept new ships in the coverage area:
 - it takes 40 to 50 seconds after the first all ship call is received; this call is transmitted automatically every 5 minutes (configurable) from the shore station, or manually as required;
- precision of DGPS units:
 - Trimble 12-channel receiver;
 - position jumps (2 to 3 NM) observed with the 12500 transponders.

(AIS) SYSTEM ACCEPTANCE

February 10, 1998

EQUIPMENT DETAILS

Site name	Power/Sensitivity	Loss in cavities	Antenna gain	Remarks
Lauzon 70 Tx-RX	25 Watts 0.25 μ V for 12 db SINAD	2.2 db	9 db	
Lauzon TX-23	55 Watts	1.6 db	9 db	
Lauzon RX-23	0.25 μ V for 12 db SINAD	2.2 db		
Mont-Bélair 142.25 mhz TX / RX	10 Watts 0.5 μ V / 20db S/S+N	3.2 db	0.7 db	
Trois-Rivières channel 70	25 Watts 0.25 μ V for 12 db SINAD	3.0 db	9 db	
Trois-Rivières channel 27	7.5 Watts 0.25 μ V for 12 db SINAD	3.5 db 2.0 db	9 db	
Sorel channel 70	55 Watts 0.25 μ V for 12 db SINAD	4.5 db	9 db	
Sorel channel 87	7.5 Watts 0.25 μ V for 12 db SINAD	3.0 db 2.0 db		
Île Charron channel 70	25 Watts 0.25 μ V for 12 db SINAD	1.5 db	3 db	
Île Charron channel 27	7.5 Watts 0.25 μ V for 12 db SINAD	2.0 db	3 db	

To conduct these tests, we installed the antennas on a vehicle with the communications and test equipment.

Equipment	Function	Accessories	Remarks
ROSS model 12500 transponder with computer	Communication with the Lauzon site and user interface.	GPS, VHF and DGPS (LF) antenna.	Equipment from the <i>Tracy</i>
GP&C transponder with Toshiba computer	Communication with Bélair and user interface	GPS and VHF antenna	Spare equipment and equipment from the <i>Radisson</i> .

RESULTS

System	Signal required for normal operation	Coverage	Remarks
ROSS	-119 db	Ste-Croix (south shore) Portneuf (north shore).	The sensitivity of the DSC-500 was greatly improved with the revision made in late August.
Swedish Space / Nor- control	-100 db (-105 db for operation without message)	Signal reliable and steady until the middle of Lac St-Pierre (except a passage at the Trois- Rivières bridge.	Even at this level, the messages are received with no errors (Reference point C on the chart) Close to the Plessisville exit on Highway 20 (Reference point B on the chart)

4.2.9 Impact on operations and frequencies used

TE.11 Evaluate the advantages and disadvantages of the SCC system's autonomous and controlled modes for MCTS operations and for marine information services.

Objective

Left blank intentionally

4.2.9 Impact on operations and frequencies used

TE.1 Investigate and compare each of the two (AIS) architectures being tested.

Objective

Describe the architecture, components and communication protocols of the two technologies being evaluated.

Observations

1. GP&C (Norcontrol) system

Operation

- Use of a single radio frequency;
- TDMA (time division multiple access) protocol;
- the land-based communication site consists of a transponder that not only transmits its own position (less frequently), but also acts as a repeater for frames received from the ships;
- each transponder first listens to the traffic on the frequency to determine which frames are available to it;
- permits direct ship-to-ship and bidirectional ship-to-shore communications;
- update rate for the transponders is configurable on installation, with two possible modes:
 - normal operating mode: between 1/second and 1/ minute;
 - passive mode:
 - for a speed < X knots;
 - rate = xx/minute

2. Ross Eng.

Operation

- based on VHF-DSC protocol;
- use of the VHF-DSC protocol is defined by:
 - ITU-R, recommendation 493:¹ “Use of DSC for marine mobile services”;
 - ITU-R, recommendation 821: “Expansion of DSC system for marine mobile services”;
 - ITU-R, recommendation 825: “Characteristics of a transponder system using DSC for marine traffic services and ship identification”;
- Channel 70 is used to make the first contact in each area;
- after three messages have been exchanged (about 30 seconds) between the ship and the control station, the control station automatically identifies the duplex channel to be used in the area and the reporting rate (determined by the regulator), which is between 2 seconds and 90 minutes;
 - when an area change occurs, the mobile unit automatically returns to Channel 70 and waits for an all ship call from a new base station, which will then assign it a new working channel for the new area.

¹ The titles of these recommendations have been translated, because English equivalents were not found - Tr.

Appendix E

Architecture used

- Four shore sites with two frequencies each (Channel 70 and a duplex channel);
- sites connected to a control station at the MCTS via a dedicated telephone line;
- no communication link between control stations.

Ships

Left blank intentionally

4.2.10 System reliability

TE.6 Determine the robustness of the (AIS) data transmission system in a radio environment.

Objective

Left blank intentionally

4.2.10 System reliability

TE.24 Evaluate operational and technical reliability and the reliability of the message protocol used.

Objective

Left blank intentionally

4.2.14 Feasibility study

TE.2 Collect the information necessary to develop technical and operational specifications to be used in a future call for tenders for an (AIS) system.

Objective

Left blank intentionally

4.2.14 Feasibility study

TE.20 Determine the real costs of an (AIS)-based marine information system; take into account the necessary costs for managing information in addition to basic (AIS) information.

Objective

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APPENDIX F

TEST OUTLINE

In order to measure the technical performance of the systems, we developed a series of tests to be conducted on board CCG vessels, commercial vessels, and in the shop. The organizational chart in Figure 10 depicts the link between the objectives (4.2.n) and the tests to be conducted to fulfill each of the technical objectives (T.n).

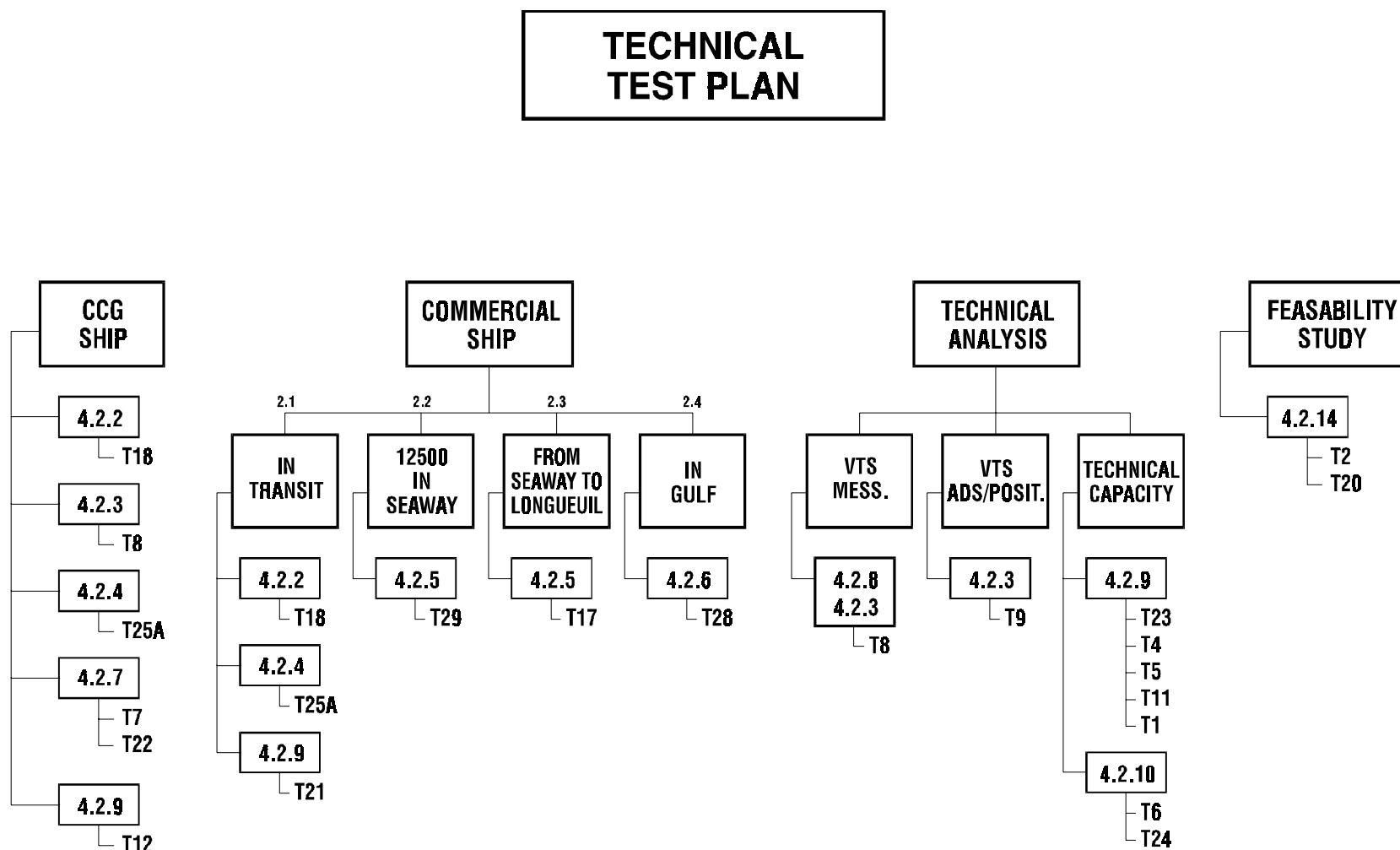


Figure 10 - Links between Objectives and Tests to be conducted

APPENDIX G

DETAILED INFRASTRUCTURE AND ONBOARD EQUIPMENT COSTS

Scenario 1 - Implementation in MCTS radar zones					
Ross-CCG Network Equipment			GP&C - CCG Network Equipment		
Radio Site			Radio Site		
	Tx/Rx Ch70 (50W)	\$ 4,009		Tx/Rx Radio	\$ 22,000
	Tx/Rx Dx Ch (50W)	6,150		GPS Ant.	
	Computer	9,000		VHF Ant.	
	Cable & Ant.	1,500		Power	
	Cavities	2,000		Cavities	1,000
	Modem & Int.	1,000		Modem	1,000
	UPS	1,000		UPS	1,000
	Sub-total	\$ 24,659		Sub-total	\$ 25,000
Control Station			Control Station		
	Computer	\$ 30,809		Computer	\$ 31,000
	Sub-total	\$ 30,809		Sub-total	\$ 31,000
Network Sites			Network Sites		
	Longueuil	1		Longueuil	1
	Lauzon	1		Lauzon	1
	Escoumins	1		Escoumins	1
	Sub-total	3		Sub-total	3
Network Sub-total			Network Sub-total		
	Radio sites	\$ 73,977		Radio sites	\$ 75,000
	Ctl station	92,427		Ctl station	93,000
	Sub-total	\$ 166,404		Sub-total	\$ 168,000
	Soft cost	37.8%		Soft cost	37.8%
	TOTAL	\$ 229,305		TOTAL	\$ 231,504
Ross - Onboard equipment			GP&C Onboard equipment		
Complete Onboard Equipment (incl. DGPS/ECS)			Complete Onboard Equipment		
	12500 Transp.	\$ 21,440		Complete transponder	\$ 15,000
	Laptop	20,093		Laptop	14,000
	Sub-total	\$ 41,533		Sub-total	\$ 29,000
Basic Onboard Equipment (AIS) only			Basic Onboard Equipment		
	DSC-500A	\$ 3,350			
	Int. DSC-500AIA	3,350			
	Sub-total	\$ 6,700			

Scenario 2 - Implementation from Montreal to Les Escoumins					
	Ross-CCG Network Equipment			GP&C - CCG Network Equipment	
Radio Site			Radio Site		
	Tx/Rx Ch70 (50W)	\$ 4,009		Tx/Rx Radio	\$ 22,000
	Tx/Rx Dx Ch (50W)	6,150		GPS Ant.	
	Computer	9,000		VHF Ant.	
	Cable & Ant.	1,500		Power	
	Cavities	2,000		Cavities	1,000
	Modem & Int.	1,000		Modem	1,000
	UPS	1,000		UPS	1,000
	Sub-total	\$ 24,659		Sub-total	\$ 25,000
Control Station			Control Station		
	Computer	\$ 30,809		Computer	\$ 31,000
	Sub-total	\$ 30,809		Sub-total	\$ 31,000
Network Sites			Network Sites		
	St-Bruno	1		St-Bruno	1
	Mont-Bélair	1		Mont-Bélair	1
	Montmagny	1		Montmagny	1
	Les Escoumins	1		Les Escoumins	1
	Sub-total	4		Sub-total	4
Network Sub-total			Network Sub-total		
	Radio sites	\$ 98,636		Radio sites	\$ 100,000
	Ctl station	123,236		Ctl station	124,000
	Sub-total	\$ 221,872		Sub-total	\$ 224,000
	Soft cost	37.8%		Soft cost	37.8%
	TOTAL	\$ 305,740		TOTAL	\$ 308,672
Ross - Onboard equipment			GP&C Onboard equipment		
Complete Onboard Equipment (incl. DGPS/ECS)			Complete Onboard Equipment		
	12500 Transp.	\$ 21,440		Complete transponder	\$ 15,000
	Laptop	20,093		Laptop	14,000
	Sub-total	\$ 41,533		Sub-total	\$ 29,000
Basic Onboard Equipment (AIS) only)			Basic Onboard Equipment		
	DSC-500A	\$ 3,350			
	Int. DSC-500AIA	3,350			
	Sub-total	\$ 6,700			

Scenario 3 - Implementation from Montreal to Sept-Iles (66 west)					
	Ross-CCG Network Equipment			GP&C - CCG Network Equipment	
Radio Site			Radio Site		
	Tx/Rx Ch70 (50W)	\$ 4,009		Tx/Rx Radio	\$ 22,000
	Tx/Rx Dx Ch (50W)	6,150		GPS Ant.	
	Computer	9,000		VHF Ant.	
	Cable & Ant.	1,500		Power	
	Cavities	2,000		Cavities	1,000
	Modem & Int.	1,000		Modem	1,000
	UPS	1,000		UPS	1,000
	Sub-total	\$ 24,659		Sub-total	\$ 25,000
Control Station			Control Station		
	Computer	\$ 30,809		Computer	\$ 31,000
	Sub-total	\$ 30,809		Sub-total	\$ 31,000
Network Sites			Network Sites		
	St-Bruno	1		St-Bruno	1
	Mont-Bélair	1		Mont-Bélair	1
	Montmagny	1		Montmagny	1
	Les Escoumins	1		Les Escoumins	1
	Grosses-Roches	1		Grosses-Roches	1
	Sub-total	5		Sub-total	5
Network Sub-total			Network Sub-total		
	Radio sites	\$ 123,295		Radio sites	\$ 125,000
	Ctl station	154,045		Ctl station	155,000
	Sub-total	\$ 277,340		Sub-total	\$ 280,000
	Soft cost	37.8%		Soft cost	37.8%
	TOTAL	\$ 382,175		TOTAL	\$ 385,840
	Ross - Onboard equipment			GP&C Onboard equipment	
Complete Onboard Equipment (incl. DGPS/ECS)			Complete Onboard Equipment		
	12500 Transp.	\$ 21,440		Complete transponder	\$ 15,000
	Laptop	20,093		Laptop	14,000
	Sub-total	\$ 41,533		Sub-total	\$ 29,000
Basic Onboard Equipment (AIS) only			Basic Onboard Equipment		
	DSC-500A	\$ 3,350			
	Int. DSC-500AIA	3,350			
	Sub-total	\$ 6,700			

APPENDIX H

INITIAL COMPOSITION OF THE VARIOUS PROJECT COMMITTEES

Steering Committee (AIS):

Lea Barker, CCG, Director - Marine Communications and Traffic Services (MCTS), Chairman
William A. Anderson, CCG, Director, Electronic Engineering Services, MTSS
Pierre Boisvert,
Steve MacPhee, Director General, Canadian Hydrographic Services, DFO
Norman Hall, President, Canadian Shipowners Association
Frank Nichol, President, Shipping Federation of Canada

Project Management Committee:

Bert Tepper, CCG, Chief, Surveillance Systems, Chairman
Jean-Claude Cyr, CCG, Regional Superintendent, Electronic and Informatics Systems
Spencer Martin, CCG, Chief, Operational Programmes, MCTS
Ivan Lantz, Manager of Marine Operations, Shipping Federation of Canada
Rejean Lanteigne, Director of Operations, Canadian Shipowners Association

Project Committee - Laurention Region:

Jean-Claude Cyr, CCG, Regional Superintendent, Electronic and Informatics Systems, Chairman
Gilles Ringuette, Electronic Engineer
Jean Dusablon, Regional Superintendent, Operational Planning
Pierre Cloutier, Regional Superintendent, Marine Communications and Traffic Services (MCTS)
Patrick Hally, Canadian Hydrographic Services, DFO

APPENDIX I

PARTICIPANTS POST PROJECT COMMENTS

Comments were solicited from project participants and interested parties after circulation for review of the Draft report in April 1997.

Copies of the comments which were received are included as this appendix. They were submitted by:

1. United States Coast Guard. Signed by R.G. Ross, Chief, Office of Vessel Traffic Management.
2. The Shipping Federation of Canada. Signed by Ivan A. Lantz, Manager Marine Operations.
3. Fisheries and Oceans. Signed by David Bevan, Director General, Conservation & Protection Directorate.
4. Saint Lawrence Seaway Development Corporation. Signed by Stephen C. Hung, Director, Engineering & Strategic Planning.
5. Canadian Hydrographic Service Science. Signed by S.B. MacPhee, Dominion Hydrographer.
6. The St. Lawrence Seaway Authority. Signed by P. Vincelli, Chief, Operational Services.
7. Canadian Coast Guard, Marine Technical and Support Services, Electronic Engineering, HQ by Roy Penney AWTJ-F.

U.S. Department
of Transportation

United States
Coast Guard



United States Coast Guard
Office of Vessel Traffic Management

2100 Second Street, S.W.
Washington, DC 20593-0001
Staff Symbol: G-MOV-2
Phone: (202) 267-6274
FAX: (202) 267-4826

16633
June 13, 1997

Mr. Bert Tepper
CGC, Chief, Surveillance Systems
Canada Building
344 Slater Street
Ottawa, Ontario K1A 0N7

00575

Dear Mr. Tepper:

The United States Coast Guard greatly appreciated receiving a copy of your report comparing the two AIS technologies on the St. Lawrence River. As you know, the USCG is using a DSC transponder based system for vessel reporting at Prince William Sound, Alaska. Our application is a stand-alone system which uses a different design protocol than what you tested as it was created before current DSC standards were established. The USCG supports using an internationally accepted AIS system that is based on functional standards. We concur with your conclusion that availability and utilization of an AIS system in VHF coverage areas would prove an advantage both in exchanging information and reducing radio communication.

We offer the following observations:

Ross-DSC System

Two major problems were described in the report. The first seemed to be directly related to the system control and display software maturity. The second stated that the Ross system was not originally designed to operate in a "river type" environment. Our major safety concern echoes those stated in paragraph 7.1.1, where vessels converging at the outer limits of two adjacent sectors operating on different working channels could find themselves heading for a collision without receiving information about the others existence. A significant portion of this problem appears related to the apparent inefficient frequency hand-off between adjacent sectors. This appears to be a factor of the operating system and not related to the DSC protocol. If the individual VTC sectors were interfaced for the purposes of vessel data information sharing, vessels would have the information available by re-broadcast when facing a meeting situation at the outer limits of two VTC sectors. Also with VTC sectors sharing vessel positional data, a more efficient direct working channel handoff between VTC sectors could be achieved preventing the handoff to channel 70.

It is unfortunate that the problems were not resolved earlier in the testing period to allow a more complete testing evaluation. Currently we are reviewing a proposed annex to the ITU-R 825 DSC standard, that would allow a "Gateway" approach towards a more robust DSC operating system that appears to fulfill our VTS requirements based on international standards. As you are aware, the concept of DSC in a broadcast mode is being explored by Ross Engineering.

GP&C System

The results of your testing indicated a more robust system in reporting intervals, traffic handling capabilities and direct ship to ship positional reporting utilizing a single working frequency. The GP&C system operating in the "slave mode" does not allow the VTC to have active control over vessel reporting intervals. It appears to be actually designed to operate independently, providing automated position reporting without VTS involvement. The "master mode" can provide VTS control rather than automatic self-organizing reporting intervals, but has not been implemented in any port listed utilizing the GP&C system. Also of concern are the lack of an internationally accepted standard and a world wide operating frequency, as well as the facts that the system is proprietary/patented and all equipment is produced by a sole source supplier.

In summary, we have a lot of optimism for emerging AIS technologies. We look forward to building upon our experiences of DSC at Prince William Sound as well as your recent tests. We are continuing work with IMO, IALA and ITU to evolve AIS to an international standard. One of our AIS goals in 1998 is to install 40-50 transponders on vessels transiting the Lower Mississippi River so that we may evaluate a system under load. We will keep you apprised of this endeavor.



R. G. ROSS
Captain, U.S. Coast Guard
Chief, Office of Vessel
Traffic Management
By direction of the Commandant

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P.

**THE SHIPPING FEDERATION OF CANADA
LA FÉDÉRATION MARITIME DU CANADA**308 DU SAINT-SACREMENT, SUITE 326, MONTRÉAL, CANADA H2Y 1X4
TÉL: (514) 849-2325 • FAX: (514) 849-6992 • TÉLEX 855-61042 • SHIPPED MONTRÉAL

Bert Tepper
Chief, Surveillance Systems
Electronic Engineering Branch
Canadian Coast Guard
Marine Technical and Support Services
Canada Building, 7th floor
344 Slater Street
Ottawa, ON K1A 0N7

May 23, 1997

File: MG-15

Re: Comments on the Final Report / AIS Pilot Project

Dear Bert,

I have read the final report of the AIS Pilot Project and, if you permit, I will comment at random.

Throughout all the report, I came across only one comment in the vicinity of page 35 and again at page 66 where I disagree. MCTS commented that Radar shows the vessel's course and AIS does not have this ability. I disagree. Both Radar and AIS show a target vessel's direction of movement. The actual compass heading of the vessel is not displayed to the observer. Only AIS has the potential to pick up, transmit and have the target vessel's compass heading displayed to the observer. As stated at the bottom of 7.2.2 on page 36, a number of display features that parallel information displayed at the side of a radar/ARPA are desirable. There are a number of "information display" wishes throughout the report that would appear to be practicable and possible in a purpose designed and installed system. A response to this report should contain clarification on the points on target heading information and a future work project on AIS display should draw on the comments in this report.

Recommendations 1 to 5; These are honourable recommendations that I can agree with. At our last meeting, it was decided that this report should be used as the foundation of an implementation project. I think this coincides with both recommendation 2 and 3. Recommendation 5 is the key conclusion and the only reservation I have is the reality of INNAV.

The text message abilities of the two AIS systems tested takes up considerable space in this report. Throughout this project you have constantly reminded me that AIS information/data is one thing and general communications is something else. The report clearly indicates that others also expected to receive water level information, etc. via AIS. The report does not reflect your teachings (preachings!) and should clearly indicate that AIS is a data supply, not
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.2.

an Internet supply; nor is it intended as a replacement for VHF voice radio. AIS is vessel identification and position indicating. The display and data management system that receives and displays AIS can be many things, depending on the sophistication of the observers own software. Perhaps it is best that messages remain limited so as not to obscure paragraph 3 of 10.0: the "advantage of assisting the (navigational) decision-making process". I note also the report's positive comments about message confirmation at Section 7.1.6.2 (B).

According to this report, I would conclude that the ability to send text messages though the AIS transponder is a handy and desirable safety enhancement feature. Relationships between AIS and extended text message capabilities for Notices to Shipping, water levels, berth availabilities, et cetera, could be part of a separate exercise that might integrate AIS and general communications services.

10.2 Comparative Analysis

The report clearly indicates to us here at the Federation that the GP&C or Broadcast System is the clear winner of this comparative test. The report clearly indicated in almost all cases where any shortcomings are found that these would be correctable in a functioning and established system. (Table XIV, page 53)

Pilots are reported to have problems with the portable display size and the compatibility of an information table on the same screen as the navigation chart. As previously commented, there appears to be a number of concerns about both ECDIS and AIS displays that will have to be addressed in future work.

10.3 Technical Performance

GP&C is the only transponder in this test that was incorporated into ECDIS as mariners desire. Throughout the report we find that general compatibility and reliability, ease of installation, lack of interference, etc., lead us to the conclusion that the GP&C has already been "debugged". The Federation feels this could be important when considering "after purchase" installation and integration costs.

10.4 Cost Benefit

GP&C is autonomous (Section 7.1.3., Table VI, Section 9.1) and this was a feature the Federation considers extremely important. We therefore believe it to be the only one of the two systems with a potential to reduce CCG's terrestrial infrastructure and direct communications costs. This could and should be quantified because this benefit will eventually be reflected on the industry side of the equation during the more detailed discussion of costs at Section 8.

Conclusion:

In our opinion, the conclusions and recommendations of the report clearly indicate that AIS is a technological advancement that can assist and improve the efficiency of marine traffic management for both mariners and shore-side, supporting industries and agencies.

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.3.

According to the report, the testing of two systems clearly rules out VHF-DSC. Of the two systems tested, Broadcast / GP&C is the one that could be used "as is" and still meet the majority of AIS objectives.

From what I can see from this report, industry and CCG have little choice. We now have to see how this report can be used to respond to the original mandate from the Marine Advisory Board. Federation interest in AIS is a technology that we believe is a key element in the search for improved the efficiency of marine traffic management, reduction of CCG direct costs attributable to commercial shipping, and improved availability of reliable marine traffic information that will further improve the efficiency of ports, waterways and marine services. The report tells us this is technically the case but it must now be incorporated into a larger plan in order to show results.

Where from here?

Using the findings of the project, a number of things can now be done:

- a) modify the AIS message/data string, (although it already appears quite complete)
- b) modify the display / or create display options for the various users
- c) look at a "network" application such as the Seaway, pilotage or port might need for a "long distance" look (now installed at MCTS Samia)
- d) review the regulatory management functions of MCTS and adapt them to AIS
- e) write the specifications for the shipboard equipment package, and packaging
- f) find a supplier(s) and product availability
- g) set the date
- h) implement

NOTE: Perhaps e) and f) should be drafted first and if we feel comfortable that these can be delivered, then we can afford the time to proceed to the rest.

In announcing the go-ahead of AIS implementation, the questions of "deliverables" and return on investment (ROI) will inevitably be raised. Recommendation No.2 must therefore be answered in the very near future.

I would like to extend my thanks to you and the project team for your endurance and tenacity throughout this phase of the project.

Sincerely,


Ivan A. Lantz, Manager
Marine Operations

** TOTAL PAGE.003

Fisheries
and OceansPêches
et Océans

MEMORANDUM

NOTE DE SERVICE

To
ABert Tepper ✓
Chief, Surveillance Systems
Electronic Engineering BranchFrom
DeDirector General
Conservation & Protection Directorate

Security Classification - Classification de sécurité
Unclassified/Non classifié
Our File - Notre référence
8550-24-12
Your File - Votre référence
AWT 8052-30-29-25 dated April 15, 1997
Date MAY 12 1997

Subject
Objet

AIS PILOT PROJECT - DRAFT FINAL REPORT

The report is complete, addresses the issues, provides a comparison of the technologies and leads logically to a valid conclusion. The project was undertaken within a CCG/Industry context (para 2.2) to see if the AIS technology was viable for use as a VTS system. The conclusion reached is that AIS is a technology that is not viable at this time in an operational setting as a stand alone system.

I would suggest that Canada could continue to follow the development of AIS, however, it is questionable if significant resources should be allocated to develop a made-in-Canada solution, using foreign suppliers, that would have a low probability of being adopted as an international standard.

It would be appropriate to follow the development of AIS, support the adoption of international standards and if appropriate implement an AIS as an operational system when it is beneficial and the technology is proven.

David E. Evans

R'd. 12/5/97

Canada

U.S. Department
of Transportation180 Andrews Street
P.O. Box 520
Massena, N.Y. 13662-0520
315-764-3200

May 13, 1997

Saint Lawrence
Seaway Development
Corporation

Mr. Bert Tepper
Fisheries and Oceans
Canadian Coast Guard
Marine Technical and Support Services
Canada Building, 7th Floor
344 Slater Street
Ottawa, Ontario K1A 0N7
Canada

Re: Review of AIS Pilot Project - Draft Final Report dated
Feb. 28, 1997

Dear Mr. Tepper:

The following are general comments and observations with respect to
the above mentioned report:

1. It is a comprehensive report with lots of valuable testing and operating data for both Ross and GP&C Systems.
2. Despite the establishment of a series of objectives by Canadian Coast Guard and marine industry, there were no established technical or operational requirements defined in the report. The report, therefore, lacked of specific and supportable conclusions that both, either or neither of the systems tested met the AIS requirements for Seaway operation.
3. The report did not adequately address the requirements and the findings of the portable version of the AIS units which are of great importance to the masters and pilots of foreign vessels.
4. The report should address in more detail, the communications frequency problems and possible solutions for both systems. Comments could have been added to address any potential system-wide problems including methods for logging ships into the system and handling ships between sectors.

The following conclusions are based on our review of the report:

1. A GPS-based AIS system tested by the Volpe Center for the St. Lawrence Seaway Development Corporation in 1994 and 1995 has demonstrated that AIS technology is both feasible and cost-effective for meeting the Seaway requirements of the vessel traffic center operations. Tests that were carried out under the Pilot Project further reinforced AIS benefits to VTC operations in addition to the capabilities of shore to ship, ship to shore and ship to ship communications.

Operations FAX
315-764-3250

Administration Building FAX
315-764-3235

Maintenance FAX
315-764-3258

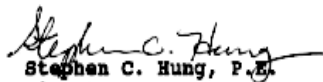


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2. Seaway Entities continue to maintain that the responsibility of navigating and maneuvering a vessel must remain with the master and pilot. Therefore, the AIS information reporting rate of two (2) minutes in the River and five (5) minutes in the Lakes would be more than sufficient to enhance the scheduling of lockage and to locate the vessel position during the emergency.
3. Installation of AIS on board vessels should reduce but not eliminate the usage of the existing VHF radio communication by VTC personnel and ship masters/pilots. Radio communication between masters/pilots on the vessels that are meeting or passing in the Seaway system remain essential and necessary.
4. Tests that were carried out under this pilot project proved that two way ship to shore, shore to ship and ship to ship communication and messaging through AIS were feasible.
5. Tests demonstrated that AIS broadcast system (GP&C) worked well in transmitting vessel and other data without retransmission procedures. The proprietary features of GP&C system, however, could compromise its acceptability as an operations system.
6. Analysis of the test scenarios and the test results indicate the need for a higher data rate than is provided by existing DSC standards.

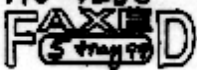
We appreciate the opportunity in reviewing the report. Without active participation in the 1996 field tests, we could not provide any detail technical comments other than the above general comments.

Sincerely,


Stephen C. Hung, P.E.
Director,
Engineering & Strategic Planning

SCH:smc

cc: P. Vincelli, SL&A
M. Moroney, Volpe Center

 Government of Canada / Gouvernement du Canada			
		MEMORANDUM	NOTE DE SERVICE
TO / À	Mr. Bert Tepper Chief, Surveillance Systems Electronic Engineering Branch -CCG		Security - Classification - de Sécurité
FROM / DE	Canadian Hydrographic Service Science		Our File - Notre Référence CHS/2635-1
			Your File - Votre Référence
			Date May 2, 1997
SUBJECT / OBJET	AIS Pilot Project -Draft Final Report		

I have reviewed the referenced report and have found it to be an excellent technical report. It is clear, easy to read and provides results from the trials. I feel, however, that there should be a clear decision on whether AIS is being installed to replace radar, to complement radar or to meet regulations. It is felt that enough information has been gathered on the two systems to know that at best they would only complement the radar installations.

I look forward to the AIS Steering Committee/Project Management Committee meeting to discuss the next steps to be taken.


S.B. MacPhee
Dominion Hydrographer
Canadian Hydrographic Service

*Nautical Charts Protect Lives, Property and the Marine Environment
Les cartes marines protègent la vie, la propriété et l'environnement marin*

THE ST. LAWRENCE
SEAWAY AUTHORITYL'ADMINISTRATION
DE LA VOIE MARITIME
DU SAINT-LAURENT202 Pitt Street,
Cornwall, Ontario.
K6J 3P7

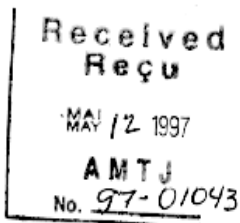
May 5, 1997.

Our File: 60-4-1-13

Mr. Bert Tepper,
Fisheries and Oceans,
Canadian Coast Guard,
Marine Technical and Support Services,
Canada Building, 7th Floor,
344 Slater Street,
Ottawa, Ontario. K1A 0N7

Dear Mr. Tepper:

Re: Operational Comments
- AIS Pilot Project
- Draft Final Report



The following are some general comments and observations with respect to the above mentioned report:

1. Tests that were carried out proved that the AIS system will provide Traffic Centres with valuable vessel position information.
2. Traffic Centres within the Seaway (Montreal to Long Point on Lake Erie) presently concentrate on scheduling and dispatching vessels through the canal and lock systems and providing vessel location information on other vessels that will be met, etc. Traffic Control within the Seaway leaves the responsibility of collision avoidance and navigating the ship to the Master/Pilot. Therefore, updates rates 1 to 2 secs on vessel position are not a requirement. For our Traffic Control purposes and for data entry updates every 1 to 2 minutes would be more than sufficient.

Canada

.../2

Mr. Bert Tepper

- 2 -

May 5, 1997

3. For a large system involving many sectors such as the St. Lawrence/Great Lakes, the AIS selected should provide for direct Ship to Ship communications to avoid:
- a) the problems with the Ross system at sector boundaries (use only one frequency)
 - b) high cost of infrastructure to provide the retransmission of the information. (AIS is a tool for Traffic Control to use to help optimize traffic scheduling, if it fails, it will not stop traffic.)

We will be providing technical comments jointly with SLSDC within the next couple of days.



P. Vincelli,
Chief, Operational Services.

PV:pf

(AIS) PILOT PROJECT - COMMENTS

Areas which have not been included, in no specific order:

1. Add some form of comment that the “broadcast system” supplied was not capable of “CONTROLLED” operation as may be needed by VTS. Since this was not provided we cannot confirm that the system actually does work in this mode!
2. Our shore station provided “rebroadcast” or acted as a repeater. When doing this there has to be some degradation of overall system capacity. Some discussion to this effect should be noted.
3. Continuing from 2) at times the repeater mode allowed both shore stations to indicate ships in each other’s areas. Although with low traffic this could be seen as an advantage with high density it would be a distinct disadvantage and some form of RF protection would be needed to prevent this happening.
4. No form of “Remote Monitor” was provided with the “Broadcast” system.
5. Should note that the radio used with the “Broadcast” system does not work in the marine band and would need changing to be able to be licensed.
6. VHF DSC system should note that it meets the GMDSS requirement for VHF DSC channel 70 Distress Watch.
7. Need a comment on the VHF costs that if used would not need extra expense in providing a system to meet VHF DSC Distress for GMDSS.
8. At 9.2.3 Question why not use NAVTEX to distribute NOTSHIPS?
9. VHF DSC costs are different to the cost study (Rick Stratton/Roy Penney) because ROSS ENGINEERING have changed their prices for the software & license for the VTS and the radio sites!
10. Suggest CCG should suggest the best approach for Ports is a cheap radar and (AIS). Radar would give indication of non participating vessels and a low (AIS) report rate would identify most ships. (AIS) would appear to offer distinct advantage where no radar is currently used but report rate does not need to be excessively (radar rate) high.

Roy Penney

May 2, 1997