IceNav^{tm} Shipboard Radar Integration Phase II

TP12920E

November 1996

Prepared for
Safety and Security
Transportation Development Centre
Transport Canada

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Transport Canada / Transports Canada

PUBLICATION DATA FORM

1. Transport Canada Publication No. TP 12920E	2. Project No. 8772	3. Recipient's Catalogue No.
4. Title and Subtitle IceNav™ Shipboard Radar Integration Phase II		5. Publication Date November 1996
		6. Performing Organization Document No.
7. Author(s) C. Marton and D.J. Lapp		8. Transport Canada File No. ZCD-1460-238-16
9. Performing Organization Name and Address Canarctic Shipping Company Ltd. 150 Metcalfe Street, 19th Floor, Box 25 Ottawa, Ontario K2P 1P1		10. PWGSC File No. XSD95-00066-(671)
		11. PWGSC or Transport Canada Contract No. T8200-5-5510/01-XSD
12. Sponsoring Agency Name and Address Transportation Development Centre (TDC) 800 René Lévesque Blvd. West 6th Floor Montreal, Quebec H3B 1X9		13. Type of Publication and Period Covered Final
		14. Project Officer Charles Gautier

15. Supplementary Notes (Funding programs, titles of related publications, etc.)

Co-sponsored by Panel on Energy Research and Development (PERD). Phase I of this project is documented in Shipboard Radar Interface Component (SRIC).

16. Abstract

Marine radar is an integral part of the solution to the problem of navigating ships in ice infested waters. In Phase I of this program, Canarctic and Titan demonstrated the feasibility of networking the Canarctic IceNav Client and the Titan Radar Server. Due to the success of this endeavor, Canarctic and Titan, again under the sponsorship of TDC, undertook to further refine the operator requirements and to then implement them. To fully demonstrate and test the capability of this IceNav Radar integration in different ice and ship operation environments, three field trials were also conducted.

In addition, a considerable quantity of digitized marine radar data was gathered during these field trials. This data will be of use in future research.

The feasibility and field robustness of using networked PCs to distribute timely radar information were tried and proven. The client and server communication architecture worked well with a single MRI radar installation, but was more complex and difficult to use with the MRI dual installation required for the M.V. *Arctic*.

The outcome of the project was definitely positive and was very well received by the marine community who performed the evaluation. This included two separate commercial operators and the Canadian Coast Guard.

More work is required to address the operability of the IceNav-MRI system and to expand and improve functionality. Further integration with Electronic Chart Display Systems (ECDIS) is recommended.

17. Key Words Ice navigation, SINSS, image processing, cross polarization, marine radar, network application, radar data, ice intelligence system, MRI	18. Distribution Statement Limited number of copies available from the Transportation Development Centre

19. Security Classification (of this publication)	20. Security Classification (of this page)	21. Declassification (date)	22. No. of Pages	23. Price
Unclassified	Unclassified	—	xiv, 46, apps	—

Transports Canada | Transport Canada

FORMULE DE DONNÉES POUR PUBLICATION

1. N° de la publication de Transports Canada: TP 12920E	2. N° de l'étude: 8772
3. N° de catalogue du destinataire:	
4. Titre et sous-titre: IceNav™ Shipboard Radar Integration Phase II	5. Date de la publication: Novembre 1996
	6. N° de document de l'organisme exécutant:
7. Auteur(s): C. Marton et D.J. Lapp	8. N° de dossier - Transports Canada: ZCD-1460-238-16
9. Nom et adresse de l'organisme exécutant: Canarctic Shipping Company Ltd. 150 Metcalfe Street, 19th Floor, Box 25 Ottawa, Ontario K2P 1P1	10. N° de dossier - TPSGC: XSD95-00066-(671) 11. N° de contrat - TPSGC ou Transports Canada: T8200-5-5510/01-XSD
12. Nom et adresse de l'organisme parrain: Centre de développement des transports (CDT) 800, boul. René-Lévesque Ouest 6e étage Montréal (Québec) H3B 1X9	13. Genre de publication et période visée: Final 14. Agent de projet: Charles Gautier

15. Remarques additionnelles (programmes de financement, titres de publications connexes, etc.)

Coparrainée par le Groupe interministériel de recherche et de développement énergétique (GRDE), la phase I de ce projet est décrite dans le Shipboard Radar Interface Component (SRIC).

16. Résumé

Le radar de bord est un appareil indispensable à la navigation maritime dans des eaux chargées de glaces. La phase I a permis à Canarctic et à Titan de montrer la faisabilité de mettre en réseau un système-client, l'IceNav de Canarctic, et un serveur, le Modular Radar Interface (MRI) de Titan. Dans la lancée de leur succès, ces deux entreprises, là encore avec le concours financier du CDT, ont entrepris d'affiner davantage les caractéristiques du système et de les implémenter. Afin de mettre à l'épreuve et d'essayer en service cette version intégrée de l'IceNav, trois séries d'essais en mer ont été menées dans des conditions environnementales et glacielles variées.

Ces essais ont servi à amasser une quantité considérable de données radars numérisées qui seront d'une très grande utilité pour les recherches à venir.

La recherche a confirmé la faisabilité et la robustesse d'une configuration réseau pour la distribution de l'imagerie radar. L'architecture du réseau de communication client-serveur a bien fonctionné dans le cas de la liaison avec un MRI unique, mais s'est révélée plus complexe et malaisée dans le cas d'une liaison avec deux MRI, comme c'est le cas pour le N.M. *Arctic*.

Les résultats ont été probants aux yeux des intervenants, c'est-à-dire les deux armateurs ainsi que la Garde côtière canadienne.

De plus amples recherches seront néanmoins nécessaires sur l'interopérabilité du système et de son interface utilisateur, pour étendre ses fonctionnalités et pour les améliorer. Enfin, une intégration plus poussée avec le système de visualisation des cartes électroniques et d'information ECDIS est recommandée.

17. Mots clés: Navigation dans les glaces, SINSS, traitement d'images, polarisation croisée, radar de bord, mise en réseau, imagerie radar, système de reconnaissance des glaces, MRI	18. Diffusion: Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

19. Classification de sécurité (de cette publication)	20. Classification de sécurité (de cette page)	21. Déclassification (date)	22. Nombre de pages	23. Prix
Non classifiée	Non classifiée	—	xiv, 46, ann.	—

CDT/TDC 79-005
Rev. 96

Canada

ACKNOWLEDGEMENTS

A number of individuals contributed to the completion of this phase of the project. We would like to extend *extra special* thanks to Mr. Charles Gautier of the Transportation Development Centre for his many valuable suggestions and thorough review of this and related documentation.

We extend our sincere thanks and appreciation to the Captains and navigating officers on board the M.V. *Arctic*, the C.C.G.S. *Pierre Radisson* and the M.V. *Cicero* for their interest, support and feedback.

EXECUTIVE SUMMARY

In 1988 Canarctic completed the five-year Shipboard Ice Navigation Support System (SINSS) development program. The purpose of the SINSS program was to develop an ice intelligence system that would enable ice-class vessels to safely and efficiently navigate through heavy sea ice conditions. This program resulted in the implementation of a first generation ice navigation system comprising of strategic satellite information (VIEWFAX), a strategic and tactical airborne radar imagery display system (STAR-VUE), and a tactical and close range hazard detection marine radar system (MARINE-VUE).

To address the limitations of SINSS, Canarctic defined the functional specifications (TP 10565E) for a second generation (G2) ice navigation system. This specification formed the basis for the G2 Ice Navigation System Implementation Program. The G2 experience provided valuable insight and prompted Canarctic to design, develop and commercialize its own ice navigation system trademarked IceNav^tm^.

In order for IceNav to more fully address the dynamic and real time requirements of ice navigation, some form of radar interface had to be added. Rather than design a scan converter from scratch, a commercial vendor, Titan Radar International Inc. provided an almost off-the-shelf solution. Canarctic would interface to this radar digitizer via an Ethernet interface. The IceNav system could now get the marine radar data it required.

Phase I of the project dealt primarily with the specifying, designing and implementing a distributed client/server application interface. This interface, titled the Shipboard Radar Interface Component (SRIC) would enable the IceNav program to request radar data and status from the Modular Radar Interface (MRI), and then display that data and status in the IceNav application. Once communication between the IceNav host and the Radar Server simulator was established, basic radar controls, and on-line help were also added. The basic radar controls included:

- Requesting and displaying radar imagery,
- A graphical user interface,
- Windows style on-line help,
- Network communication interface.

In Phase II, extra functionality was added and the system was tested in field operations. This included:

- Performing three field trials. These were on the M.V. *Arctic*, the C.C.G.S. Radisson and the M.V. *Cicero*;
- Added functionality was added including position fixing and radar image overlay;
- Determining the range and bearing of object(s) from ship's radar;
- Adjusting the brightness and contrast of these images;
- Controlling the radar range, scan-to-scan and filter mode;
- Setting the data request rate.

The field trials provided the opportunity to test the IceNav/MRI system for a variety of operating environments and ice conditions. The trials proved the functionality of the interface; however, more work is required on the operability of the system and the user interface if it is to be used and used effectively by the navigator. Semi-automated image processing of the marine radar display would also reduce the time required of the navigator to work with the images and facilitate better interpretation of the received images in IceNav. Therefore more work is needed to develop reliable, effective semi-automated image processing techniques that work in real-time.

SOMMAIRE

En 1988, la société Canarctic a mené à bien le programme de développement quinquennal du système auxiliaire embarqué de navigation SINSS (Shipboard Ice Navigation Support System). L'objectif visé était de réaliser un système intelligent permettant de naviguer efficacement et sûrement dans des eaux fortement chargées de glaces. C'est ainsi que fut réalisée la première génération d'un système complet de navigation formé d'un module VIEWFAX d'information stratégique satellitaire, d'un module STAR-VUE qui reçoit, stocke et affiche l'imagerie tant stratégique que tactique d'un radar aéroporté, et d'un module MARINE-VUE qui affiche les images reçues d'un radar de bord et qui permet la détection d'objets flottants à une distance allant de tactique à rapprochée.

Pour pallier les faiblesses du SINSS, Canarctic a défini ensuite les spécifications fonctionnelles d'un système plus évolué (voir TP 10565E) qui a servi à la réalisation d'un système de navigation de deuxième génération ou G2. Les progrès réalisés grâce à G2 ont permis à Canarctic de se lancer dans la conception, le développement et la mise en marché de son propre système de navigation dans les glaces, qu'elle a baptisé IceNav^{MD}.

Afin de permettre au système IceNav de mieux refléter en temps réel les conditions glacielles qui sont dynamiques, il fallait ajouter une interface radar sous une forme ou une autre. Plutôt que d'étudier un convertisseur de balayage complètement neuf, Canarctic a préféré s'adresser à un fabricant, la Titan Radar International Inc. Celle-ci propose un numériseur radar avec lequel il est possible de communiquer via une interface Ethernet. C'est ainsi que le système IceNav pourra recevoir les signaux radars qui lui manquaient.

La phase I de la recherche a consisté surtout à faire la spécification, la conception et la réalisation d'une interface distribuée client-serveur appelée Shipboard Radar Interface Component (SRIC). Ce composant permet au système-client, l'IceNav, de demander au serveur, le Modular Radar Interface (MRI), des signaux radars sur les conditions glacielles, que le SRIC affiche ensuite sur l'écran d'IceNav. D'autres modules ont été ajoutés par la suite, tels que des commandes radars et un fonction d'aide en direct. Les fonctionnalités du SRIC étaient les suivantes :

- Demander, recevoir et afficher une imagerie radar;
- Servir d'interface graphique utilisateur;
- Fournir de l'aide en direct, format Windows;
- Assurer la communication avec le réseau.

Les travaux de la phase II ont consisté à ajouter de nouvelles fonctionnalités et à tester le système en service, c'est-à-dire :

- Effectuer des essais en mer à bord des N.M. *Arctic* et *Cicero* et du NGCC *Radisson*;
- Ajouter de nouvelles fonctionnalités, y compris la détermination du point et la surimpression d'imagerie radar;
- Déterminer la distance et le gisement de divers objets flottants à partir de cette imagerie;

- Régler la luminosité et le contraste de l'imagerie;
- Régler la portée du radar, l'intégration de balayage et le mode filtre;
- Régler la fréquence de rafraîchissement des données.

Les essais en mer ont été couronnés de succès. Ils ont permis de mettre à l'épreuve le système IceNav/MRI dans des conditions environnementales et glacielles variées, en plus de vérifier le bon fonctionnement du SRIC. De plus amples recherches seront néanmoins nécessaires sur l'interopérabilité du système et de son interface utilisateur, et sur son efficacité comme outil de navigation. Le procédé de traitement semi-automatique de l'imagerie devra lui aussi être amélioré de façon à réduire le temps de mise en oeuvre et à faciliter l'interprétation des images affichées sur l'écran d'IceNav.

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LIST OF ABBREVIATIONS, ACRONYMS, SYMBOLS AND SPECIAL TERMS

AMR	Arctic Marine Radar
CCG	Canadian Coast Guard
CCMC	Canadian Centre for Maritime Communications
CRIHD	Close Range Ice Hazard Detection
DLL	Direct Link Library
ECDIS	Electronic Chart Display and Information System
ECPINS	Trademark of Offshore Systems Limited
GUI	Graphical User Interface
IceNav	Trademark of Enfotec Technical Services Inc.
INSS	Ice Navigation Support System
MR	Marine Radar
MRI	Modular Radar Interface
OSL	Offshore Systems Limited
SINSS	Shipboard Ice Navigation Support System
SR	Ship's Radar
SRIC	Shipboard Radar Interface Component
TN	Trial Navigator

1. INTRODUCTION

Over the last several years, Canarctic has studied and analyzed the problems of ship navigation in ice covered waters. The Shipboard Ice Navigation Support System (SINSS) program resulted in the specification of a first generation ice navigation system comprising strategic satellite information (VIEWFAX), a strategic and tactical airborne radar imagery display system (STAR-VUE), and a tactical and close range hazard detection marine radar system (MARINE-VUE). Subsequent studies and research led to the development of a second generation (G2) Ice Navigation System. This development, although never commercially viable, provided valuable insights and prompted Canarctic to design and develop its own ice navigation system trademarked IceNav^{tm}. IceNav^{tm} was developed to run under the Microsoft Windows 3.x, 95, and NT operating systems.

IceNav^{tm} is capable of ingesting many different forms of data. However, prior to this project, no capability existed within IceNav^{tm} for correlating the marine radar data with the airborne or satellite SAR/SLAR and NOAA satellite imagery. Depending on the season, weather conditions and timeliness of the ice imagery, ice floes can be in different positions from those indicated in the imagery. Only marine radar data can provide navigators with the immediate and real-time positions of ice floes in dynamically-changing ice conditions. Additionally, certain types of radar (e.g. HH/HV cross-polarized) are predisposed to differentiating new and multi-year ice types. This capability is particularly useful in areas that are either covered with snow or in complete darkness. The same radar could, with the aid of some signal processing, also be used to detect small targets such as bergy bits and growlers in open water or larger targets such as drifting icebergs. Marine radar data is therefore an integral component of any ice navigation system. In order for IceNav^{tm} to be truly useful in all ice situations, an interface to marine radar was required.

1.1 Project Objective

The objective was to develop within IceNav^{tm} the capability to interface the Modular Radar Interface (MRI) unit, manufactured by TITAN Radar International, and to provide the functionality to use and manipulate the shipboard radar images to support ice navigation.

1.2 Specific Objectives

In Phase II of the program, the objective was to provide the basic data communication network link between the IceNav and the Titan Radar systems, to enable marine radar data to be passed electronically and dynamically from the marine radar to IceNav, and to implement a basic set of marine radar control functions in IceNav, so that the Titan radar could be controlled from the IceNav system. In this phase all the emphasis was placed on completing the missing functionality not completed in Phase I and perform three field trials in order to test the operability and robustness of the system. At the same time, operator feedback was collected during the trials.

The software developed to provide the interface functions and other features outlined in this project consisted of a group of software modules which provided enhancements to the functions of the IceNav system. In order to distinguish these functions from the existing IceNav modules, the new modules were known as the Shipboard Radar Interface Component (SRIC). Development of these modules began in Phase I and was continued in Phase II.

1.3 Report Organization

This report is organized and submitted in one volume which contains the Final Report and four Appendices.

2. SUMMARY OF PROJECT TASKS

The project followed the typical "waterfall" software development cycle with the added benefit of a second iteration of design and implementation following the first field trial on the M.V. *Arctic*. The complete list of all the tasks in this project is given below.

Task 1: Work Plan
Task 2: Functional Requirements Definition Update
Task 3: Preliminary Design Update
Task 4: Detailed Design Update
Task 5: Software Development First Stage
Task 6: Prototype Integration & Testing
Task 7: Field Trial and Data Collection (M.V. *Arctic*)
Task 8: Software Development Second Stage
Task 9: Field Trial and Data Collection (CCGS *Pierre Radisson*)
Task 10: Field Trial and Data Collection and Dissemination (M.V. *Cicero*)
Task 11: Final Report

Task 1 outlined in detail the individual work items that were to be performed throughout the project.

Task 2 consisted of analyzing and documenting the functional requirements for the Shipboard Radar Interface Component (SRIC) software and resulted in the production of an updated **Functional Requirements Document**. This document outlined the conceptual definition of the system and defined the functional and user requirements of the system. It also formed a basis for the work done in Task 3. It is included in this report as Appendix A. To ensure that the design of the SRIC provided for all of the necessary features, a wide variety of documents and information were reviewed: Second Generation Ice Navigation System Functional Specifications, High Resolution Image Transmission to Ships results, current GPS technology, current AES and CCG policy concerning ice information, availability of RADARSAT images, performance limits of the PC platform, Modular Radar Interface specifications, results from the Phase I work and future requirements from ongoing ice navigation radar research.

Task 3 mapped the functional requirements, defined in task 2, into the set of high level software functions/procedures/objects that comprise the SRIC software. This mapping provided a first pass at the overall software definition. The results of this work were written up into the form of a **Preliminary Design Document (PDD)** which was reviewed and commented on by TDC. The PDD contains a list of functions, data definitions and graphical user interface designs. As such, it served as a building block for the following phases of the project, specifically Task 4 “Radar Input Component Detailed Design”. The document serves as a means of defining the product to all groups involved with the project, including Canarctic, Titan Radar International, TDC, and other scientific advisors.

During **Task 4** more detail was added to the preliminary design. This included corrections made based on rapid proto-typing and a better understanding of the project as a whole. The output from this task was the **Detailed Design Document**. This document was a refinement of the preliminary design and provided a final specification of the system. It is included in this report as Appendix B. The purpose of the Detailed Design Document was to provide the final, overall specification for the SRIC before software coding proceeded. As such it was reviewed, commented on and finally approved by TDC before formal coding started.

Tasks 5 involved the individual coding and testing of the modules listed in section 5. This included the SRIC application software plus the client and server distributed application stubs.

Task 6 consisted of integrating the system. At this stage the software development was switched over to maintenance and field trial support.

Task 7 consisted of field testing the system together with data collection of digitized radar imagery.

Task 8 saw the software upgraded from the outcome of the field trial on board the M.V. *Arctic*.

Task 9 had IceNav and the MRI run on a CCG icebreaker where the requirements are different from commercial operators.

Task 10 involved using the marine radar as a remote sensor. Radar imagery was sampled and sent back to CCMC (Canadian Centre for Maritime Communications).

Task 11 was the task required to produce the final report and project deliverables.

3. SRIC FUNCTIONAL OVERVIEW

Figure 3-1 shows the connection scheme of the MRI Server computer to the IceNav^{tm} Client computer (Host system).

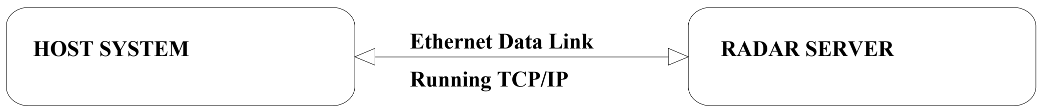

Fig 3-1 Host to Radar Server Connection Scheme

To date the SRIC software can:

- Request and display grey scale or monochrome images of size 512 X 512 to 1024 X 1024 pixels;
- Determine the range and bearing of object(s) from ship's radar;
- Do the position fixing by feature or by overlay;
- Adjust the brightness and contrast of these images;
- Adjust the viewing size of the images;
- Manage the marine radar by sending commands to:
  - -Put MRI on-line or off-line;
  - -Set MRI radar sampling range;
  - -Enable/Disable scan to scan conversions and their frequency;
  - -Enable/Disable the OSCFAR mode;
  - -Set rate at which the SRIC requests image data;
  - -Set data width or dynamic range;
  - -Provide calibration interfaces of manual gain/offset and antenna azimuth angle.

In addition the SRIC provides:

- The graphical user interface (GUI);
- Windows style on-line help;
- The IceNav/MRI interface.

Figures 3-2 and 3-3 illustrate examples of the graphical user interface as it exists today.

Figure 3-4 illustrates the Software Context Diagram of the SRIC software.

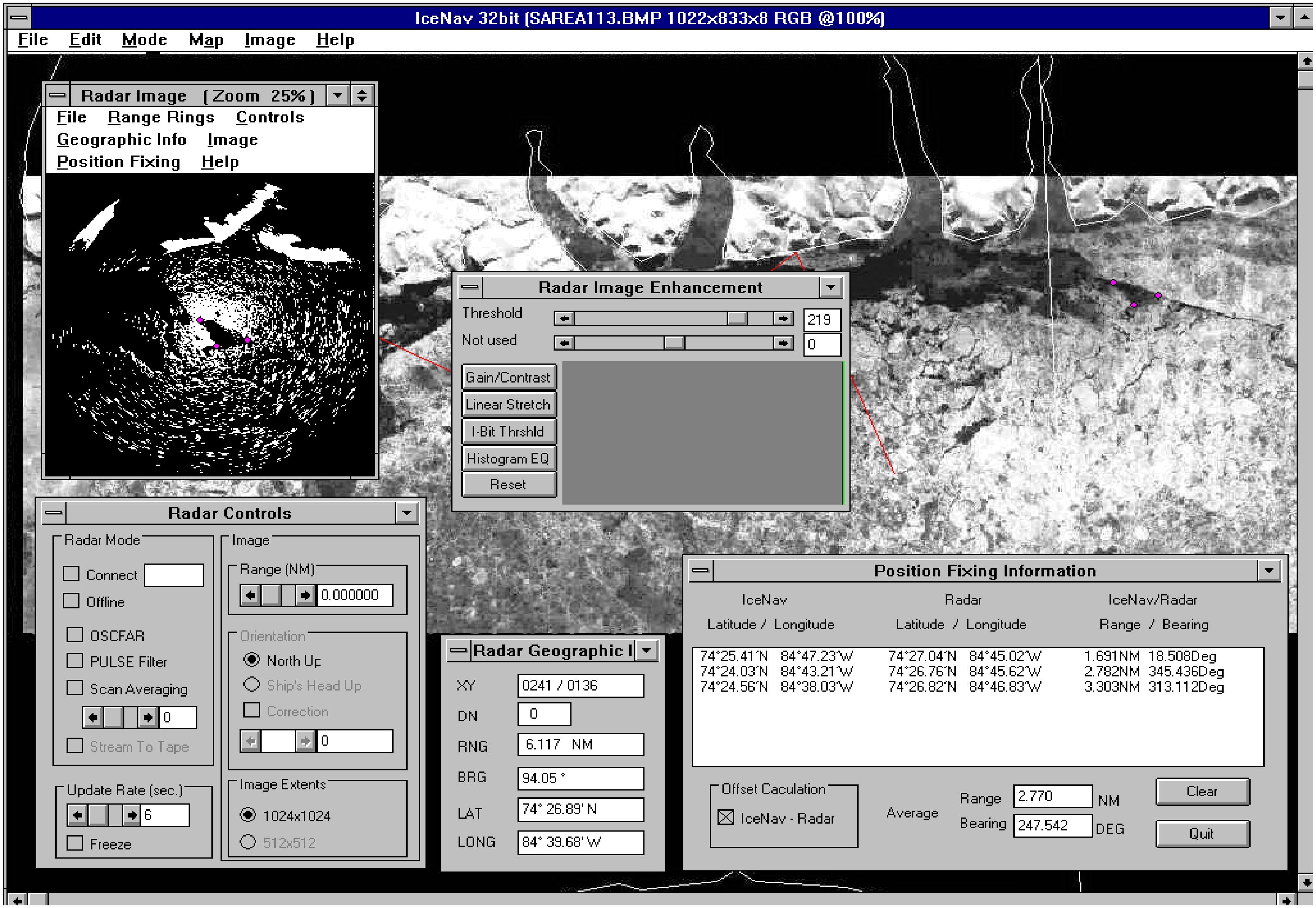

Fig 3-2 Sample of SRIC GUI

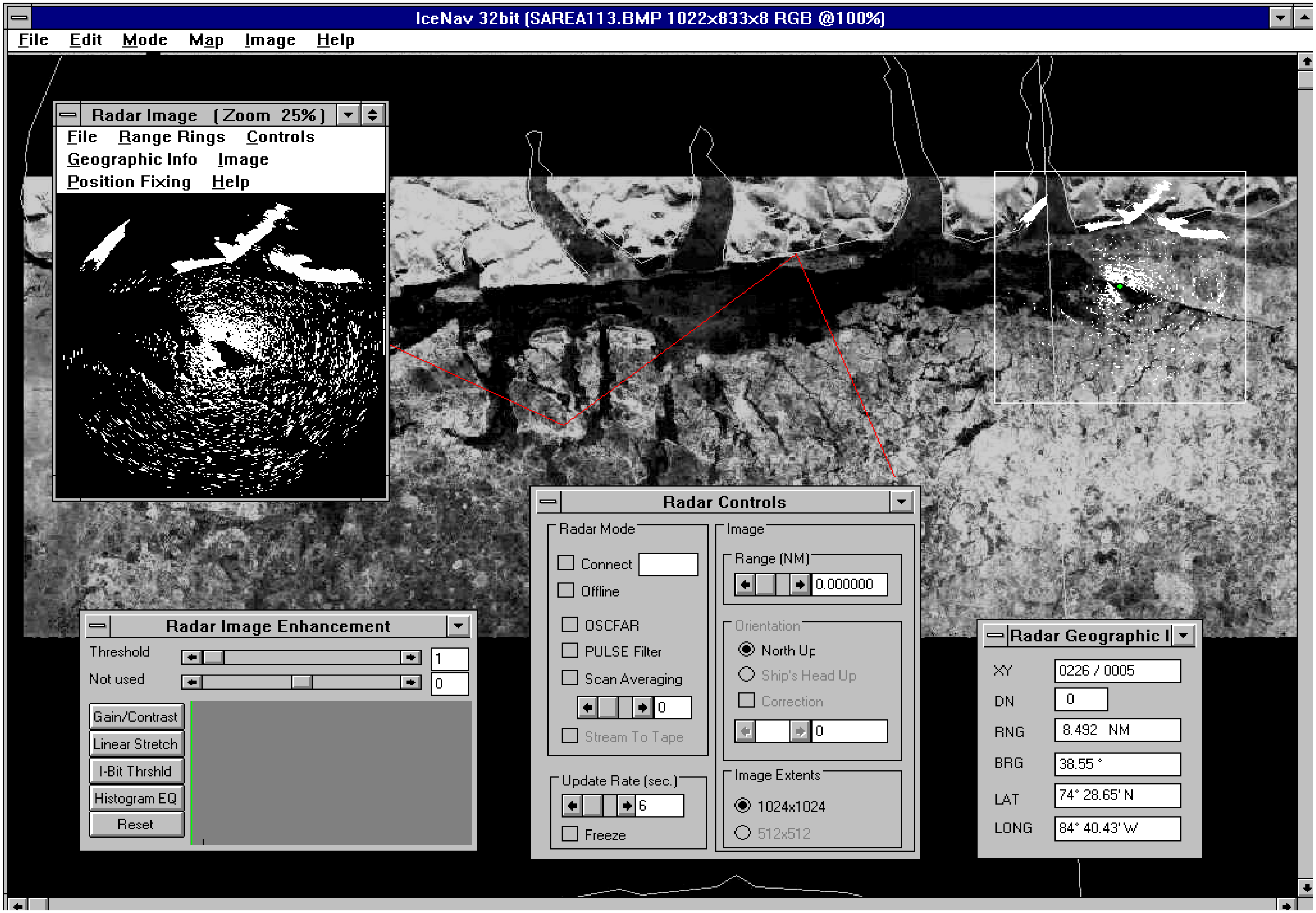

Fig 3-3 Sample of SRIC GUI

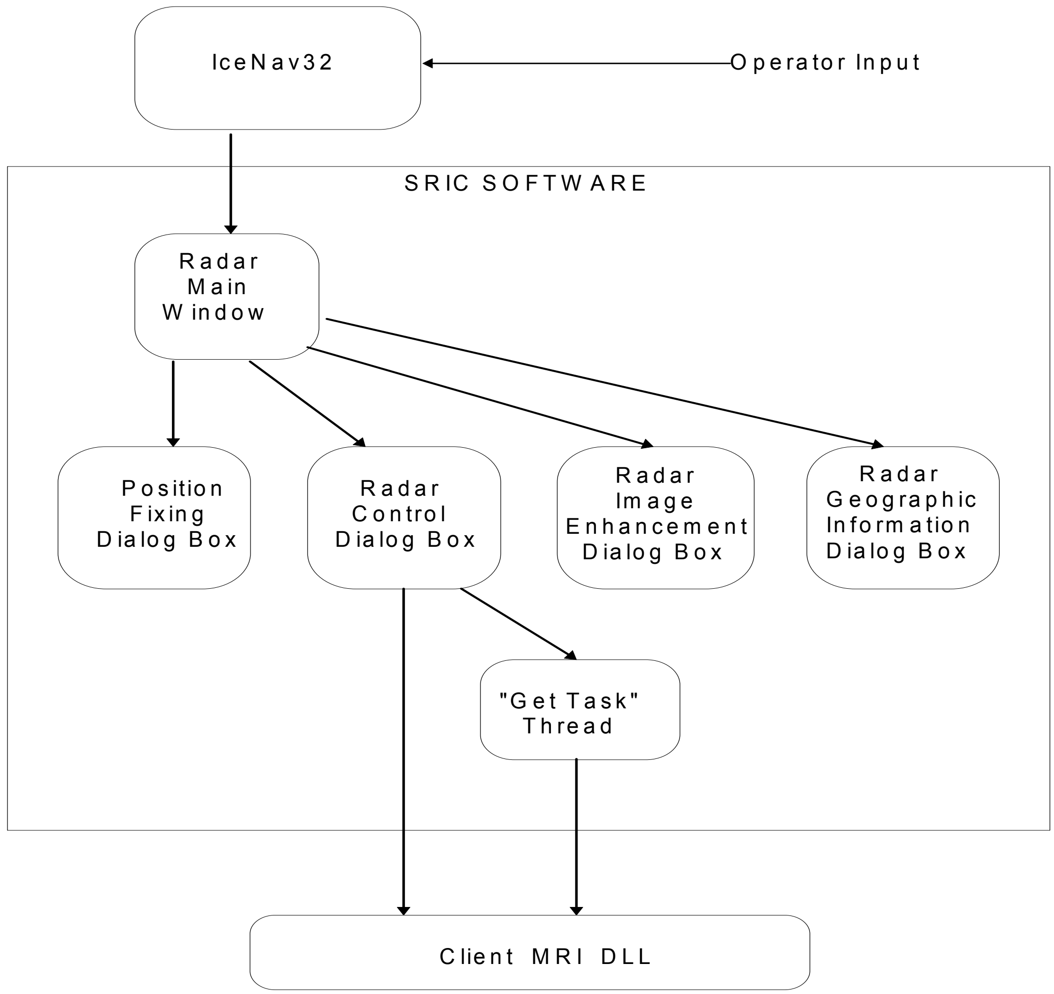

Fig 3-4 Software Context Diagram of SRIC Software

4. SRIC SOFTWARE DESCRIPTION

The SRIC software follows the windows programming model. This means that the SRIC software must conform to the windows messaging architecture. Generally speaking, a windows program reacts to and processes messages sent to it from the operating system. A predefined message structure, definition and window application determine what processing will have to occur. Each window object processes the windows message sent to it. The SRIC software comprises a number of window objects. These are:

- "Radar Image" Main Window;
- "Radar Controls" Dialog Box;
- "Position Fixing Information" Dialog Box;
- "Radar Image Enhancement" Dialog Box;
- "Radar Geographic Info" Dialog Box.

The SRIC makes no use of ICONS or toolbars at this time.

A description of the above items follows.

4.1 The "Radar Image" Main Window

When the IceNav^{tm} menu item "View Radar Data" is selected, IceNav^{tm} creates a window titled "Radar Image". This window object has associated with it a callback function named "Radar_CB". This callback function contains the code for decoding the following windows messages:

WM_INITDIALOG:	Initializes the "Radar Image" window;
WM_INITMENU:	Initializes the menu check items of "Radar Image" window;
WM_CLOSE:	Closes "Radar Image" window and quits SRIC;
WM_SIZE:	Processes size message;
WM_MOUSEMOVE:	Processes mouse move message;
WM_KEYUP:	Translates KEYUP message to scroll message;
WM_KEYDOWN:	Translates KEYDOWN message to scroll message;
WM_HSCROLL:	Processes horizontal scroll message;
WM_VSCROLL:	Processes vertical scroll message;
WM_LBUTTONDOWN:	Processes the left button down of mouse message;
WM_PAINT:	Processes paint message of window;
WM_COMMAND:	Processes user commands;
WM_MRIDLLDONE:	Processes DLL return message;
WM_TIMER:	Processes time out message of timer.

Most of the windows messages listed above are straightforward, but more explanation is needed for the WM_COMMAND message. This message is used to indicate, to the callback function, the selection made by the user when selecting a menu item from the "Radar Image" window. The callback function, "Radar_CB", processes the following WM_COMMAND cases:

File: Has following sub selections:

- Open: Opens a radar imagery stored in "C:\Radar" directory.
- SaveAs: Saves the current displayed radar imagery in "C:\Radar" directory in user entered name.
- SnapShot: Saves the current displayed radar imagery as "C:\Radar\Snap.bmp".
- Exit: Closes "Radar Image" window and quits SRIC.

Range Ring: Has following sub selections:

- On: Displays the radar grid on top of the radar imagery. The ship's position will be in the center of the grid.
- Off: Disables grid.

Controls: Invokes the "Radar Controls" dialog box explained in Section 4.2, which has various menu choices to control the Radar Server.

Geographic Info: Invokes the "Radar Geographic Information" dialog box explained in Section 4.3, which displays the range and bearing of the mouse position in the radar imagery.

Image: Invokes the "Radar Image" window, which provides two menu commands: the brightness and contrast of the displayed radar imagery.

Zoom: Invokes the zooming function to zoom the radar image of 25%, 50% or 100% settings.

Enhance: Invokes the "Radar Image Enhancement" dialog box explained in Section 4.4, which contains numerous selections to adjust the brightness and contrast of the displayed radar imagery.

Position Fixing: Invokes the "Radar Position Fixing Information" dialog box explained in Section 4.5, which displays the feature position fixing in the radar imagery.

Overlay: Invokes the position fixing by overlay function and an "Overlay Information" message box, which overlays the radar image on the IceNav imagery in the main window.

Help: Invokes an on-line help file. This file has an overview of the SRIC functionality and all the menu function indexes and instructions on them. The file is in windows help format.

4.2 The "Radar Controls" Dialog Box

The "Radar Controls" works in a fashion similar to that described above. The menu command "Controls" of the "Radar Image" window invokes "Radar Controls" dialog box. A "RadarMode_CB" callback function is responsible for processing the message sent to this window object.

The messages include:

WM_INITDIALOG: Initializes the "Radar Controls" dialog box.
WM_CLOSE: Closes the "Radar Controls" window.
WM_HSCROLL: Processes horizontal scroll messages. These messages are used in setting up the following parameters:

Scan Averaging value
Set range, Select a valid mode from the TITAN_ MODES[16] structure array

WM_COMMAND: Processes user commands.

The "Radar Controls" dialog box displays the command types that a user can send to the Titan Radar via the "RadarMode_CB" callback function. The command types are grouped into three categories:

Radar Mode;
Update Rate; and
Image.

More specifically, the "RadarMode_CB" callback function processes the following WM_COMMAND cases:

Radar Mode [First group]

Connect: A check box marker indicates whether the MRI Server is connected. Check the box invokes a “Select MRI” Dialog Box which allows the user to select the MRI server available to connect or disconnect. The connected MRI server will be indicated in the text box beside the Connect check box.

Off-line:	Set the selected radar unit off-line.
OSCFAR:	Check box. Set/Reset the OSCFAR switch of the radar unit.
PULSE Filter:	Check box. Set/Reset the PULSE Filter switch of radar the unit.
Scan Averaging:	Check box. Set/Reset the radar scans to average. The horizontal scroll bar below the check box sets its number.
Stream To Tape:	Function not valid. (Greyed).

Update Rate [Second group]

Update Rate:	The horizontal scroll bar indicates the interval in seconds between consecutive image requests.
Freeze:	Freezes the image requests issued by the client computer.

Image [Third group]

Range:	The horizontal scroll bar indicates a valid range in nautical miles assigned to the radar.
North Up:	The radio button specifies that the image will be aligned to true north up when selected.
Ship's Head Up:	The radio button specifies that the image will be aligned to the ship's heading when selected.
Correction:	Function not valid. (Greyed)
512x512:	Radio Button. Sets data width and height to 512x512. Not implemented.
1024x1024:	Radio Button. Sets data width x height to 1024x1024.

In summary, when the selected radar unit is on, i.e. off-line is NOT invoked, a thread is created to get data from the radar server. The rate of getting data from the server is managed via "Update Rate" (scroll bar and edit buffer). All other mode functions in the "Radar Controls" dialog box are running with the IceNav^{tm} thread.

This multi-threaded design is based on the following considerations:

The client processor would become too busy [therefore locking out user commands] if the SRIC software requested data/imagery in the same thread as the IceNav^{tm} task. Therefore, a separate thread is needed to run this task independently from the main IceNav^{tm} process. This ensures that IceNav^{tm} will not be stopped/suspended by the radar server/SRIC communication for unreasonably long periods of time. In the design and implementation, a semaphore is used to synchronize requests to the network.

4.3 The "Radar Geographic Information" Dialog Box

Choosing the menu command "Geographic Info" from the "Radar Image" window invokes "Geographic Information" dialog box. The "RangeBearing_CB" callback function is responsible for handling the commands sent to this window object and processes the following window messages:

WM_INITDIALOG:	Initializes the "Range and Bearing" Dialog Box.
WM_CLOSE:	Closes "Range and Bearing" Dialog Box.
WM_USER+100:	An application-defined message. See below.

When WM_MOUSEMOVE messages are processed, in the parent "Radar Image" window and the "Geographic Info" dialog box is active, then the application-defined message (WM_USER+100) is posted to this dialog box. This occurs whenever the mouse moves. The mouse position and radar imagery geo-referencing are used to calculate and display the following information:

<u>XY</u>:	The XY value of the mouse position in windows.
<u>DN</u>:	The intensity of the pixel at the mouse position.
<u>RANGE</u>:	The range of the mouse position.
<u>Bearing</u>:	The bearing of the mouse position.
<u>Latitude</u>:	The latitude of the mouse position.
<u>Longitude</u>:	The longitude of the mouse position.

4.4 The "Radar Imagery Enhancement" Dialog Box

Selecting the menu command "Enhance" of the "Radar Image" window invokes "Radar Imagery Enhancement" Dialog Box. An "Adjust_CMap_CB" callback function processes the commands for this window object . A list of the commands follows.

WM_INITDIALOG:	Initializes the "Radar Imagery Enhancement" dialog box.
WM_CLOSE:	Closes the "Radar Imagery Enhancement" dialog box.
WM_HSCROLL:	Processes horizontal scroll message. This message is used in setting up the following values: Gain Contrast. 1 bits threshold Linear Stretch
WM_COMMAND:	Processes user commands.
WM_USER+98:	Processes user-defined messages.
WM_USER+99:	Processes user-defined messages.

The "Radar Imagery Enhancement" Dialog Box displays the commands user can send to the "Adjust_CMap_CB" callback function. The commands are as follows:

Gain:	Scroll bar and edit buffer. Sets the brightness.
Contrast:	Scroll bar and edit buffer. Sets the contrast.
Linear Stretch:	Push button and scroll bar. Performs and displays linear. stretch between upper and lower bound set by the scroll bar.
1 Bit Threshold:	Pushbutton and scroll bar. Performs and displays 1-bit thresholding.
Histogram Equalization:	Push button. Performs and displays histogram equalization.
Reset:	Push button. Resets the palette to the old one.

Functions in this dialog box run locally, no RPC is invoked. Actually, the "Adjust_CMap_CB" callback function is shared with IceNav^{tm}'s enhancement function. This callback function is in ADJCMAP.CPP.

4.5 The "Position Fixing Information" Dialog Box

Choosing the menu command "Position Fixing" and "Feature" from the "Radar Image" window invokes "Position Fixing Information" dialog box. The "PositionFix_CB" callback function is responsible for handling the commands sent to this window object and processes the following window messages:

WM_INITDIALOG:	Initializes the "Radar Imagery Enhancement" dialog box.
WM_CLOSE:	Closes the "Radar Imagery Enhancement" dialog box.
WM_WINDOWPOSCHANGED:	Processes the message when the dialog is moving around.
WM_COMMAND:	Processes user commands.

The "Position Fixing Information" Dialog Box displays the commands user can send to the "Adjust_CMap_CB" callback function. Here are the commands and the information calculated and displayed:

Offset Calculation:	Check box. Allows the user to choose the subtraction scheme of the position fixing.
Clear:	Push button. Clear information of the position pairs.
Quit:	Push button. Quit the position fixing dialog box.
Average Range:	Display the calculated average range of all chosen pairs.
Average Bearing:	Display the calculated average bearing of all chosen pairs.
Position:	Display the latitude, longitude, range difference and bearing difference of each pairs of position fixing.

5. SOFTWARE MODULES

5.1 Software Configuration

The SRIC software configuration is implemented in the networked computer system using a Client/Server model. The IceNav^{tm}/SRIC resides on the CLIENT computer and the Titan/MRI resides on the SERVER computer. The Client code comprises the following:

Table 5.1 Description of SRIC Client Code Modules

File Name	Description
ICEMAIN.CPP	Decodes Main Menu Selection and handles modeless dialogue boxes. When the View Radar Data menu item is selected the program calls "CreateDialog" to start up the main radar window.
RDRMAIN.CPP	Contains the code for the Main Radar Display Window as well as invocation of the child dialogues.
RDRPOSF.CPP	This module performs the position fixing function. It uses the routines in RDRGEO.CPP to compute the latitude and longitude of main radar display position fixes.
RDRMODE.CPP	Contains the MRI control GUI. Sends and gets message from the Radar Communication Thread. In this way the main application program is not kept in a "busy wait" state.
RDRTHRED.CPP	Contains the code to communicate with the Client MRI DLL. The MRI Services Thread processes thread messages sent to it from the application dialogues. These messages signal the thread to perform specific functions. This module gets the procedure address from the MRI Client DLL, builds the stack variables and then calls the routine.
RDRGEO.CPP	Contains routines for computing, displaying range and bearing to cursor object as well as the routines for computing latitude and longitude for the position fixing function.
ADJCMAP.CPP	Contains the routines to adjust the colour map. There are several algorithms from which to choose. Gain/Contrast/Linear, Stretch/One-Bit-Threshold/Histogram Equalization.
BMPOL.CPP	Contains routines for computing, displaying and the overlaying the radar imagery onto the base IceNav imagery.
MRI_CALL_DEFS.H	Contains type definitions for MRI function calls.
MRI_CALLS.H	Contains MRI Call prototypes.
RADARBOUNDS.H	Contains radar parameter boundary specification.
RADARMSG.H	Contains radar messages and thread information.
PFIX.H	Contains position fixing definitions and prototypes.

5.2 Source Code Configuration Control

The software configuration control has been done manually. However, Canarctic is currently in the process of procuring the PVCS for Windows software package for this purpose (available from InterSolv). This software will assist the software developers to achieve automatic program version control.

5.3 Software Documentation

The SRIC software documentation consists of the following items:

- Functional Requirements Document containing the functional, operational and user requirements.
- Preliminary Design Document containing the module/function names and parameters.
- Detailed Design Document containing pseudo-code for each of the module/function names. It is from this document that the programmers write their code.
- The SRIC source code itself. This code is documented with in-line comments that follow an informal commenting style. Some "HUNGARIAN" variable naming conventions were also followed. The source code has already been delivered to TDC as a separate volume of information not for general redistribution. The source code fits on a single 3.5" floppy diskette.

6. EXECUTION OF FIELD TRIALS

6.1 Overview

The IceNav/MRI development included the conducting of three field trials in different operational situations and differing ice conditions. The first trial, conducted on the M.V. *Arctic* in October 1995, was intended to test the system after completion of the first period of development. The M.V. *Arctic* has a special cross-polarized radar known as an AMR (Arctic Marine Radar), with separate horizontal and vertical radar channels. The AMR is the ice-detection radar, and was connected through the Titan/MRI system to IceNav..The two channel AMR required installation of two MRI systems which were interfaced to IceNav in a networked, Client-Server configuration version of the SRIC software. The installation of IceNav-MRI coincided with the installation of an Electronic Chart Display system (ECDIS), the Offshore Systems Limited (OSL) ECPINS, which interfaced separately with IceNav. The 3 components: ECDIS, IceNav and AMR form a high level navigation system known as Frontier ECDIS. This system is the subject of a companion TDC-sponsored project, Phase I and II [2] [3], which included a field trial conducted on the M.V. *Arctic* concurrently with the MRI project.

The second trial occurred on the Canadian Coast Guard icebreaker, CCGS *Pierre Radisson*, to support winter operations in the St. Lawrence River at Matane in February 1996. This trial followed completion of a second period of software development and refinement of the interface.

A third trial was added late in the project on the commercial vessel M.V. *Cicero* to examine the utility of the system for a commercial ship operating in the Gulf of St. Lawrence in winter ice conditions.

Each trial had several objectives, some of which were common to all three trials, and some which were unique to each trial by virtue of the operating environment, the availability of field personnel and the stage in the project. In all trials, marine radar data of various ice conditions were recorded using the MRI system. These data were to be analysed later to develop image processing algorithms.

The M.V. *Arctic* trial included the use of a Trial Navigator (TN). The TN essentially became the operator of the IceNav system, and operated it with the MRI and ECPINS in a variety of ice conditions. The last voyage of the M.V. *Arctic* was slightly later than normal, and ice conditions were relatively severe. The conditions necessitated considerable attention by the navigating officers to proven systems to facilitate ice navigation decision-making. This meant that the navigating officers had limited time to spend with the integrated system, especially at critical times. Therefore the TN, who was a navigating officer on the M.V. *Arctic* but was not on active duty, became the critical element in the proper and effective evaluation of the system. For the other two trials, a TN was not used because of budget restrictions. However, these trials were conducted in considerably easier ice conditions and less demanding operating environments, i.e. the navigating officers had time to work with the system. The latter two trials were simpler installations because they did not include cross-polarized radar or ECDIS.

The trials helped to test and evaluate the performance and robustness of the developed software in actual operating environments. They also served a very useful purpose in that feedback from the mariner on the functionality and operability of the system was gained during several stages in the development cycle. The feedback helped to identify major bugs to be fixed, as well as focus development on the higher priority items. Feedback from the navigating officers on the SRIC and MRI was obtained through formal and informal means. The officers were asked to complete an Evaluation Kit, which consisted of a questionnaire that was filled out sometimes with and sometimes without the assistance of field personnel deployed from the project team. A sample copy of the **ICENAV/MARINE RADAR INTERFACE (MRI) Evaluation Kit** is included in Appendix D of this Final Report. Equally important feedback was gained through informal discussions.

Each field trial installation was different to some degree, particularly for the M.V. *Arctic* with two MRIs installed, but the general connection scheme remained the same. Figure 6-1 is a photograph of the installed system on the M.V. *Arctic*. The ECDIS monitor is on the left, and the IceNav monitor is on the right. The general connection scheme for all installations is shown in Figure 6-2.

Figure 6-1 Bridge Installation of IceNav MRI System
M.V. *Arctic* - October 1995

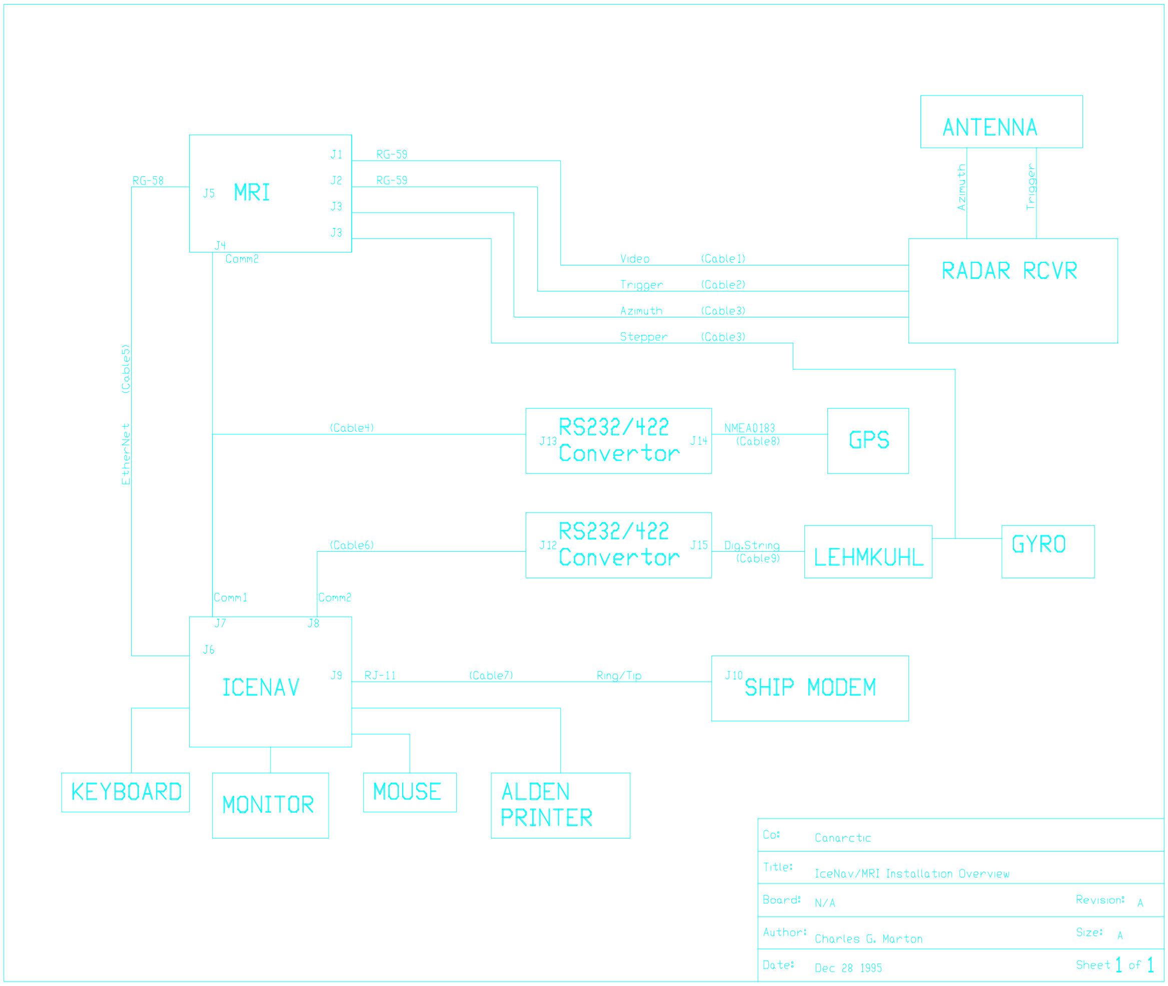

Fig 6-2 IceNav/MRI Installation Overview

The more complex M.V. *Arctic* installation, which was also the first field installation of the IceNav/MRI system, included a pre-installation task while the vessel was in Montreal in late August 1995. This was extremely useful in that many of the problems that could have occurred during actual installation when time is short were identified and solved. This pre-trial installation was also the first test of communication protocol between the two systems and it helped in identifying bugs and other problems that were worked on in the weeks prior to actual installation in October.

The installations on CCGS *Pierre Radisson* and M.V. *Cicero* were single MRI installations, and were completed within 48 hours which did not impede the subsequent conduct of the field trials.

A number of documents were produced during the project as interim reports for the management of the field trials. Prior to each trial, a Test and Operations Plan was submitted to TDC, and served as the basis for trial execution. Following each trial, a Field Trial and Data Collection Report was submitted to TDC.

The following is a brief synopsis of each of the three field trials. Further details are contained in the Test and Operations Plans and the Field Trial and Data Collection Reports. A summary of the main findings of the trials appears in Section 7 of this report. The recommendations arising out of these trials are presented in summary form in Section 8 of the report.

6.2 Field Trial #1 - M.V. *Arctic*

The trial was executed on the last inbound voyage of the M.V. *Arctic* to Little Cornwallis Island in October-November 1995. The IceNav system was already onboard the M.V. *Arctic*, and final installation of the two MRIs was completed in Antwerp prior to departure for the *Arctic*. In August 1995, a temporary installation of the MRI was completed while the M.V. *Arctic* was in Montreal prior to departure to the Arctic to pick up crude oil from the Bent Horn terminal. The temporary installation coincided with the installation of the ECPINS system, and this allowed the placement of the monitors for the two systems to be resolved. The MRI was tested by itself and with IceNav, and this proved to be very useful in identifying problems with installation that could be dealt with immediately and well before the actual field trial. The final installation was complicated because it involved two MRI systems each interfacing to the H and V channels for the cross-polarized radars.

The system architecture comprised an IceNav computer connected via Ethernet Link (10 Mbs) to the two MRI interfaces. These MRIs were in turn connected to the Sperry cross-polarized radar, one to the horizontal channel and the other to the vertical channel.

The objectives of this first field trial were as follows:

- Conduct a field demonstration of the IceNav/MRI interface functionality and evaluate the performance of the software to test the software and evaluate its functionality and operability by the mariner;
- Collect and record horizontal and vertical polarized marine radar data and associated environmental data for various ice conditions encountered by the M.V. *Arctic* during its voyage;
- Have the navigating officers evaluate the system.

This trial included a separate, but related, field trial of the Frontier ECDIS system. The Frontier ECDIS included a network connection between ECPINS and IceNav plus file exchange capability to facilitate the transfer of routes between the two systems. Although it is outside the scope of this report, it is worth mentioning that the trial offered the first opportunity to see and work with all three systems. The test plan for Frontier ECDIS evaluation was created and conducted in close coordination with the IceNav/MRI field evaluation.

The trial started in Antwerp Belgium on October 23, 1995 and was completed at LCI on November 3, 1995. Table 6.1 summarizes the Noon Positions from Antwerp to Polaris:

Table 6.1 Summary of Noon Positions from Antwerp to Polaris

Relevant Information	Date	Latitude (N)	Longitude
Oct. 23/95 Depart Antwerp @ 2218	Oct. 24/95	53 04.5	002 42.1E
	Oct. 25/95	58 43.2	003 05.5W
	Oct. 26/95	59 38.5	009 51.5W
	Oct. 27/95	60 03.0	019 15.1W
	Oct. 28/95	59 43.5	031 53.5W
	Oct. 29/95	59 33.8	045 08.8W
	Oct. 30/95	63 39.4	053 24.6W
	Oct. 31/95	68 39.4	059 59.0W
	Nov. 1/95	73 10.7	071 00.0W
	Nov. 2/95	74 28.1	082 14.5W
Nov. 3/95 Arrived Polaris @ 2004	Nov. 3/95	74 38.2	092 46.6W
Nov. 5/95 Depart Polaris @ 1345	Nov. 6/95	74 09.0	087 31.5W
Nov. 7/95 Arrived Nanisivik @ 0820	Nov. 7/95		

Figures 6-3 and 6-4 illustrate the route followed for the field trial.

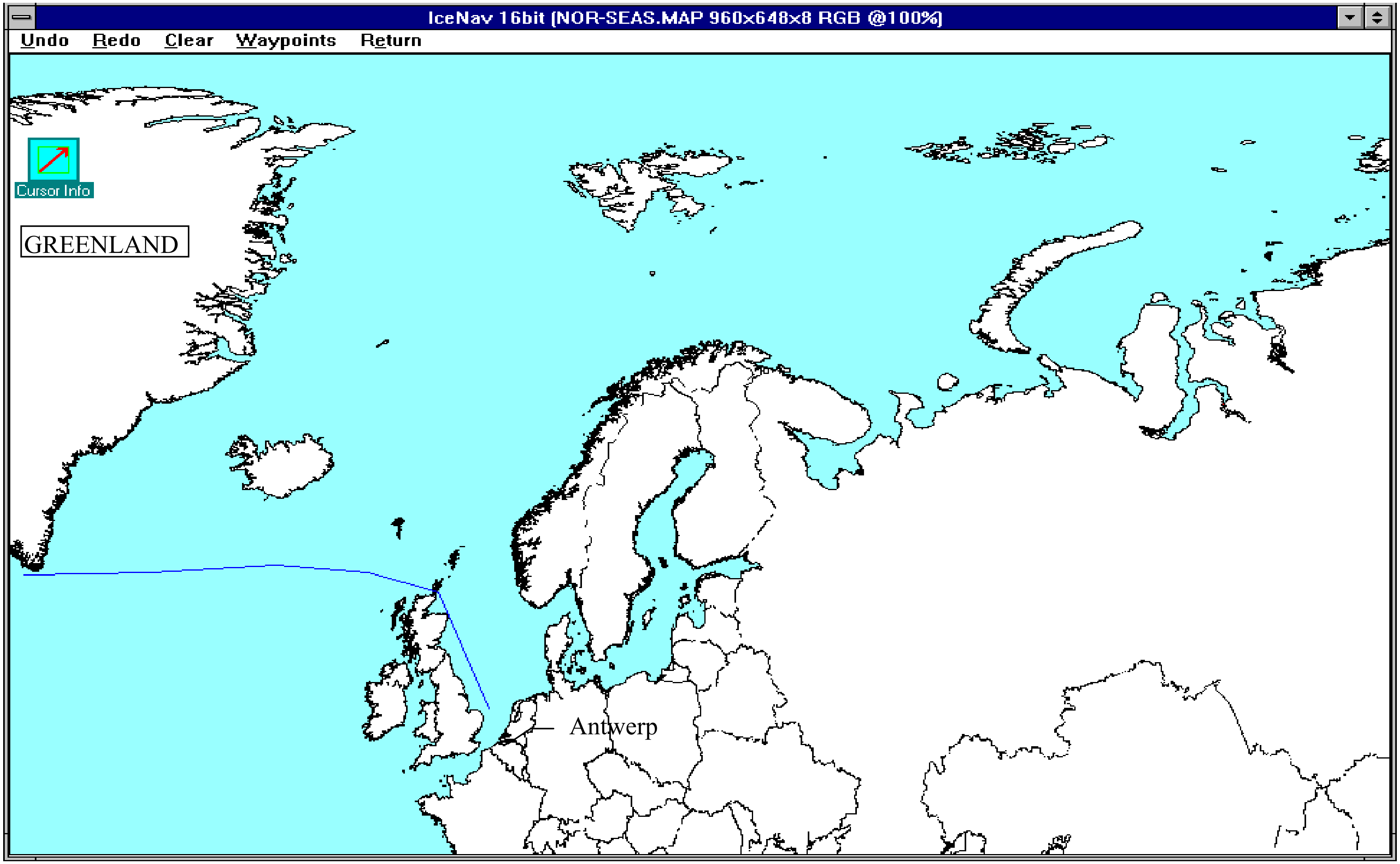

Fig 6-3 Field Trial Route - M.V. *Arctic* Voyage Antwerp to Polaris

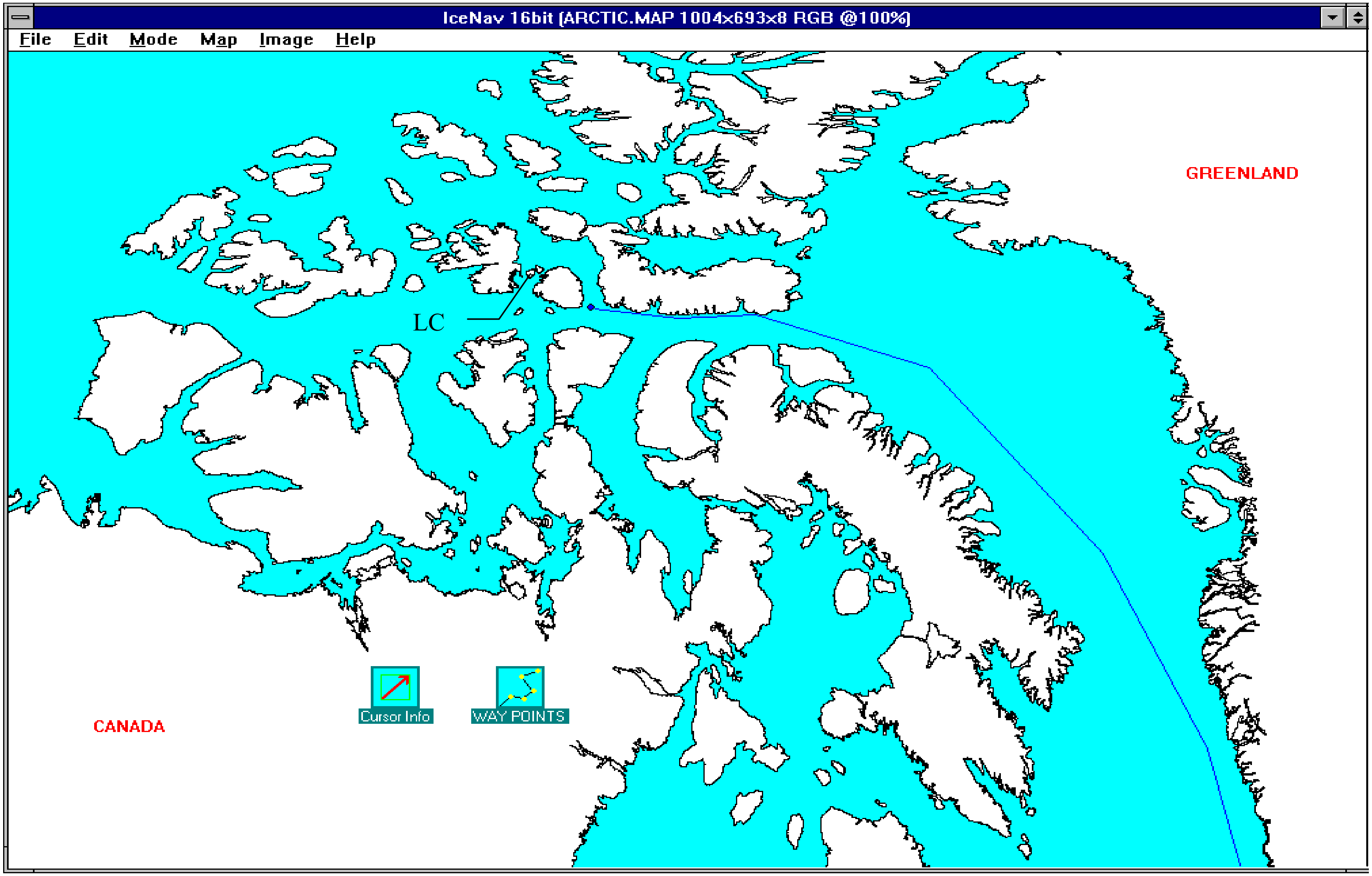

Fig 6-4 Field Trial Route - M.V. *Arctic* "Inbound" Voyage to Little Cornwallis Island

The trial involved three field personnel who traveled with the M.V. *Arctic* on its inbound voyage. These people included the Trial Navigator, a software specialist and a project scientist. The TN was responsible for completing the evaluation of the IceNav/MRI system functionality and operability as if he was using the system for actual navigation decision-making (without having the actual responsibility) as well as getting the responsible navigating officers to use the systems and provide feedback. The software specialist was on board to assist in fixing any software problems with IceNav and the SRIC, as well as to some extent, the MRI. He also assisted in data recording. The project scientist was responsible for the documentation of environmental and marine radar data collection, and to assist in demonstrating and operating the system as and when required.

During the trial, the system was functional for most of the voyage. There were some communication problems early in the voyage between the MRI computers and in receiving the GPS data, but these were soon corrected during the voyage. The major problems were in getting the MRI computers to record the radar data - various problems were encountered with the recording software in actually getting the data to record onto the tape. Complete data collection was achieved and a large amount of data was successfully recorded, and in that regard the operation was a success. Problems with software functionality were identified and fixed to the extent they could be while on board, but some had to be fixed after the field trial. These were identified in the Field Report and are not presented here, since many of these problems were subsequently addressed.

During the trial many data recording sessions were completed. These included:

- Open water small target detection;
- Sea clutter;
- Icebergs, bergy bits and growlers;
- Ice edge;
- Mixed multi-year and first year ice regimes.

The responsible navigating officers' use of the system was limited because of severe ice conditions and lack of available time to work with a clearly experimental system. However, the TN and the navigating officers filled out the Evaluation Kit.

6.3 Field Trial #2 - CCGS *Pierre Radisson*

The trial was conducted during February 1996, while the CCGS *Pierre Radisson* was providing support to ferries operating across the St. Lawrence River at Matane. The icebreaker was berthed at Matane, and provided daily escort and where required, break-out of the ferries as they navigated across the river. The operation was such that the CCGS *Pierre Radisson* returned to port each evening. This operational scenario provided an opportunity to evaluate IceNav/MRI on an icebreaker.

The schedule of ferries and required support by the icebreaker meant that, in contrast to the M.V. *Arctic* operation, considerably more time was available to the ship's navigating officers to work with the system and evaluate its functionality and operability. This also allowed the installation to occur at the start of the trial which evolved into IceNav/MRI operation when completed.

The objectives of the trial were threefold:

- Confirm and validate the performance of the latest version of the SRIC software under a variety of ice and weather conditions for a variety of operational scenarios of a Coast Guard icebreaker operating in Canadian east coast waters in wintertime;
- Evaluate the functionality and operability of the latest version of the IceNav/MRI system by navigating officers;
- Collect marine radar data for a variety of ice regimes and conditions that typify those of the Gulf of St. Lawrence and St. Lawrence River during the winter months.

Figure 6-5 shows the block diagram for the simpler IceNav/MRI installation for the icebreaker. The same configuration was used for the third field trial on the M.V. *Cicero*.

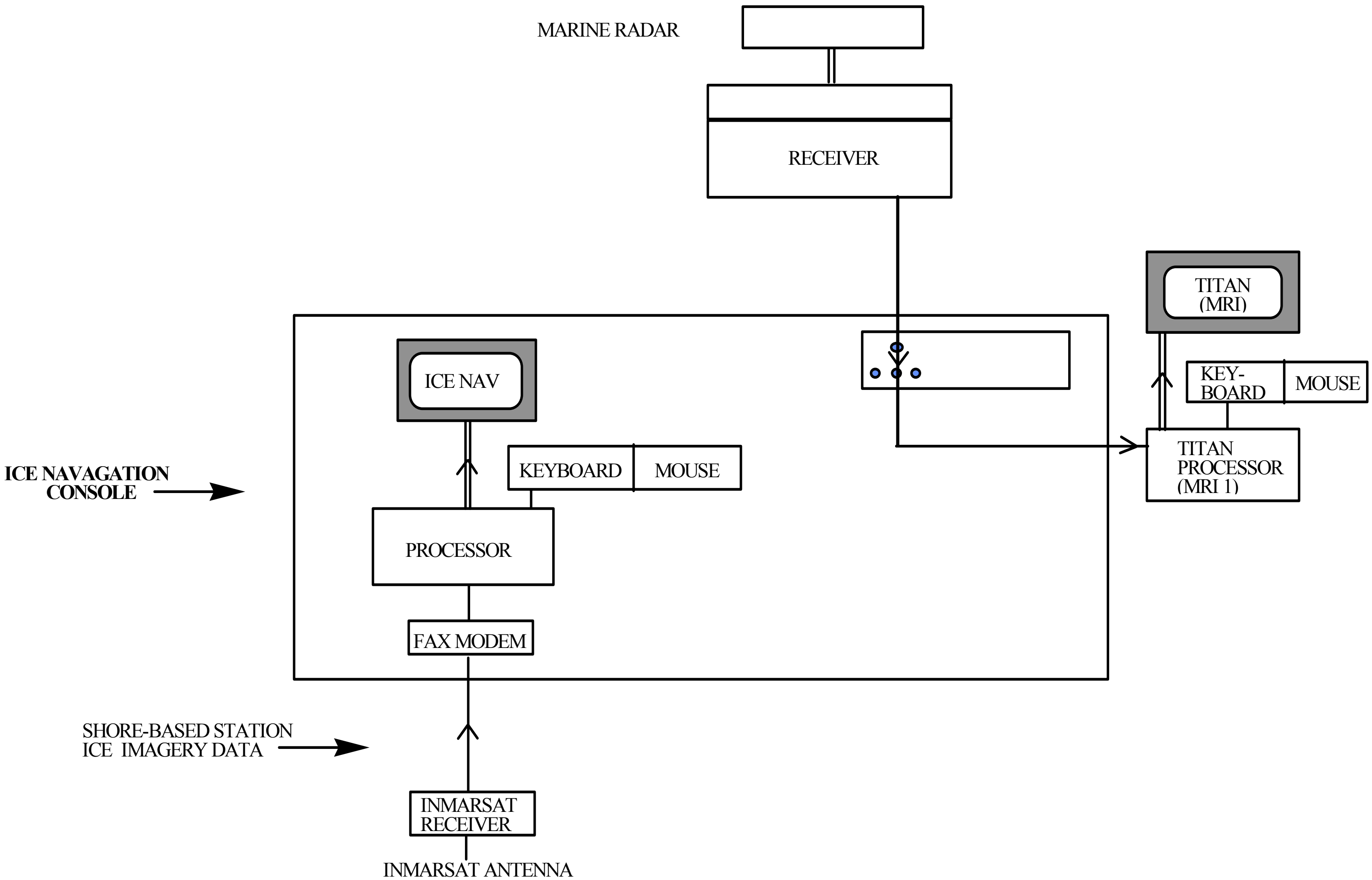

Fig 6-5 Block Diagram of the IceNav/MRI Installation

The trial commenced on February 1, 1996 and finished in Matane on February 14, 1996. It was conducted on a non-interference basis with Coast Guard operations. The trial was extended from its original five days because of considerable interest in the system by Coast Guard officers. Funding for this additional period was provided by Canarctic.

The Coast Guard operational scenario during this period for this icebreaker was limited to operations in and near the Matane harbour. Therefore, the field trial was completed for a limited variety of ice conditions and operational scenarios.

Two field personnel were deployed for the trial: a project scientist and a software specialist. Both had participated in the M.V. *Arctic* field trial. It was not necessary to have a Trial Navigator because there was more than sufficient time for the officers to test and evaluate the system.

The trial achieved the objectives of providing an evaluation of the system performance and an evaluation of its operability by navigators. The ice conditions were not as variable as expected and the area of the icebreaker's operations was limited to the St. Lawrence River. A useful set of MRI images was recorded.

6.4 Field Trial #3 - M.V. *Cicero*

An opportunity arose late in the project to trial IceNav/MRI on a commercial vessel conducting regular trade through the Gulf of St. Lawrence. The Canada Centre for Marine Communications (CCMC) and the Canadian Coast Guard were interested in a field trial concerning the transmission of MRI digital images of ice to a central facility for dissemination to third parties. In essence, the IceNav/MRI was being used as a remote sensor for the collection and dissemination of close-tactical ice information. TDC arranged to coordinate with this project, and developed a coordinated field trial using the IceNav/MRI system. The two projects were combined into the one field trial. The chosen vessel, the M.V. *Cicero* owned by Oceanex Inc., operates between Montreal and St. John's, Newfoundland. The trial was conducted between March 9 and 16, 1996. In this time, one round trip between Montreal and St. John's was completed.

The objectives of the trial were as follows:

- To confirm and validate the latest version of the SRIC software under a variety of ice and weather conditions for a variety of operational scenarios of a commercial vessel operating in Canadian east coast waters;
- To evaluate the functionality and operability of the latest version of the IceNav/MRI system by navigators;
- To collect marine radar data for a variety of ice regimes and conditions that typify the Gulf of St. Lawrence at this time of winter;
- To relay radar imagery captured by the IceNav/MRI system to CCMC to be re-distributed to other clients;

The installation of IceNav/MRI was very similar to the one completed for the CCGS *Pierre Radisson*. The same version of the SRIC software was used. The installation was started in Montreal on March 9, 1996 and completed March 10, 1996 just prior to departure for St. John's. Installation included an M-SAT terminal provided by CCG.

The field team consisted of one member from Canarctic Shipping Company with a representative from CCG. Figure 6.6 shows a map of the route followed by the vessel on its voyage to and from St. John's. The ice conditions had little influence on the choice of route since they were much lighter than average for this time of year.

The MRI radar imagery was captured and IceNav was used to relay this information via M-SAT communications satellite to CCMC who in turn sent the data to third parties via E-mail. A total of nine (9) images were sent to CCMC via M-SAT. The system proved reliable in the collection and delivery of data.

The ice conditions during the course of the trial were not as heavy as in normal years and ranged from open water to thin first-year ice. Most of the MRI data recording occurred in grey and grey-white ice which predominated the ice that was encountered by the vessel.

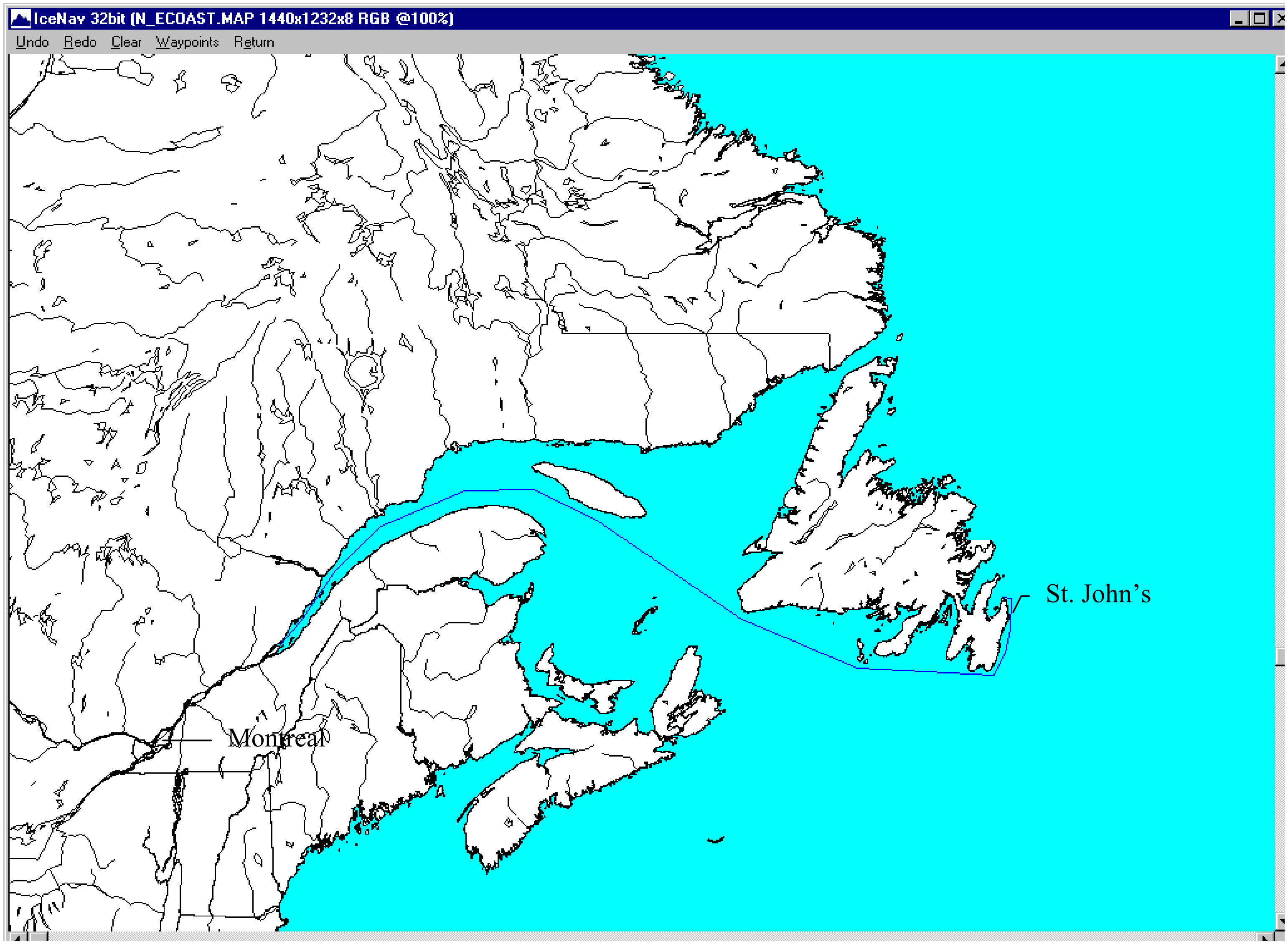

Fig 6-6 Field Trial Route - M.V. *Cicero* between Montreal and St. Johns, Nfld.

6.5 Summary of Data Recordings

Table 6.2 summarizes the data recorded over the three trials. Recordings consisted of recorded MRI images on Exabyte tape that was part of the MRI system supplied by TDC and Titan Radar. Included with the Exabyte data recordings are VHS video and photographs of the ice conditions at the time of MRI recording as well as other miscellaneous video and photographs of the ice conditions and other aspects of the field trial. These were provided separately to TDC and are only summarized here in the table.

Table 6.2 Data Recording Summary

Trial #	Ship Name	Photographs	Videos	Exabyte Tape	Written Log
1	M.V. *Arctic*	6 Rolls of 35mm colour prints labeled M01, M02, M03, C01, C02, C03	9 Sets of VHS video data. These are labeled: VPA01, VPA02, VPP03, VP04, VP05, VPP06, VPP07, VPP08, VPP09	19 sets of corresponding Horizontal and vertical Radar return imagery. These are labeled: 01H .. 19H for the horizontal data. 01V .. 19V for the vertical data.	Date, time, Sperry radar settings, MRI settings, ice and target descriptions, meteorological conditions and ship particulars.
2	CCG *Pierre Radisson*	3 rolls of 35mm colour film labeled 1 through 3.	5 VHS video tapes were filled. These are labeled 01 through 05.	9 Exabyte tapes were used in total during the field trial. These are labeled 01 through 09.	As above.
3	M.V. *Cicero*	1 roll of 35mm colour film labeled 1.	1 VHS video tape was filled. This is labeled 01.	2 Exabyte tapes were used in total during the field trial. These are labeled 01 through 02.	As above

7. MAIN FINDINGS OF FIELD TRIALS

This section presents the detailed results of the field trial and provides an interpretation and discussion. All the field trials had two primary goals. The first was to evaluate the implementation of the control functions of the SRIC. This is referred to as the **functionality** evaluation of the SRIC in the remainder of this section. The second goal was to evaluate the performance of the SRIC in use during navigation in ice. It is referred to as the **operability** evaluation in the remainder of this section. These results are reported separately below.

7.1 Sample Users Group

This section discusses the roles of the crew members who used the system during the trial. It is provided to describe and qualify the sample group of users of the SRIC for the various field trials.

On the M.V. *Arctic*, the users were in two groups - regular crew and trial navigator crew. The regular crew consisted of the Captain, Relief Captain, Chief Officer, Second Officer and Third Officer. The regular crew's primary responsibility was their regular shipboard duties; their secondary responsibility was to use the Frontier ECDIS on an opportunity basis. All crew used the system during watchkeeping duties. In addition, the Captain, Relief Officer and Second Officer used the system during navigation tasks. The trial navigation crew consisted of a trial navigator, whose primary responsibility was to operate and evaluate all the Frontier ECDIS functions. His secondary responsibility was to facilitate the operation of the system for the crew while performing their regular shipboard duties. The trial navigator made detailed and repeated use of the entire system. The primary working document of the trial was the **Frontier ECDIS Evaluation Kit**, which provided a means of capturing the users feedback. It was distributed to all crew members who used the system during the trial.

On the Coast Guard icebreaker CCGS *Pierre Radisson*, the users were the regular navigation crew. These navigators' primary responsibility was their regular shipboard duties; their secondary responsibility was to use the SRIC on an opportunity basis. The primary working document of the trial was the **ICENAV/MARINE RADAR RADAR INTERFACE (MRI) Evaluation Kit**, (Appendix D) which provided a means of capturing the users' feedback. It was filled out by two navigators who used the system during the trial.

On the Oceanex vessel M.V. *Cicero*, the user was the Captain, who used the SRIC on an opportunity basis. The primary working document of the trial was the **ICENAV/MARINE RADAR RADAR INTERFACE (MRI) Evaluation Kit**.

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7.2 Evaluation of IceNav SRIC Functionality

The emphasis in this evaluation was on the implementation of the SRIC functions installed on the IceNav for control of the MRI and the radar functions, i.e., how easy it was for the mariner to invoke and use the function without regard to the particular navigation mode the mariner was in. The procedures for the evaluations were given in the **Evaluation Kit.**

The functions are listed below by name, which appears in bold italics. The evaluation was both objective and subjective. The objective part consisted of rating each function from 1 to 5 according to whether the equipment features and method were **acceptable** for performing the function. The rating responses from all users were averaged and are given below where they are instructive. The subjective evaluation consisted of comments provided by the operators and these are in the text that follows the function name.

Use of the histogram equalization dialogue box (function modifies appearance of MRI image)
Operators preferred default settings.
On one occasion clicking on RENDER did not give any display on the graph, but radar image was modified correctly.
On M.V. *Arctic*, of no value - it would only stay on for one scan.
Acceptability = 3.8.

Use of the Ice Imagery Shift Routine
Easy to use, gave a good estimate of the derivative (change in ice position lat-long). Feature not totally in operation.
Once one chooses VIEW RADAR DATA, connection to Titan should be automatic and seamless.
Acceptability = 4.3.

7.3 Evaluation of SRIC Operability

The emphasis in this evaluation was on the operation of the SRIC while performing various ice navigation tasks. These ice navigation tasks were defined in the associated project Frontier ECDIS phase II. These tasks as well as the procedures for the evaluations were given in the **Evaluation Kit.**

The functions are listed below by function name. The evaluation was both objective and subjective. The objective part consisted of rating each function from 1 to 5 according to whether the implemented feature was **useful** in doing what it was supposed to do i.e. whether the feature was useful and operable in assisting the performance of the navigation tasks. A separate rating was made for each mode of navigation where this feature was used. The rating responses from all the users were averaged and are given below where they are instructive for the navigation mode that the rating was evaluated for. The subjective evaluation consisted of comments that the users provided. These are provided in the text that follows the function name.

Note: A conceptual rating for usefulness was given for functions that were not working. The conceptual rating was based on the function being fully implemented and functioning.

Determine amount of shift in ice using ice image and radar image on IceNav

Would be useful but extremely difficult to identify like features in ice image and radar image.
Relative scale of ice imagery (small scale to get good pixel definition) and radar (large scale to identify targets) did not allow effective matching. When matches were achieved they could be off by 3 miles.
Even in Arctic, floe shape and sizes changed too much for feature to be of much use.
Must keep in mind that shift is linear estimate only. Ice very often rotates, and feature does not show this information.
Shift between ice on image and on radar should be output in terms of direction and distance. Drift of ice can also be calculated because the times of IceNav image and radar images are known. Recording of the route taken would allow one to evaluate the drift of the ice.
Usefulness = 4.0.

Steer vessel through ice field using IceNav and Titan radar

Feature was not very useful because of poor imagery definition using BBS imagery, and limited useful radar range of MRI (not more than 9 n.mi.). Useful in reduced visibility, otherwise navigators rely on visual.
Useful in big floes, but small and medium floes still need to be done visually.
Usefulness (conceptual) = 3.3 for Tactical Navigation.

Use range ring markers on radar image

Usefulness = 3.7.

Use OSCFAR

Not good in ice field, makes image homogeneous which obliterates small targets. Useful in heavy sea clutter. Good in open water with limited returns.
Usefulness = 2.6.

Use pulse filter

Reduces erroneous targets drastically. Usually left on.
Usefulness = 3.5.

Use scan averaging on radar image

Of value when differentiating between heavy multi-year and first year ice. In consolidated ice, optimum value = 4. In ice field rubble, optimum value = 8 or 16.
On M.V. *Arctic* change had to be done one increment at a time - not acceptable.
Usefulness = 4.0.

Change update rate on radar image

Navigators prefer rapid update rate - reassures navigator that image is updating and that image is truly near real time.
Usefulness = 3.7.

Change range control of radar

Vital feature. No short range was available (minimum range = 9.0 n.mi.) Useful ranges are 1.5, 3.0 and 6.0 n.mi., not useful above this. Most useful range = 3 or 6 n.mi. for identifying thin ice, and 3 n.mi. in fields of new ice and multi-year ice.
Difficult to use on M.V. *Arctic* - change had to be carried out on Titan computer plus IceNav plus Sperry.
Usefulness = 3.5.

Change gain of radar image

Not tested. Gain control on radar unit used instead.
Usefulness (conceptual) = 3.5.

Change contrast on radar image

Usefulness = 3.0.

Change value of 1 bit threshold of radar image

Usefulness = 3.0.

Change to night view mode for radar image

Not useful on M.V. *Arctic* - would only stay on for one scan. Evaluated on M.V. *Cicero* trial.
Usefulness = 4.0.

Perform histogram equalization to improve colour display of weak radar images.

RENDER command is useful, however the result appears to change from one day to the next, and the user doesn't know why. Not demonstrated on M.V. *Arctic* trial.
Usefulness = 3.7.

Detect small ice hazards on radar image

On M.V. *Arctic* trial, feature was not demonstrated during Close-Range Ice Hazard Detection (CRIHD) because a target spotted at long range could not be tracked coming into short range. Radars were not suitable. AMR (Arctic Marine Radar - Sperry) - tracking depended on transceiver performance. Titan radar processor operating on Sperry data gave no return from small objects. ARPA on ship's radar (Decca Bridgemaster) not working. Would be useful if implemented correctly.

On CCG trials, image from ship's radar (Sperry 3400) was superior to the Titan. Titan radar shows the potential for being very good for ice identification, but at the present state of development it cannot replace conventional radar. More software controls should be added to the Titan to make it similar to conventional radar. The ARPA capability of the Sperry 3400 made it more useful than the Titan. Detection of small targets on *any* radar is difficult - depends on transceiver performance and external factors such as weather, sea swell, etc.
A good visual lookout is still a better method of doing CRIHD than using a radar.
Usefulness = 2.3.

Determine ships position with respect to land or ice using MRI radar

Very poor image on MRI display. Range and bearing controls must be fitted before position fixing can be done effectively. A useful feature if it worked.

Fixing position with respect to land - Usefulness = 2.3.

Fixing position with respect to ice - Usefulness = 2.8.

7.4 Feature Comparison

An additional evaluation of the SRIC's usefulness was obtained by comparing the old method without MRI to the new method with the MRI for performing the navigation task. The methods for these evaluations were outlined in the **Evaluation Kit**. The evaluation consisted of two sets of ratings from 1 to 5, one for the previous method and one for the new method. The difference in these ratings gave an indication of the usefulness of the MRI towards improving the mariner's performance on the bridge. Separate ratings were obtained for each navigation task. The measurements foe each task were then averaged for all operators.

Table 7.1 - Comparison of Ratings for Navigation without MRI to Navigation with MRI

Item	Nav Task	Description of Condition	Rating
Compare location of MRI radar image inside/outside IceNav screen	TP	radar image on window in IceNav radar image on separate display	3.8 3.3
	TN	radar image on window in IceNav radar image on separate display	2.7 3.7
Compare OSCFAR function for target detection	TN	OSCFAR off OSCFAR on	3.3 1.7
Compare scan averaging function at optimum value	TN	Scan averaging off scan averaging on	2.5 4.0
Compare benefits of using MRI radar in detection of hazardous objects	CRIHD	without MRI radar with MRI radar	4.5 2.8

TP: Tactical Planning
TN: Tactical Navigation

7.5 Additional Comments and Observations

Comments common to all trials

The users readily understood the benefits of using the marine radar data in conjunction with the ice imagery depicted on IceNav for navigation in ice covered waters. These benefits are due to two primary features. Firstly, the marine radar data shows the pattern of the ice in the immediate vicinity of the ship, while the imagery on IceNav shows a similar though much larger view of the ice pattern extending as much as 200 n.mi. from the ship. By matching the radar's ice pattern with a similar pattern on the imagery, the ship can be located on the ice imagery. This allows the ice image to act like a marine radar image which extends to 200 n.mi. from the ship and allows route planning through the ice to be performed on the ice imagery. Secondly, the two different images represent the ice pattern at different times since the marine radar image shows the present position of the ice (via the ship's lat long position at the centre of the image), while the IceNav image shows the ice cover at an earlier time when the data was collected. This enables the system to be used to determine the drift in the ice.

Realizing this utility, the operators suggested various functions which would increase the navigational utility of the system. Many of these features involve the integration of the MRI radar and IceNav with electronic charts. This is best realized by integrating the SRIC and IceNav with an ECDIS, which is the subject of the Frontier ECDIS project. The important features suggested by the operators are listed below. All have been previously identified in the Frontier ECDIS project and are being evaluated there.

- ability to provide complete route planning functions on the IceNav image;
- ability to use Titan radar for navigation by adding more software controls similar to those found on a conventional radar;
- creation of an IceNav user interface which does not intrude on the use of IceNav, i.e. eliminate dialogue boxes which cover the ice images, minimize permanently open dialogue boxes, put most operator control selections at the bottom of the image;
- ability to record the route taken on the IceNav image;
- ability to append notes generated by the navigators to the image, for instance to note information like preliminary analysis, Captains' orders, information on conditions, etc.;
- ability to import route plans from an ECDIS.

During these field trials, the operators used the system as a tool to determine the amount of shift in the ice using the ice image on IceNav and the marine radar image. In the trials conducted by the CCG and Oceanex, it was found that in the St. Lawrence River, it was extremely difficult to identify the ice pattern on the IceNav image with what was seen on the radar when it was brash ice, which therefore limited the utility of this process. Also, the ice situation in the river changes very quickly with changes in wind and dramatically alters the ice image. In the Gulf of St. Lawrence, the ice situation is more stable, and the tool was more useful. On the other hand, in the Arctic, the ice floes are well-defined, and the navigators predicted that the system would be more efficient and useful there. There is also more information and support available in the Gulf and the St. Lawrence River, and the *Cicero* commented that this system was not necessary in those regions. In the Arctic, however, mariners are more isolated and there is a greater need for sophisticated systems such as the SRIC.

Comments during M.V. *Arctic* trial

Further refinement of the HV (vertical) radar channel is required. HV of little value in open water. Could not easily pick up large icebergs or southern Greenland coast. Never saw a bergy bit. HV valuable in pack ice for delineation of MY areas, and very good at showing interface between MY ice and new/first year ice in snow cover. HV required maximum gain on Sperry radar most of the time.

Too much time required "fiddling" with controls to get usable image - navigator doesn't have that much time. Quicker and easier to switch back and forth between HH and HV on Sperry.

Changes to parameters were not secure - operators weren't sure if change desired had actually been achieved. Time taken to refresh screens after each change far too long - navigator cannot spare that time.

Once a good image is achieved it is of definite value in pack ice.

Comments during C.C.G.S. *Pierre Radisson* trial

Officers expressed a strong interest in the IceNav/MRI system, and it was appreciated for its ease of use, making it possible to be utilized by all the navigating officers and not just specially trained operators.

Officers clearly expressed the need for a navigating tool as opposed to an image analysis tool.
Officers stressed the need for route planning functions to allow for multiple routes, absolute routes, more editing of routes and waypoint catalogues.

SRIC user interface should be more intuitive. Connection to the MRI image should be more automatic than presently configured.

Comments during M.V. *Cicero* trial

Ice conditions were not as heavy as in normal years and ranged from open water to thin first-year ice. These conditions were not really severe enough for the captain to give a proper evaluation of the system.

Most of the MRI data recording occurred in grey and grey-white ice. The marine radar was able to quite reliably distinguish grey from grey-white ice and open water from grey ice. Floes of thicker first- year ice were clearly evident amongst grey and grey-white ice covers.

Reactions of ship's navigating officers to the IceNav/MRI system were very similar as compared to the CCGS *Pierre Radisson*. An additional request was to enable route planning on ice charts and facilitate the ability to overlay ice chart on ECDIS display.

7.6 Summary of Main Findings

The SRIC was used in ice navigation tasks, and the controls were exercised during this evaluation. The evaluations successfully demonstrated the concept of the use of the SRIC in ice navigation.

All control features of the system were exercised over their ranges, and in the different operational modes and all were found to be useful. The mode(s) in which each control was useful was observed and recorded through analysis of the mariners' responses in the Evaluation Kits. In certain cases, the values of the settings along with the conditions that apply, were recorded. The operational modes included open water with limited returns, light and heavy sea slitter, consolidated ice field, mixture of young ice and multi-year ice, etc.

The implementation of some features and controls was found to be inadequate and further work on these is required before they can be considered complete. These items are as follows:

- Ice imagery shift routine - routine not fully implemented. Further implementation would consist of automatically adjusting the scale of the ice image to match the radar range setting. The officers also prefer to know the offset as a direction/distance as compared to the present method which is delta lat./long. It would be useful to semi-automate this process so that the user can click on three or four identifiable ice features on both images and the system automatically calculates the offset as a direction/distance that is displayed upon completion of the task. The routine would be complete if the system then shifted the ice image by the calculated amount.

- Determine amount of shift in ice using ice image and radar image on IceNav - difficult to identify like features on the images due to differences in scale;

- Steer vessel through ice field using IceNav and Titan radar - usefulness limited in part by poor definition of BBS imagery. Usefulness was also limited by the fact that in order to adjust the radar range it is necessary to change the settings in three locations: the marine radar itself, the MRI computer and in the IceNav SRIC software. This made the system awkward to use, especially when radar settings had to be frequently changed in varying ice conditions.

- Perform histogram equalization on radar images - result of operations appears to be inconsistent and not always beneficial;

- Detect small ice hazards on radar image - target spotted at long range could not be tracked coming into short range on radar.

It is recommended that these operability issues be investigated, and the deficiencies should be corrected or improved upon. The revised system should then be submitted to another field trial in which it is subjected to extensive use. The emphasis in further evaluations of the system should be on plenty of use in ice navigation common situations. More software controls and features should be added to the SRIC operator interface on IceNav to make it similar to a conventional radar; for example, the addition of range and bearing control. The result of this process should be a system which is simple, effective and user friendly, and will be used by the mariners.

It was also apparent that the detection of small ice objects on the Titan radar was not as good as on the other radar units on the vessels. For instance, on the CCG trial, the image of the ice from the ship's radar (Sperry 3400) was superior to the MRI-supplied image on IceNav. Together with the ARPA on the Sperry 3400, this radar was superior and this opinion was expressed by the mariners using these systems. Detection of small targets on any radar is difficult since it depends on external factors such as transceiver performance, weather, seaswell, etc.; however, the MRI/Titan radar showed the potential for being very good for ice identification. More development of the MRI itself will be required on both the single channel and dual channel versions of the system. In order to realize this potential these developments should include:

- compensation for the external factors mentioned above;
- image processing algorithms to enhance detection of the critical ice features.

It would seem that the SRIC was more useful in the Arctic than the Gulf of St. Lawrence. In the Gulf, the availability of other sources of information and timely icebreaker support means that the mariner places less value on more advanced ice navigation systems which cost money. However, should the situation change where information and icebreaker support begin to cost substantial money to access and use, the value of ice navigation support systems such as SRIC in Icenav will become more apparent as these would lessen dependence on these outside services.

8. CONCLUSIONS AND RECOMMENDATIONS

The Phase II development of the Shipboard Radar Interface Component was completed successfully. The SRIC was developed, tested and evaluated in several different operational situations and different ice conditions. The interest and participation of the Captains and navigating officers on all three ships was excellent. Their feedback allowed the development team to focus on the highest priority developments during the course of this phase of development, and provided development priorities for the future. There is no doubt that the concept and development of the SRIC is welcome by the navigating officers as a valuable addition to Ice Navigation Support Systems (INSS). The first conclusion is as follows:

1. **The development of SRIC has been validated through the field trials. SRIC can be considered an important component of an Ice Navigation Support System because it ties together the marine radar with remotely sensed imagery from aircraft and satellite.**

   Much was learned from the feedback of the Captains and navigating officers from the three trials. The project schedule allowed the team to respond to the results of the first field trial by using the results from the first trial to plan and execute the second period of software development. The other two field trials occurred late in the project, and the team was not able to make requested changes in the time or resources available. However, the many comments and suggestions have been noted and will be used to plan further development efforts.

   Although the development has been successful, there remain many issues to be addressed before an operational, robust system can be realized. The key complaint with the system as it now exists concerns the responsiveness and operability of the SRIC interface. Operability is fundamentally important. Ease of use and rapid response are vital for extensive use in ice navigation. The number of steps and operations to complete a function must be reduced and streamlined. Unless these issues are solved, the use of the system will not be advanced enough to sustain any position in the suite of navigation support tools available to the ice navigator. He/she will simply rely on existing systems which are familiar and reliable. IceNav/SRIC must “find its place” and this will require more work to simplify the operability of the functions of the system.

The second conclusion from the project is as follows:

2. **The responsiveness and operability of the SRIC interface needs considerable improvement by way of reducing the number of steps to perform functions and simplifying the user interface. This will be required before the system will be used routinely by the Captains and navigating officers.**

The field trials were conducted on three different vessels operating in three very different operating environments. The trials represent a sufficient testing of the IceNav/MRI system as presently configured. Therefore it is concluded that:

3. **The project successfully tested the IceNav/MRI system over a wide range of ice conditions and operational environments that are sufficiently representative of the situations in which the system will have application for ice navigation in Canadian waters.**

During the field trials considerable effort was spent in the collection of marine radar data and associated environmental information. The recording system for the MRI worked adequately for the purpose of recording the imagery, although some limitations on the number of recorded images on an Exabyte tape were encountered. This was a limiting factor in the first trial on M.V. *Arctic*, but proved to have limited impact for the other two trials. It is evident that the MRI recording system was sufficient for limited recording, but suffered some limitations in an ambitious program of ice data recording. In future data collection efforts, it is important to ensure in advance that the recording system have sufficient capability and capacity to perform this task.

In the context of the marine radar data collection effort, the project was very successful in collecting a wide suite of marine radar images of various ice regimes in several geographic areas. Therefore it is concluded that:

4. **The field trials collected a considerable quantity of recorded marine radar images over a wide range of ice conditions that can be used for the subsequent development of image processing and analysis algorithms.**

It was evident from the feedback of the field trials that the development of SRIC is valid, and has the potential to become a part of every INSS. The project is on the right track towards a successful and hopefully commercially viable system. However, further work is required in order to ensure long-term, sustained utilization of this system which, in terms of its intended purpose and demonstrated functionality, met many of the needs of the ice navigator. This work is needed to ensure the system can become commercially viable, rather than a continuing, perhaps never-ending development.

In this respect, the needs of the navigator come to the forefront. Operability is the highest priority issue. The system must be intuitive to use, and require a minimum of operator intervention and manipulation. For commercial operators, it is apparent that:

5. **The SRIC in Icenav meets many of the functional needs of the ice navigator; however, further work is required to make the system simpler to use and more responsive. The issues of operability and to a lesser extent functionality need further attention before the system development can be considered complete.**

This conclusion leads to a number of recommendations for improvements in system operability and functionality. Requested improvements to the existing IceNav/MRI system can be classified into improvements in IceNav, improvements in the MRI and improvements in the SRIC. The issues to be addressed can be subdivided into functional ones, i.e. add or improve a given feature of the software or user interface ("**functionality issues**") and operational ones, i.e. improve how the function is implemented or accessed or used by the user ("**operability issues**"). The following is a compendium of conclusions and recommendations for further work from the results of the three field trials. They are listed in order of priority, but it is expected that most, if not all of them, should be undertaken to complete the development such that the system will be used operationally by ice navigating officers.

IceNav Operability

1. Add function in IceNav to be able to determine range and bearing between *any* two points, either on the ice image or the radar image. This function could be used to measure the size of ice floes.

IceNav Functionability

1. Make the system even easier to use. Reduce the number of operations to complete a function. For example, one button image optimization.
2. Split the screen so that it would be possible to view more than one image at a time, e.g. ice image and radar image.
3. Examine ways to provide better night view capability for the screens as they are too bright. Devise other colour schemes besides monochrome grey scale.

SRIC Operability

1. Provide a heading indicator for the marine radar display in IceNav.
2. More work is required on the orientation of the MRI radar image in IceNav. It would be more useful if the MRI image could be set to be displayed in "north up" or "ship's head up" mode.
3. The MRI unit suffered memory leaks on all three trials when radar images were being displayed on IceNav. The MRI computer had to be rebooted regularly to overcome this limitation which is not acceptable in operation.

SRIC Functionality

1. Provide SRIC with a faster response time from commands issued in IceNav. Operator commands issued on IceNav take too long between invocation and the appearance of the result on the IceNav image.
2. Simplify the SRIC user interface so that it has the look and feel of a regular radar user interface.

The M.V. *Arctic* field trial offered an exceptional opportunity to test the concept of Frontier ECDIS which is a system that links ECDIS with an INSS. This trial coincided with the IceNav MRI trial and provided the opportunity to view the three systems in operation for the first time. The MRI and ECPINS had separate interfaces to IceNav which were independent of one another, but IceNav was the common system between all three.

Although this development consisted of IceNav and the MRI on separate computers connected by an Ethernet link, this configuration is expensive and complex. The following recommendation is made:

6. An investigation should be undertaken to evaluate the feasibility of putting the MRI hardware and software functions into the IceNav computer, providing a simpler, faster and cheaper combined system.

It will be advantageous in many applications to put the MRI hardware (two printed circuit boards from Titan Radar International) plus software into the IceNav computer provided that this configuration functions properly. The resulting system would be cheaper and simpler, requiring one less computer and no network. Both the IceNav software and the Titan Radar software are designed for a PC so are compatible in the same computer; this is a very **strong** advantage.

Although SRIC and Frontier ECDIS were developed independently, the field trial met the objectives of both projects. Through the Trial Navigator (TN), the three systems were examined together in the context of ice navigation support. All three systems support, in varying ways, <u>*all*</u> the elements of passage and route planning in ice at the strategic, tactical and close-tactical levels. In our opinion, the union of all three systems will complete the development of an Ice Navigation System that supports all three levels of navigation decision-making. We therefore recommend:

7. Development of an Integrated Voyage Planning and Ice Navigation System that encompasses IceNav (32 bit technology), with the SRIC software and MRI hardware in the IceNav computer according to recommendation 6 and networked with a fully functional, simple user interface. This development should focus on making the

system operable by minimizing the number of steps required of the operator to perform required functions.

The proposed system would perform several functions for the Arctic Navigator:

- passage planning;
- strategic route planning;
- tactical route planning and updating; and
- close-tactical routing and course adjustment.

The system could also incorporate an electronic version of the Passage Planning Manual, now in draft final form for Transport Canada, as well as a real-time version of the Tanker Navigation Safety System so that the risk of specific chosen routes could be an input to passage and strategic route planning.

The Integrated Voyage Planning and Ice Navigation System should be modular in nature so that each of the three ice navigation systems involved, IceNav, MRI and ECDIS can operate singly or in combination with one, two or all three systems. This approach recognizes the fact that the commercial marketplace may not require all three systems or be willing to purchase them.

The integrated system will be the culmination of ten years of effort and will keep Canada at the forefront of Arctic navigation technology development. It combines two technologies in which Canada has world leadership — IceNav and ECDIS with a third technology, the MRI, in which Canada is highly competitive. It will allow Canada to provide leadership in the development of circumpolar rules for navigation in ice.

9. REFERENCES

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Appendix A

Functional Requirements Document

ICENAV SHIPBOARD RADAR INTEGRATION PHASE II

FUNCTIONAL REQUIREMENTS DOCUMENT

SEPTEMBER 28, 1995

PRESENTED TO:

TRANSPORT CANADA
TRANSPORTATION DEVELOPMENT CENTRE
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MONTRÉAL, QUÉBEC
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1.0 PROJECT OVERVIEW

The objective of this project is to develop, within Canarctic Shipping Co. Limited's Ice Navigation System "IceNav", the capability to interface with the Modular Radar Interface Unit (MRI) manufactured by TITAN Radar International Inc. and provide the functionality to use and manipulate the shipboard radar images to support ice navigation.

Concurrent with this development, TITAN Radar International Inc. will be developing the MRI unit under a separate contract with TDC.

2.0 INTRODUCTION TO TASK 2

The purpose of Task 2 was to produce the Functional Requirements Definition for the Shipboard Radar Input Component (SRIC) based on work during Phase 1.

The purpose of the Functional Requirements Document is to define the SRIC and outline its functional and user requirements. The Document is intended to serve as a functional, or conceptual definition of the SRIC component of the system. It will serve as the basis for the software design.

3.0 BACKGROUND AND RELEVANT PREVIOUS WORK

In order to insure that this document included all of the necessary functional requirements, the following documents and information were reviewed:

- Functional specifications resulting from the Second Generation Ice Navigation Support System (G2) development
- Results from the High Resolution Image Transmission to Ships project
- Recent availability of powerful and inexpensive computer stations (486 and PENTIUM based) that can support a navigation system's functionality
- Availability of Global Positioning Satellite (GPS) which simplifies the positioning process to a large extent (92/93)
- Planned discontinuation (1995) of Atmospheric Environment Service's (AES) Comprehensive Ice Reconnaissance Service (CIRS) performed by Intera Technologies and its replacement by the RADARSAT satellite
- Availability of ice imagery and ice information by a dial-in BBS service (1995/96) to replace the direct downlink of airborne SAR data
- Revised Canadian Coast Guard (CCG) icebreaking services strategy and government budget cuts throughout
- Prevailing economic conditions which preclude the acquisition of expensive ice navigation equipment by commercial operators
- Emerging Electronic Charting and Display Information Systems (ECDIS) technologies to which an Ice Navigation System will have to interface
- Development of the Hibernia Oil Field which will result in the apparition of new commercial operators with specific ice navigation requirements

The above research exercise is reported in the following sections. The results of the research are folded into the Operational Requirements given in Section 4.0, and the User Requirements given in Section 5.0.

3.1 Computing Technology and Economics

During the era of the SINSS/G2 development, detailed and complex systems were envisioned in order to integrate the marine radar, the primary ship ice navigation tool, with the airborne Synthetic Aperture Radar (SAR) in a complete ice navigation system (Gautier and Gorman, 1990). These plans included the acquisition of large and expensive hardware systems with complex software development requirements for system functionality control. The current economic situation now precludes the acquisition of such expensive and complex systems by commercial, as well as government (i.e. Coast Guard), operators. The recent availability of powerful and inexpensive personal computer stations (486 and PENTIUM based) which can support an ice navigation system's functionality and the future evolution of these systems make them the logical alternative to previously envisioned complex, expensive, and non-portable systems.

Additionally, government cutbacks and changes in data and information acquisition and distribution policies (discussed further below), both within the CCG and AES, the primary providers of icebreaking and ice information services respectively, have an impact on ice navigation systems development. There is the potential increased desire for many ships and shore-based users to have access to high quality ice information at an affordable cost and to be able to use it effectively (Gorman, 1994), particularly in light of the Hibernia Oil Field development which should result in new commercial operations with specific ice navigation requirements. This will become increasingly apparent in the years to come with decreased support from government icebreakers for navigation assistance due to budgetary restraints as well as increased demand from government regulators and insurers for safer vessel transits through ice covered waters.

3.2 Data and Information Sources

The imminent discontinuation of the airborne SAR program planned by AES and its replacement with the RADARSAT satellite as a primary data source for acquiring ice information has a significant impact on the ice navigation systems development. Direct downlink of SAR data on an "as needed" basis as originally identified during G2 development will no longer be the primary mechanism by which high resolution image data will be received on board a vessel to aid in ice navigation. Instead, vessels operating in ice will require the capability to access bulletin board systems (BBS) via dial-in communications channels, most likely using satellite communications and/or cellular telephone systems technology, which are also advancing at a rapid rate. There are many aspects of these changes which are relevant to ice navigation systems development including: spatial and temporal resolution of RADARSAT image data, cost and coverage of data communications, data compression methods, and the processing and handling of data by shore-based stations prior to transmission to ship.

Based on work as part of the TDC-sponsored project, Shipboard Reception and Use of High Resolution Imagery Products, most of the ice features used in tactical navigation that are identifiable on the marine radar can be identified with SAR data of 100 m pixel resolution that has been subjected to a lossy compression (Gorman and Flett, 1994). However, for certain difficult navigation situations it is considered necessary to have data of 25 m available. RADARSAT will be able to meet these resolution requirements. However, current planning for ice surveillance using RADARSAT is to utilize only the 50 and 100 m resolution modes of data acquisition. Thus, these data may be insufficient to perform accurate feature correlation with the marine radar for certain navigation situations. In terms of temporal resolution, RADARSAT can provide daily coverage of the Arctic using the 100 m resolution SCANSAR Wide mode. However, if other data acquisitions and modes are requested, this complete coverage may not be achieved and a ship operator may or may not have "immediate" access to the appropriate data they require, either in terms of geographic coverage or spatial and temporal resolution.

Communications systems are already in place which facilitate the acquisition and distribution of ice information, image or otherwise. INMARSAT is currently used to perform data transfer from shore-based stations to ships but it is costly and does not provide complete geographic coverage and stability, particularly at higher latitudes. Several communications satellite technologies are on the horizon which must be closely monitored to determine the most efficient and cost-effective means of data communication. The processing, handling, and presentation of data by the shore-based stations is also important as image quality must be preserved such that the data are useful when received on the ship. These developments coupled with recent and ongoing work in new and alternative image data compression methods will serve to maximize the effectiveness of data communications in an ice navigation system.

Similarly, the introduction of the GPS navigation system has enabled highly accurate geopositioning data to be available to manufacturers of navigation equipment, and ultimately the mariner. As the system becomes more and more operational, its performance becomes better. When the system was first implemented, there were not enough satellites in orbit, and the user in the Arctic frequently had to receive data from a satellite that was too low on the horizon to provide accurate data. At the present time, the full compliment of 24 satellites is in orbit, and there are at least 3 satellites in view at any moment in time at any point on earth. A user may purchase a receiver unit, and receive reliable geo-referenced positioning information virtually anywhere in the world. The positioning information available with a standard receiver (normal GPS mode) is accurate to within 100m 95% of the time. In differential GPS mode, the accuracy can be as high as 3 to 5m 95% of the time. Differential GPS mode may be used if the receiver is within range of a differential transmission station. These receivers are now very cheap, and their price/performance ratio will become even more favourable in the future. Differential transmission stations are typically set up by the various national Coast Guard institutions. They have a range of 200 to 300 nautical miles. The deployment of these stations is going on all over the world. It is anticipated that by mid-1996, all of the coastal US up to Alaska and all the Canadian shoreline except the Arctic will be covered by DGPS service. The Arctic will not likely be covered by DGPS service for some time to come, primarily because of the cost of setting up the differential transmission stations. However, standard GPS is available throughout most of the Arctic and is quite sufficient for the majority of the shipping in the Canadian Arctic, primarily because most of the shipping lanes are in deep water.

3.3 Marine Radar Development

Canarctic, in conjunction with other groups, has been at the forefront of developments in advanced marine radar technology for ice detection. Major improvements included TDC-sponsored development of a real time bright display of the marine radar screen (MARINE-VUE) with some control on the radar range settings as well as the gain and offset of the radar display independent of the radar display used for navigation (Gorman, 1989). Also, DFO-sponsored research on the use of dual polarization with the standard X-band marine radar as a means of differentiating between old and glacial ice in a first-year ice cover resulted in Canarctic purchasing and installing a dual polarized system (Arctic Marine Radar) as the operational system on the M.V. Arctic in 1989 (Gautier, 1990). Performance requirements of marine radar for ice navigation are unique and considerably different from normal open water navigation and have focused on the concepts of useful range and display aspect (Gautier, 1990). The radar is primarily a short-range aid and is useful to a maximum of around 6 nautical miles for ice navigation.

Several aspects of navigational operations using the marine radar have been evaluated previously and influence the definition of the functional and user requirements. These include: cross-polarization processing, filtering and enhancement techniques, SAR correlation, display orientation, georeferencing, automated tracking, precise positioning, configuration and control, and layout (Gautier and Gorman, 1990; Gautier, 1990). The cross-polarized radar images, as noted above, highlight and convey different but related information to assist in the detection of hazardous ice features. Work is being done investigating how to optimally combine and enhance the different signals to extract the most useful information, beyond simply displaying them separately. Alternative and advanced methods of signal processing, such as those used in the

TITAN radar system, offer enhanced detection of hazardous ice features. Other methods involving image and signal processing of the radar channels is also under investigation.

Correlating the SAR data with features identified on the marine radar is, as mentioned previously, the primary means by which close-range tactical navigation is performed. Thus, the ability to enhance and extract various features from the radar in order to overlay and/or correlate them with the SAR data is desirable. This correlation exercise requires knowledge of the position, scale, and orientation of the radar image and the ability to update the ship's position once correlated with the SAR. Full control of the radar image orientation should be available (i.e. ship's head up, north up, SAR orientation, etc.) dependent on the navigation situation and task (eg. open water hazardous ice detection, ice covered, etc.). In most cases in the future, remote sensing image data, RADARSAT or others, will be georeferenced and probably geocoded to facilitate positioning and orientation. This is important to be able to determine both relative and absolute positions of features within the imagery and on the marine radar. Once the radar and imagery are properly correlated it is necessary to have automatic updating of a ship's position in the imagery with active range and bearing updates. Precise positioning information and updating will be possible with current GPS technology which is readily available. Additionally, the capability of interfacing with emerging ECDIS technologies will also require precise and accurate update of position information. All of the above mentioned types of features are already partially implemented or planned to be implemented in IceNav. In particular, the ever important marine radar data acquisition and correlation with ice imagery will be possible because of the MRI.

3.4 Phase I Summary and Results

During Phase I no integration was done with the MRI. Instead Canarctic demonstrated the feasibility of using Client Server Technology in a Marine Radar context. This was done by simulating an MRI in software and demonstrating that data and commands could be sent over the network to a server application. This simulation was performed by using Remote Procedure Calls directly.

4.0 OPERATIONAL REQUIREMENTS

Fig. 4-1 illustrates the MRI in the context of an IceNav system. IceNav gets its data from a multitude of sources. The aircraft downlink provides SAR/SLAR data while the INMARSAT modem link permits IceNav to transfer and process the image and other data sets that the Data Provider make available. The ECDIS link provides IceNav the ability to exchange route plans and visually compare the routes planned in ice imagery with the safety depth and shore contours. The MRI shall make the radar data available to the IceNav system.

From an operational viewpoint, a user must be able to use the IceNav/MRI system in a variety of conditions and ways. This includes the following navigational scenarios:

- Open Water;
- Consolidated Ice;
- Dynamically Varying Ice Conditions.

And of course, it goes without saying that these scenarios are affected by weather conditions and visibility during daylight or at night.

4.1 Open Water

During open water navigation the IceNav/MRI's small target detection capability can assist the user to detect dangerous icebergs and bergy bits.

4.2 Consolidated Ice

In spring time when the ice is consolidated, navigation can be hampered by even a thin layer of snow. Although the HH radar signal can be used to detect leads in the ice, only the HV signal can supply the information necessary to discriminate between "hard" multi-year ice and the "soft" new ice. The cross polarized HV radar signal together with the MRI and SRIC software will assist the operator in determining the location of the old ice which he can then avoid.

4.3 Dynamically Varying Ice Conditions

To make the ice imagery more useful as a planning tool, fairly accurate estimates of ice drift in the original ice imagery should be available. The MRI and the SRIC software will make this possible. In this situation, a user must correlate the geo-coded ice imagery that he as received from the various sources to the actual dynamically varying ice conditions. The only real-time information source is the marine radar. The MRI will make the marine radar imagery available by making a digitized geo-referenced image available to the IceNav system. The SRIC will make use of this data by allowing the operator to perform position fixes on the radar and ice imagery thereby determining the ice drift. Route planning can then be performed relative to ice floe drifts. The safety contour and shoreline from ECDIS can validate routes picked in the ice floes.

4.4 Cross Polarized Radar Signal Selection

In cases where there is a cross polarized radar available, a facility should exist to permit the operator to switch between the polarized and non polarized channels. This will assist the operator to quickly discern between old and new ice types by viewing the cross polarized channel.

4.5 Operator Interface

The operator interface for the SRIC will be the Microsoft Windows type interface on the IceNav monitor together with a keyboard and mouse. The window dialogues, menu bars and buttons, etc. Which are already a part of all MS-Windows applications will be very familiar to anyone already using MS-Windows programs. The SRIC software will be implemented on the IceNav computer on the MS-Windows NT Platform.

4.6 Communications

The communication system between the IceNav and the Titan for both control and data signal flow will be an *ETHERNET* network system. Communication shall be maintained via RPCs above the TCP/IP protocol. In addition, *WINDOWS* sockets may be used.

Data

A description of the data that will be communicated from the MRI to IceNav is as follows:

- Bit Map Image Data
- The image data is to be received in *Windows* bitmap format.
- Max 1024 x 1024 pixels
- Bitmap specification: Monochrome, 0/1 bitmap
- RawPolar Data
- Projection Data
- X,Y pixel scale

- X,Y position of ship
- Image Orientation

Data Processing
- Range and Bearing
- Brightness and Contrast of Image

Commands

A list of the commands from the IceNav system to the MRI that will be implemented is as follows:
- Set radar online/offline
- Set range
- Set scan to scan mode
- Set OSCFAR mode
- Set bitmap attributes
- Set 0/1 bitmap threshold
- Set polar data attributes
- Set sector
- Set update rate
- Set data width or dynamic range (for 8 bit data)
- Set test pattern
- Set automatic gain control
- Set manual gain/offset
- Set stream to tape mode

Telemetry (Status)

A list of the telemetry commands from the MRI to the IceNav system that will be implemented is as follows:
- Get online status
- Get current range
- Get mode (scan to scan mode, OSCFAR)
- Get current bitmap attributes
- Get 0/1 bitmap threshold
- Get polar attributes
- Get range/sector/azimuth sampling ratio
- Get update rate
- Get data width or dynamic range (for 8 bit data)
- Get test pattern
- Get gain mode (automatic/manual)
- Get gain/offset
- Get tape status

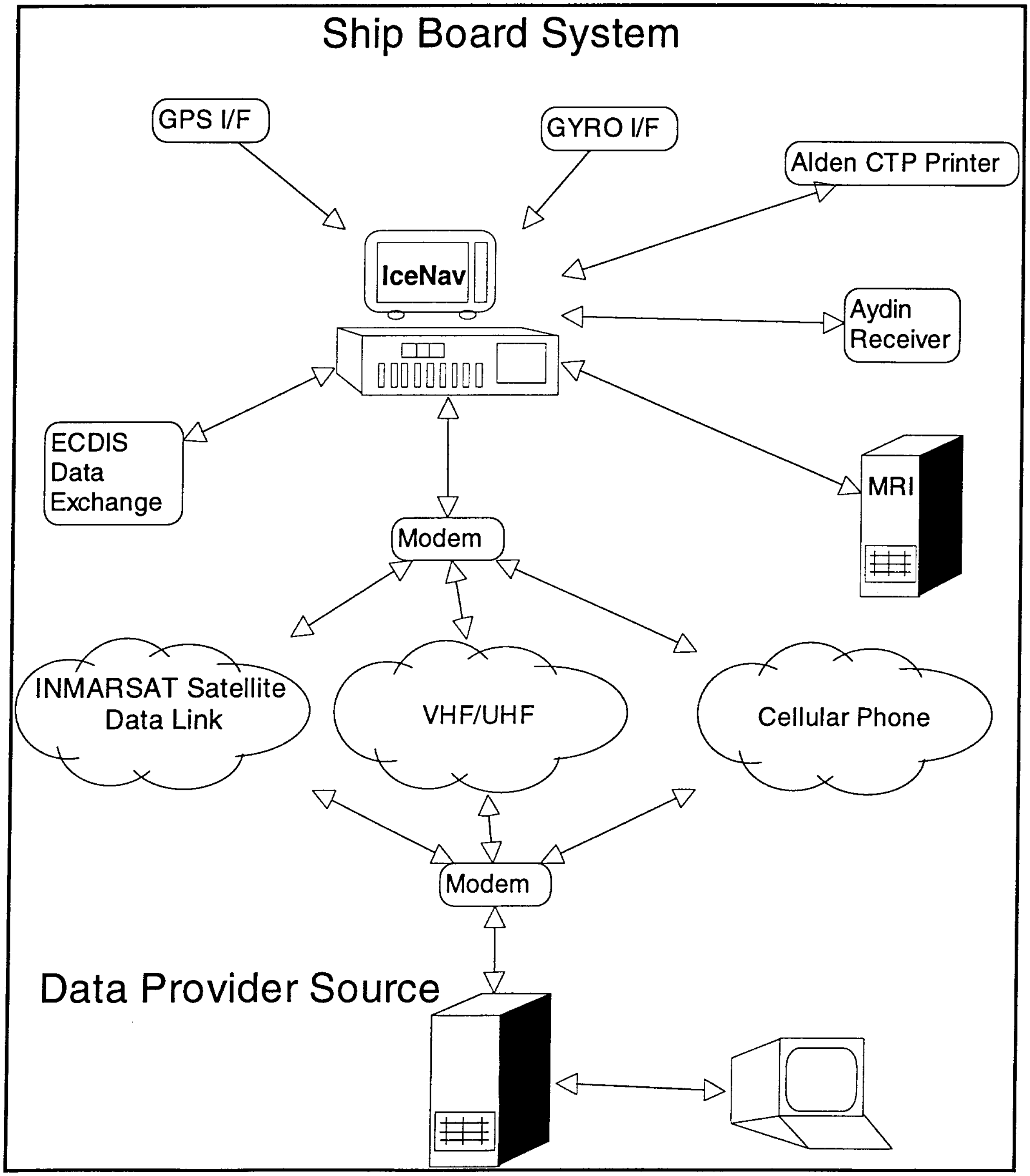

Fig. 4-1 IceNav/MRI System Context Diagram

5.0 FUNCTIONAL REQUIREMENTS

The functional requirements are meant to address to operational requirements outlined in Section 4. This section deals with the functional capability the SRIC software requires in order to meet the operational requirements listed in Section 4.

The basic functional requirement of the SRIC is to be able to provide a control interface between the MRI and IceNav systems as well as to process the data received from the MRI. The SRIC software will provide the user interface and the operational software will perform this sequence of calls for the IceNav system. The MRI system software shall execute these client application calls as they are made by the application system.

5.1 IceNav/MRI Inter-Processor Communications

The Client/Server strategy defined in Phase I has since been modified. The new strategy involves having multiple clients and multiple servers. Also Canarctic is no longer taking care of the network communications as it did in Phase 1. For this reason much of the work in Phase 1 needs to be redone, i.e. Redesigned and re-coded, integrated and re-tested. The additional features which were originally intended to be completed in this phase are listed below in section 5.5 and marked with an asterisk. These will be completed as time and budget permit.

In Phase II the MRI software will "hide" the network application with a series of functions contained in a DLL. The scope of the SRIC software developed in Phase 1 has been modified. It no longer has to deal with network communications directly and so the data interchange strategy will be modified to suite the new functions defined in the Client Application DLL (CADLL).

The communication system between the IceNav and the Titan for both control and data signal flow will be through a Client Application DLL. Whereas in Phase 1 the IceNav system had explicit RPC library references, Phase II will link with a Dynamic Link Library (DLL) provided by Titan. This DLL will provide the interface to the MRI. This means that the IceNav system need not know in any way that the radar is "hooked" to a network. All network related software shall be the domain of the MRI Software.

All MRI services on the client computer shall be invoked by the client and no MRI service shall be performed without the client application requesting it.

5.2 Data Exchange Categories

The data exchange between the MRI and the IceNav system shall consist of the following categories:

- MRI Radar Image Data (either HH or HV rasterized data).
- MRI Commands and Status via a defined set of application call interfaces.
- *MRI Targets (to be determined).

Data is exchanged explicitly via the parameters of the function calls made to the Client Application DLL. The complete list of the functions and the prototype definitions and data structures will be found in the MRI detailed design.

5.3 Radar Data Imagery

MRI imagery exported to IceNav shall be in the ***Windows*** bitmap format. The image sizes 1024 x 1024 pixels. The color depth of the image may vary from 1 (Monochrome), 2, 4, or 8 bits per pixel. The X and Y pixel aspect ratios shall be 1:1 and the pixel size shall be computed from the range (Diameter) of the image. The image shall be oriented as per azimuth offset specified to the MRI. The center of the image shall be assumed to reflect the ship position. Imagery shall be requested at the rate specified by the requesting task. In this way CPU resources can be controlled.

5.4 MRI Control and Monitoring Functions

The SRIC will control the MRI by setting and monitoring the following MRI states:

- MRI on-line/off-line status
- MRI configuration
- MRI radar range
- MRI scan mode
- MRI OSCFAR mode
- MRI bit map attributes
- MRI 0/1 bitmap threshold
- MRI Image request update rate
- MRI data width or dynamic range (for 8 bit data)
- MRI test pattern
- MRI manual gain/offset
- MRI tape recorder

In addition the SRIC shall:

- Maintain graphical user interface,
- Provide Windows style on-line help,
- Manage the calls to the MRI Client DLL.

5.5 IceNav Host Data Processing

In addition to sending commands and receiving data from the MRI, the IceNav system shall perform the following functions:

- Store radar image to snap shot file (need some modifications),
- Request and display gray scale and monochrome images of size 512-1024 by 512-1024 pixels,
- Compute and Display Range and Bearing of objects pointed to by cursor in image,
- Provide the ability to adjust Brightness, Contrast, and perform Image Equalization
- * Configure the Radar(s),
- * Invoke Tape Recorder Facility for recording and playback,
- * Perform Feature Outline and Extraction,
- * Ice Drift Position Correlation and Position Fixing/Shifting,
- * Handle "Tracked" Target Data.

The features listed in the previous sections above are described in detail in the sections below.

5.5.1 User Interface GUI

The GUI provides the user interface between the application program and the user. The menus selection, buttons, dialogues etc. Are to be evaluated and modified as required, both by TDC as well as before and after the two field trials.

5.5.2 Tape Interface

The Tape Dialogue shall permit an operator to control the Tape Driver in the MRI. The control shall be able to initialize a recording session or play back a section of the tape to verify a recording session and also for research purposes in the future.

The functional control elements will consist of the following:

- Starting and stopping the streaming tape recording,
- Starting and stopping the streaming tape playback,
- Getting the tape contents,

- Labeling a tape,
- Loading and unloading the media, and
- Setting the tape access mode (Read/Write).

Controlling the tape shall be performed by invoking the Tape Control Dialogue Box. The user will then be presented with the functional options listed above.

5.5.3 Displaying Radar Image

Once the Radar has been brought on-line, requests for data shall be made by the SRIC software to MRI. The temporal request rate is based on the iteration rate of the Get Image Data task. Data received from the MRI "get image" DLL call can be written directly into a Device Independent Bitmap (DIB) memory area. This DIB shall be used to paint the radar image data into the dedicated Radar Window. In addition to the bitmap data, the MRI shall also return radar status data such as latitude, longitude, radar range, and azimuth angle from true north to allow geo-referencing to occur in the bitmap.

5.5.4 Storing Radar Image to Snapshot File

In addition to the tape archiving function that is part of the MRI system, the SRIC software shall have an additional feature for recording "snapshots" of radar imagery. These images will be time stamped and have ancillary geo-reference files, together with fields for describing the file. This includes fields for whether the data is HH or HV.

5.5.5 Range and Bearing to Cursor Object

The center of the image represents the position of the Radar. The range and bearing to an object shall be based on the X and Y pixels sizes and the image orientation from north. The display of these values shall be done by invoking the range and bearing dialogue. When the operator moves the cursor in a radar window to edit the fields, the dialogue box shall be updated in real-time.

5.5.6 Cursor Latitude and Longitude

The center on a radar image is assumed to be the position of the GPS indicator. The latitude and longitude of an image pixel shall be computed based on a spherical projection. This functionality shall be used for position fixing between the SAR data and the MRI data.

To display these values an operator shall invoke the latitude and longitude dialogue. When the operator moves the cursor in a radar window, the edit fields of the dialogue box shall be updated in real-time.

5.5.7 Radar Image Brightness, Contrast, Image Equalization

The IceNav software contains algorithms to adjust the brightness, contrast and image equalization. The adjust color map routines shall be used to adjust the color palette for the radar image. The operations shall be performed by adjusting the color palette of the corresponding radar image memory bitmap.

5.5.8 Feature Extraction

Raster Feature Extraction/outline is created from returns of either HH or HV imagery. Basically the MRI is instructed to send a monochrome product at a specific threshold value. This threshold can be set for what is thought to be the threshold of old versus new ice, i.e. all return data below a TBD threshold represents thicker ice.

5.5.9 Ice Drift Position Correlation and Position Fixing/Shifting

The SRIC software shall give the operator the ability to correlate real-time radar data with SAR imagery. The SAR imagery may be several hours old (or more) and the ice may have drifted considerably in that time. The Radar imagery on the other hand is real-time. By identifying features in the radar imagery and "mapping" them to features in the aircraft/SAR/SLAR or RADARSAT Imagery, it is possible to calculate how much the ice has drifted over time. The correlation vector can be used to position the ship relative to the ice.

5.5.10 Handle "Tracked" Target Data

This may involve taking targets such as icebergs and bergy bits and monitoring their relative position to the ship, from the MRI and relaying them to other systems, or it may involve display of same.

5.6 IceNav/MRI Target Performance

The IceNav/MRI system shall be able to put a new 1024 x 1024 x 1 byte gray-scale image on the screen every three seconds.

5.7 Operating System and Additional System Hardware

The operating system that will be used is Windows NT version 3.5 for both Client and Server. The MRI system shall reside on the SERVER computer and the IceNav system and the SRIC shall reside on the CLIENT (Workstation) computer.

Windows NT was chosen as the operating platform because it provides a user interface that many people are already familiar with. This minimizes training. Also the NT has an open end architecture and it supports many platforms, thereby providing a growth path for future developments.

A network card and the associated "NT" network drivers, together with the TCP/IP services must be loaded into both the MRI and IceNav computers in order to facilitate the RPC services.

5.8 Implementation Language

The implementation language that will be used is C and C++. The compiler of choice is Microsoft Visual C++ for Windows NT. This version supports C++ templates and MFC (Microsoft Foundation Classes) 3.0. It is noted that both of these are required for CARIS ODK software.

6. USER REQUIREMENTS

6.1 General

The basic user requirement of the SRIC is that the system must include an operator (man-machine) interface for transmitting information to the operator and receiving information from the operator. The "information" referred to consists of data and commands, and is listed in Section 4.6 - Communications. The "Operator" will be a mariner, generally a Captain or a Navigator, but not necessarily someone with computer experience. The operator interface will consist of a video monitor plus keyboard. It is anticipated that the existing monitor for the IceNav system will provide the interface for both commands and data. The interface functions will be designed to meet the following general requirements:

- the interface will be user friendly and will be designed to minimize operator stress;
- the interface will coordinate with the existing operator interface of the IceNav system.

This operator interface must operate effectively under a wide variety of conditions that are experienced by Arctic mariners. Some of these conditions are listed below:

- temperatures ranging from -20°C to +40°C,
- illumination must be adjustable from very bright and high contrast, to very dim, to handle the varying light conditions on the bridge,
- must be able to display a wide variety of colors and symbols, as specified by organizations involved with marine navigation regulations (IMO, RTCM, etc.).

The user interface shall use the standard windows API/GDI Graphical User Interface software. Note: *WinG* will only be used if graphics performance problems are encountered. This will ensure portability of the application.

6.2 ECDIS

The MRI is expected in future to have the ability to track objects. The range, bearing, and extents of the objects in the context of icebergs or bergy bits may need to be passed from the MRI through the IceNav system and into an ECDIS system. It is anticipated that the IceNav system (after contract award from TDC) shall be able to connect to an ECPINS to demonstrate this feature.

6.3 High Resolution Image Transmission to Ships

The data to ships will have to be able to be correlated with the radar imagery. Therefore the georeferencing and projection data date will have to be related.

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Appendix B

Detailed Design Document

ICENAV SHIPBOARD RADAR INTEGRATION PHASE II

REVISED DETAILED DESIGN DOCUMENT

April 15, 1996

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1. PROJECT OVERVIEW

The objective of this project is to develop, within Canarctic Shipping Company Ltd.'s Ice Navigation System "IceNav", the capability to interface with the Modular Radar Interface Unit (MRI) manufactured by TITAN Radar International Inc. and provide the functionality to use and manipulate the shipboard radar images to support ice navigation.

Concurrent with this project development, TITAN Radar International has developed the MRI unit under a separate contract with TDC. The current version of the software developed by Titan Radar International Inc. and used in this new version of IceNav via program calls to Client DLLs supplied by Titan, instead of simulation software developed previously within Canarctic and used in the earlier versions of IceNav.

2. INTRODUCTION TO TASKS 3 AND 4

This document contains the Detailed Design for the Shipboard Radar Input Component (SRIC) software. It contains a breakdown of the software components as well as the high level program flow and control. The key software modules and callback functions and Graphical User Interface (GUI) are outlined.

In the detailed design document, Pseudo_Code is incorporated to define the software functionality in detail. The purpose of the Detailed Design Document is to provide a final, overall software specification for the SRIC.

Delivery of this document in denotes completion of this task and constitutes Milestone 4.

3. BACKGROUND AND RELEVANT PREVIOUS WORK

Canarctic has led the development of ice navigation technology for the last 15 years. An extensive five year research program led to the recent development of a prototype ice navigation system that uses airborne SAR ice information. The marine radar interface and processing is most crucial to ice navigation, which depends heavily on positioning information derived from the shipboard radar picture. Ice navigation radar uses cross polarized signals that have to be processed in order to yield the desired glacial ice detection potential. Close range ice hazard detection in open water is the subject of particular interest, and a problem that needs to be addressed with respect to ice navigation requirements. Beyond the primary ice positioning task, supporting the shipboard radar would allow special radar processing that is not handled by currently available commercial radar systems. This in turn, could lead to advanced target detection, coast-line recognition, and eventually to automatic radar tracking to supplement GPS information.

In order to support ice navigation, an independent source of shipboard radar images is required in addition to the airborne SAR image. The functioning of an ice navigation system cannot be considered complete without the availability of this radar input.

The objective of this program is to develop a multipurpose, open architecture radar interface and processing module, capable of interfacing with any system that requires radar image input. The development is to target the following non-exclusive applications in the near future:

- ice navigation systems
- radar image display
- radar image enhancement
- cross-polarized processing
- automatic motion tracking
- electronic chart support

These applications provide a good sample of the operational requirements likely to be imposed on the radar module. The design of the new module will have to take into account the likely operational scenario of each of the outlined applications, as well as the operational and integration requirements of existing systems such as the Prototype G2 Ice Navigation System and future planned systems.

In this phase of the IceNav Shipboard Radar Integration program, the objective will be to provide the basic data communication link between the IceNav and the Titan Radar systems, to enable radar data to be passed from the radar to IceNav, and to implement a basic set of radar control functions in IceNav, so that the Titan radar can be controlled from the IceNav system. There will be relatively little effort put towards providing additional ice navigation facilities in the system. These features will be provided in future phases of the program.

4. SOFTWARE DESIGN

4.1. Operating System

Both the Client and Server will be run under Windows NT version 3.5 (Workstation).

4.2. Implementation Language

The implementation language will be C and C++. The compiler that will be used is Microsoft Visual C++ for NT. This version supports C++ templates and MFC (Microsoft Foundation Classes) 3.0, both of which are required for CARIS ODK.

4.3. Programmer Interface/Model

The operator interface shall use the standard Windows API/GDI. This will ensure portability of the application. WinG will be considered for this purpose if graphics performance problems are encountered with Windows API/GDI.

The SRIC design is based on the Windows Programming Model as outlined for example in the book "Programming Windows" by Charles Petzold.

4.4. System Block Diagrams

Figure 4.4-1 shows the connection scheme of the MRI Server computer to the IceNav Client computer (Host system).

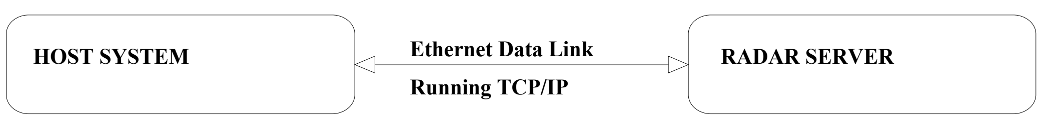


Figure 4.4 -1: Host to Radar Server Connection Scheme

Basically the two systems are connected by an Ethernet link that supports TCP/IP services. The physical connection is via Thin-Wire Coax (RG-59) and the data bandwidth is 10 Mbits/second. The bandwidth could be increased to 100 Mbits/second with fast Ethernet if required. This would require no changes to the application software.

It is important to point out that this development approach is compatible with any host that supports a TCP/IP connection and the protocol required to talk to the Radar Server. This type of client-server connection scheme is already an integral part of Microsoft Windows NT[tm]. Also, the RPC stack frames are compatible with any host that support DCE standard RPCs.

4.5. Interprocessor Communications

The interprocessor communications will be implemented using a Client/Server model (See Fig 4.5 -1). The IceNav/SRIC shall reside on the CLIENT computer and the Titan/MRI shall reside on the SERVER computer. Interprocessor communication will be provided via the Dynamic Link Libraries (DLL) provided by the MRI software. Basically a client application such as IceNav makes a call to the Client MRI DLL. This call is then passed on to the CLIENT RPC DLL who transports the data via TCP/IP to the SERVER RPC DLL. The server DLL reconstructs the stack frame and calls the appropriate driver procedure(s) in the MRI SERVER.

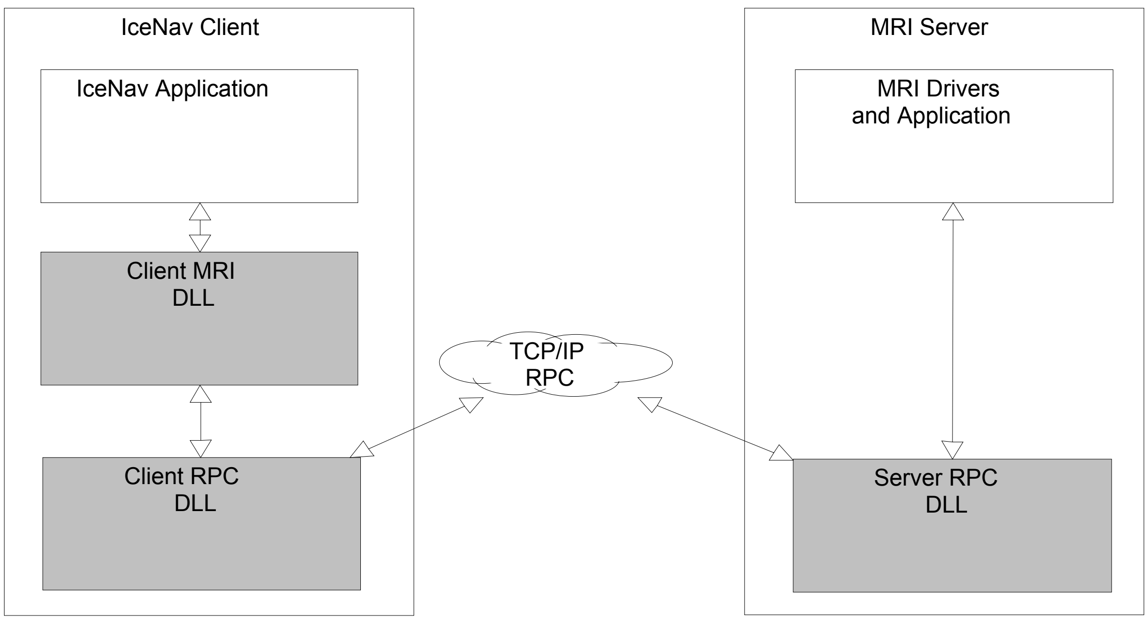


Figure 4.5-1: IceNav/ MRI Client Server Architecture

4.6. Shipboard Radar Integration Component (SRIC)

The software design for the SRIC module is based on the Microsoft Windows Programming Model. In this Model, the operating system sends data strings known as Windows Messages to each and every window/dialogue box that is active in the system. These messages are a result of events that occur in the system, such as mouse movements. Each window/dialogue box has a user supplied Windows Messages handler. These message handlers are used to decode the events of interest and transfer control to the appropriate procedures.

In the SRIC, the windows and dialogue boxes are being created using the App-Studio GUI editor which is provided with the Microsoft Visual C++ Compiler Version 2.0. These dialogue boxes provide the hooks to the program application. The application then calls the required procedures to execute the desired functions.

In the SRIC software the GUI does not interact with the Client MRI DLL directly but rather through a communications thread. The basic advantage to this approach is the main IceNav application is not kept waiting while requests are being processed by the MRI. Figure 4.6-1 illustrates this indirection.

The basic mechanism for MRI control is as follows. A user selects an action item in one of the control dialogues or windows. This results in windows generating a command message to the SRIC software. The SRIC decodes this message and then posts a thread message to communications thread which then calls the Client MRI DLL. When the function returns, the communications thread passes a notification message back to the SRIC dialogue. The SRIC dialogue updates its status based on the result of the command it issued.

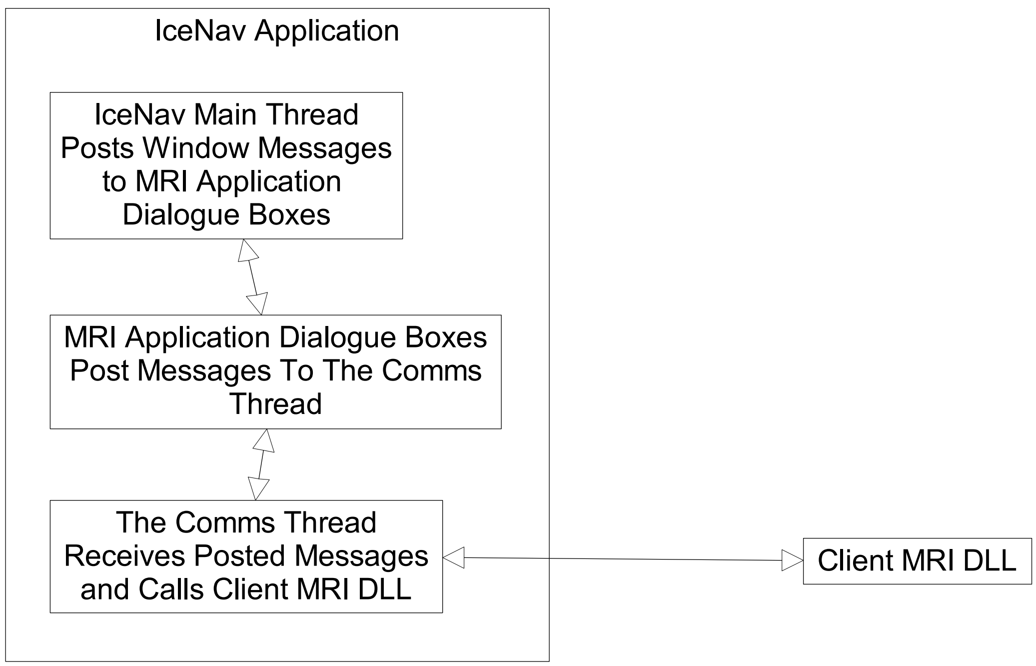


Figure 4.6-1: SRIC Communication/MRI Services Thread

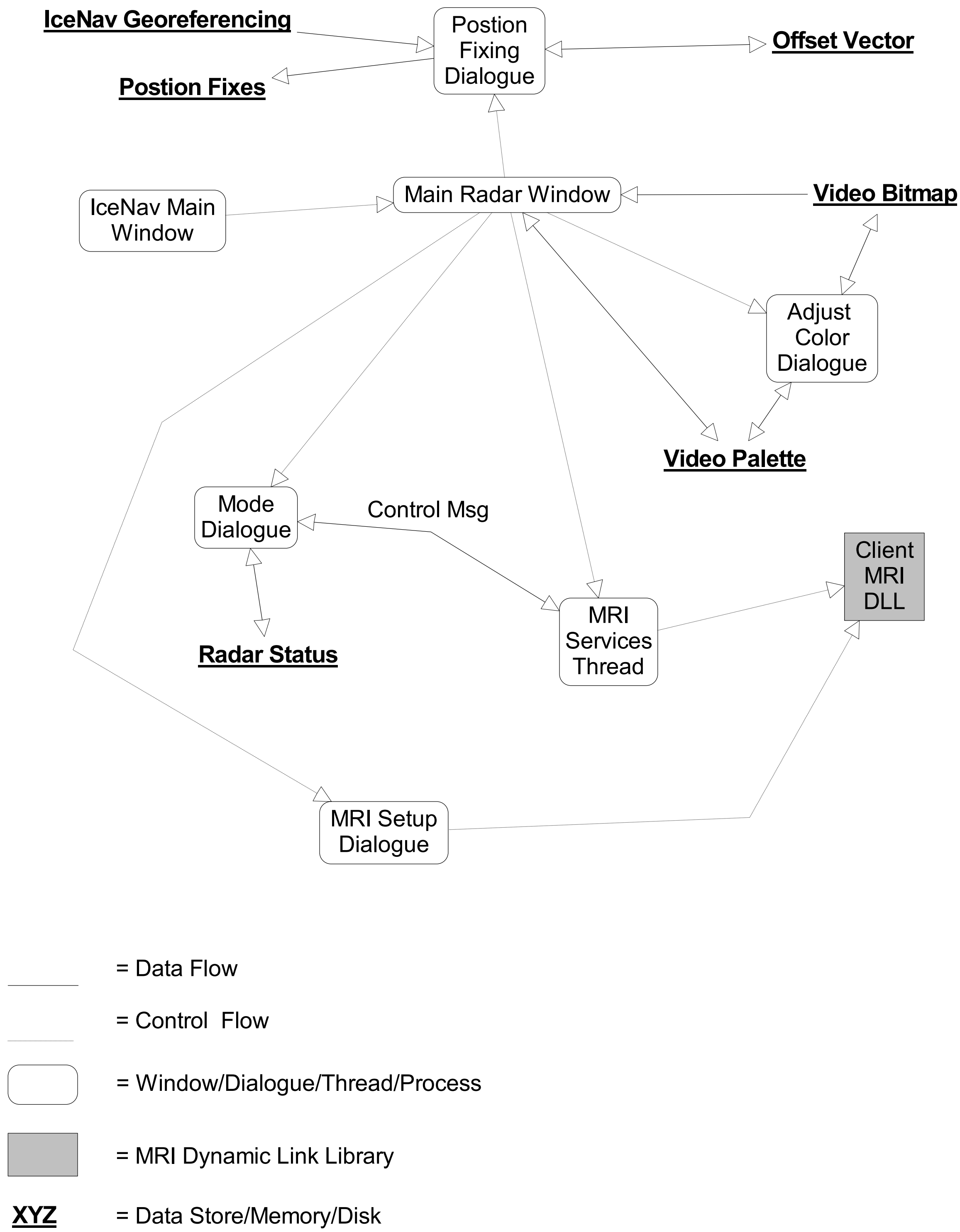


Figure 4.6-2: SRIC Data/Control Flow Diagram

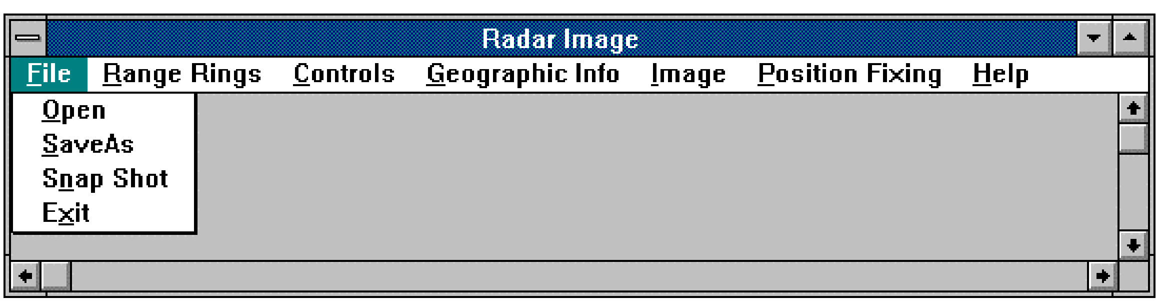
4.7. Module List and Description

Module Name	Level	Description
ICEMAIN.CPP	1	Decodes Main Menu Selection and handles modeless dialogue boxes. When the View Radar Data menu item is selected the program calls "CreateDialog" to start up the main radar window.
RDRMAIN.CPP	2	Contains the code for the Main Radar Display Window as well as invocation of the child dialogues.
RDRPOSF.CPP	3	This module performs the position fixing function. It uses the routines in RDRGEO.CPP to compute the latitude and longitude of main radar display position fixes.
RDRMODE.CPP	3	Contains the MRI control GUI. Sends and gets message from the Radar Communication Thread. In this way the main application program is not kept in a "busy wait" state.
RDRTHRED.CPP	3	Contains the code to communicate will the Client MRI DLL. The MRI Services Thread processes thread messages sent to it from the application dialogues. These messages signal the thread to perform specific functions. This module gets the procedure address from the MRI Client DLL, builds the stack variables and then calls the routine.
RDRGEO.CPP	3	Contains routines for computing, displaying range and bearing to cursor object as well as the routines for computing latitude and longitude for the position fixing function
BMPOL.CPP	*3*	*Contains routines for computing, displaying the overlay position fixing function*

The dialogue boxes for the SRIC are described below.

4.7.1. Main Radar Window

The main radar image is displayed in the Main Radar Window. The commands for control of the SRIC and the MRI are invoked via a menu structure implemented on the Main Radar Window. The Main Radar Window including the main menu is shown in the figure below.



Main Radar Window and Main Menu

Main Radar Window Functionality

The main purpose of this window is to display real-time radar imagery and facilitate user's operations on the data displayed as well as control radar parameters and data request rate. The user can also save single images to disk files as well as read in and process images saved previously. The complete list of available operations includes:

File - Open

Opens an image file saved previously. This is going to be over-written by the fresh radar online data unless the data requests are frozen via the Mode dialog box (see later herein);

File - SaveAs

Saves the currently displayed image in a disk file with a user-supplied name. The header data supplied with the image is saved at the same time in alphanumerical form in the file with the same name and extension 'RHD'. Another file with the same name having extension 'BHD' is also saved. This contains data header in binary form that is more precise than the alphanumerical one and facilitates further access. It is recommended that online radar input be frozen (see later herein) at the time when this operation is performed;

File - Snap Shot

Saves the currently displayed image in a disk file with the name 'SNAP.BMP'. The header data supplied with the image is saved at the same time in alphanumerical form in the file 'SNAP.RHD'. Another file 'SNAP.BHD' is also saved. This contains data header in binary form that is more precise than the alphanumerical one and facilitates further access. It is recommended that online radar input be frozen (see later herein) at the time when this operation is performed;

File - Exit

Closes the Radar Image window and all the online radar operations if those are being performed at that time. No more calls are made to the MRI server(s), but **no** radar offline command is issued for the sake of other possible users who may be requesting radar data;

Range Rings - On
Range Rings - Off

Draws (if On) a yellow range circle on the screen, the radius of the circle is equal to the range value in effect;

Controls

Displays the Radar Controls dialogue box (see Section 4.7.3) below) facilitating connection to one of the available MRI servers and setting its operating parameters as well as data request rate.

Geographic Info

Displays the Geographic Info dialogue box displaying pixel coordinates for the current window cursor position as well as the values of range, bearing, latitude, and longitude of the corresponding point on the Earth taking into account the image rotation with respect to true north. The appearance of the dialogue box as well as a detailed description of the function are presented in Section 4.7.5 below.

Image - Zoom

Zooms the displayed radar imagery to 25%, 50% or 100%.

Image - Enhance

Displays Radar Imagery Enhancement dialogue box (see Section 4.7.2 below) to facilitate adjustment of image brightness, contrast and color (gray scale) range. The dialogue box has menu the following functions: **Gain/Contrast, Linear Stretch, 1-Bit Thrshld, Histogram EQ and Reset**;

Position Fixing - Feature

The purpose of this function is to determine how much the ice in the Main IceNav Window has drifted over time. By choosing the Position Fixing menu item, the program starts the process which consists of selecting pairs of corresponding points in the Main IceNav Window and in the Main Radar Window and comparing their geographic coordinates. Each point selected is marked with a small purple circle. The correspondence is determined based on certain features of the images displayed in these windows. The geographic coordinates for both selected points of each pair are presented in the Position Fixing dialogue box along with the calculated displacement. Each pair of points is represented by a line in the dialogue box window, thus making a list. Each displacement value is averaged providing the information of the average change of the ice situation during the real time passed since the image in the Main IceNav Window was taken to the time of the image in the Main Radar Window. Options are included to change the order of points in each pair (this affects the order of coordinate subtraction), to clear the accumulated list, the accumulated average, as well as to quit the position fixing process. To stop the position fixing process user can also close the dialogue box. The appearance of the Position Fixing dialogue box with several sample pairs of points is presented in Section 4.7.6.

Position Fixing - Overlay

The purpose of this function is to visually correlate Radar imagery (real time) with IceNav imagery (imagery taken a certain time ago). By choosing the Overlay menu item, the program displays a Overlay Image dialogue box. Inside the dialogue box, the information of the Radar imagery overlaying on the IceNav imagery is displayed. Click the "OK" button to close the dialogue box and the software will automatically overlay the Radar imagery on top of the IceNav imagery. A user can re-adjust the overlay point by selecting the reference point with a mouse click.

Help

Like the Main IceNav Window, the Main Radar Window is provided with an online Help facility listing the main options and providing the information that helps the user find his/her way through the software.

General Schema

The general scheme of the Main Radar Window operation is as follows. To start getting images from an MRI server the application should connect to the server and set the radar online. Once put online the radar has several operating modes OSCFAR, PULSE FILTER, SCAN AVERAGE, IMAGE REQUEST Rate. All of them are controlled by the Radar Mode dialogue box. The communications thread started at client-to-server connection requests radar images according to the timer set up at the same time with the thread. The timer frequency is specified by the user (see Update Rate option). When on user request an image arrives, it is accompanied with a header including georeferencing, time information and the values of the operating parameters in effect for this specific image. The image is displayed on the screen in the Radar window and the controls of the Radar Mode dialogue box are updated with the new parameters' values. If in the process of this work the user closes the Radar Mode dialogue box, data still arrives and parameters are still updated internally, so that if the Radar Mode dialogue box is opened again later on, the values of the controls are up to date.

The commands invoked by the Main Radar Window are described below.

```
BOOL  CALLBACK Radar_CB(HWND hDlg, UINT message, WPARAM wParam, LPARAM
    lParam)
{
    switch (message)
        {
        case WM_INITDIALOG:
```

```
//message: initialize dialog box
 break;

            case WM_INITMENU:
 // initialize menu check Items
 break;

            case WM_COMMAND:
            switch(wParam)
                        {
                case IDC_FILE_OPEN:
                 //Open file dialog box
                // Display Selected Image
                break;

                case IDC_FILE_SAVEAS:
                // Save into another or same file name.
                break;

                case IDC_FILE_SNAPSHOT:
                // Store current image in a file. The filename is predefined as
                // "SNAP.BMP" and will be stored in the "radar" directory.
                break;

                case IDC_FILE_EXIT:
                // Post a Windows Close Message
                break;

                case IDC_GRID_ON:
                // Set Grid Flag In-Active
                // Disable Range Ring markers in radar display
                // and Update Radar Window
                break;

                case IDC_GRID_OFF:
                // Set Grid Flag In-Active
                // Disable Range Ring markers in radar display
                // and Update Radar Window
                break;

                case IDC_RADARMODE:
                // Open the  modeless child window called Radar Mode
                break;
```

```
                case IDC_RADAR_HELP:
                // Invoke Help Process by spawning WinHelp and WinHelp File
                break;

                 case IDC_ENHANCE:
                // Invoke Adjust Color Map Window
                break;
                case IDC_RADAR_RB:
                // Invoke Range and Bearing (Geo-Info) Window
                break;

                case IDC_RADAR_OVERLAP:
                // Invoke Radar-IceNav imagery overlap function
                break;

                case IDC_PFMENU:
                // Invoke feature position fixing function
                break;

                case IDC_RADAR_25:
                case IDC_RADAR_50:
                case IDC_RADAR_100:
                // Invoke zoom function
                break;
        }
break;

case WM_PAINT:
// Update Radar Image in radar window as well as grid if required
break;

case WM_SIZE:
// If we have a valid Radar bitmap in Memory set up the scroll ranges
break;

case WM_KEYDOWN:
        // Translate keyboard messages to scroll commands
break;

case WM_VSCROLL:
        // Calculate new vertical scroll position
// Limit scrolling to current scroll range
break;
```

```
        case WM_HSCROLL:
        // Calculate new horizontal scroll position
        // Limit scrolling to current scroll range

        case WM_MOUSEMOVE:
        // Notify Range and Bearing Dialogue of Cursor Position Change
        break;

        case WM_MRIDLLDONE:
        // DLL Get Return, Update GUI
        break;

        case WM_LBUTTONDOWN:
        // Get position fixing samples.
        break;

        case WM_TIMER:
        //post Getdata message
        break;

        case WM_CLOSE:          // message: close
        // Close radar window and all its child windows
        // Leave Radar Process running. This is taken care of in the Radar Mode Dialogue Box
        // Kill the Child Windows First
        // Set Radar Off-line
        // Clean Up Allocated Memory
        break;
    }
    return (FALSE);          // Didn't process a message
}
```

4.7.2. Radar Image Enhancement

A dialogue box will be provided to adjust the image enhancements of the radar image. This will allow the display of the radar image to be adjusted and improved. The dialogue box, known as the Radar Image Enhancement Dialogue Box is shown in the figure below.

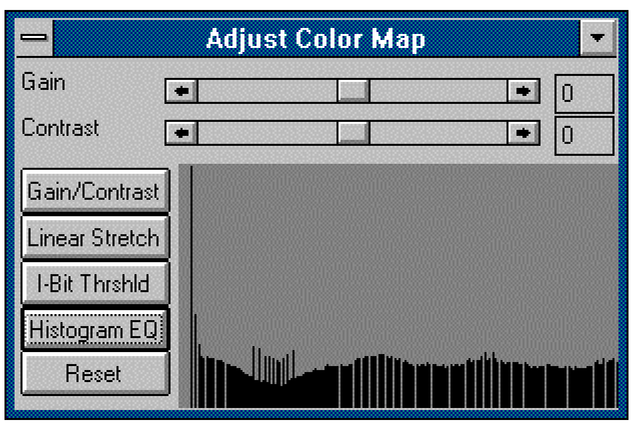
4.7.2.1. Radar Image Enhancement Functionality

The default mode of the dialogue box is Gain/Contrast. In this mode, the dialogue box allows the operator to adjust the gain (Brightness) and contrast. If an image is too bright or dark, the relative intensity can be adjusted by moving the gain slider right or left. Moving the slider left causes a down shift in the image palette while moving it to the right increasing the palette values. Contrast works in a similar fashion but its effect is to make the image contrast span from black white to gray.

Pressing the Linear Stretch will result in adjusting the imagery in a linear stretch algorithm. Two yellow lines will be drawn to represent the high and low value of the palette value.
The Set 1-bit threshold has a special purpose. It is used to extract outlines in a radar bitmap. The slider is used to set threshold. The image palette is set to 2 values. Every palette entry whose index is less than the threshold value will be set to a zero or black color while all the rest will be set to white.

Pressing the Histogram EQ Pushbutton will result in the generation of a graph representing the pixel grayscale distribution. The horizontal axis represents the gray range from 0 to 255 while the vertical axis represents the relative frequency of pixel color values. Histogram equalization involves contrast stretching the image so that the maximum dynamic range of the video driver is utilized. Basically if you have any image whose pixel values range from 0 to 128 the histogram equalization will contrast stretch the pixels so that the same distribution will occur but over a wider color spread. Pixels that were juxtaposed in color will now be separated by one or more color tones.

Pressing the Reset Pushbutton will restore the original linear color palette or look up table.



Radar Image Enhancement Dialogue Box

The commands invoked by this dialogue box are described below.

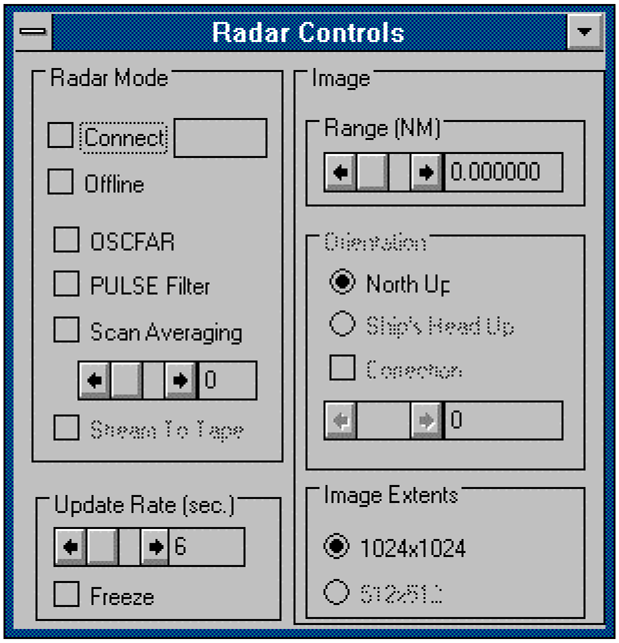
```
BOOL  CALLBACK Adjust_CMap_CB(HWND hDlg, UINT message, WPARAM wParam, LPARAM lParam)
{
switch(message)
        {
```

```
case WM_INITDIALOG:
// Message: initialize dialog box scroll bars
break;

case WM_CLOSE:
//  Destroy Dialog
break;

case WM_COMMAND:
            switch(wParam)
            {
             case IDC_GC:
             // Invoke gain and contrast
             break;

            case IDC_LS:
            // Invoke linear stretch
            break;

            case IDC_THRESHOLD:
            // Invoke 1 bits threshold
            break;

            case IDC_EQ:
            // Invoke histogram equalization
            break;

            case IDC_RESET:
            // Reset to normal
            break;
            }
break;

case WM_USER+99:
//processing user defined messages
break;

case WM_USER+98:
//processing user defined messages
break;

case WM_HSCROLL:
// Compute Gain, Contrast scales based on the scroll ranges of the
// different scroll bars and their positions
break;
```

```
        case WM_VSCROLL:
        // Compute Histogram and Histogram Equalization scales based on the scroll ranges of
the
        // different scroll bars and their position
        break;
        }
return(FALSE);
}
```

4.7.3. Radar Controls Dialogue

The Radar Controls dialogue box is designed to facilitate user application connection to one of the MRI servers available in the system and to monitor and control the radar operating parameters and image processing features. It is implemented as a modeless dialogue box, so that user can iconify it when it is no longer needed to change operating parameters and restore it again when desirable. Once connection to one of MRI servers is made, data will be requested according to the Update Rate set by the Radar Control dialogue box control and parameters will be updated with each image arriving from the server. The user should be aware of the fact that all the parameter settings he/she makes do not come into effect immediately, since they result in radar unit remote control operations. All the controls for setting/resetting radar operating parameters implement a 3-state scheme. When a control is selected, it does not immediately change to the new state, but it is rather set to a 'busy' state temporarily, since the user has only requested a change. The request still has to go through the network and reach the MRI server before the server attempts to satisfy it. It can also be overridden by some other users' requests. When in 'busy' state, the control cannot be changed again. The next state of the control depends on the result of the request made. If the request is satisfied by the MRI server, the control changes to the requested value, otherwise it changes to the value set previously. The user can toggle other controls, while some are in 'busy' state. The appearance of the Radar Control dialogue box and the detailed description of its controls are presented below.



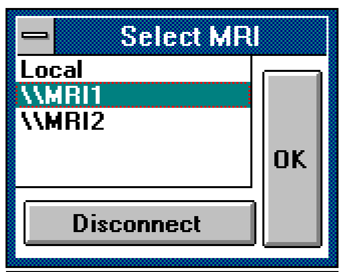
Radar Mode Command Dialogue Box

Following is the complete functional description of the Radar Control dialogue box controls.

Radar Controls Dialogue Box Functionality

Connect

This control facilitates the user connection to one of the available MRI servers. The program will automatically request the number and names of the servers available and a selection box will appear on the screen (see the picture below) to choose one of the servers or to disconnect the one connected earlier. After selection is made the program will try to set the selected server online and request its operating parameters. If some of the calls involved do not succeed, an appropriate message will appear on the screen. On success the number of the MRI server connected will appear to the right of the 'Connect' control and dialogue box controls will be updated to the parameters values obtained.



MRI Selection Dialogue Box

Offline

Sets the radar unit selected offline. It is not recommended to use this switch without definite purpose, since it may affect other users' work.

OSCFAR

Sets/resets OSCFAR switch of the radar unit selected.

PULSE Filter

Sets/resets Pulse Filtering switch of the radar unit selected. Pulse filtering is selected when there is possibilty nearby radars might "inject" pulses into the radar receiver.

Scan Averaging

The check box resets and the scroll bar sets the number of radar scans to average. The value of 1 specifies no averaging, the maximum possible value is 16. The purpose of scan averaging is to remove random noise and increase the visible of "hard" returns with respect to the background noise.

Stream to Tape

This invokes tape feature control to facilitate radar imagery recording to or playback from tape. This option is not implemented in the current version of IceNav.

Update Rate (sec.)

This is a local control. It specifies the interval in seconds between consecutive image requests issued by the local computer to the server. Its purpose is to regulate the cpu time spent getting images over the network. Also depending on ship's speed and the surrounding ice conditions, it may not be necessary to update the radar image too often.

Freeze

Freezes image requests issued by the local computer to the server. The last requested image is on the screen and it is not overwritten by new ones until the user unchecks the check box. This facilitates more deeper analysis of the image displayed on the screen.

Range (NM)

A user cannot directly assign any desirable range to the radar. They have to select a valid range from a list of available values, that the server provides. It is done automatically, and user has only to shift the position of the scroll bar for the available ranges.

North Up

This radio button when selected specifies that the image will be north aligned to true north up.

Ship's Head Up

This radio button when selected specifies that the image will be aligned so that the ship's head up.

Correction

This check box specifies whether to apply the rotational correction value presented by the accompanying scroll bar control to the image data when calculating geographic coordinates of the points within the image. This control is not implemented in the current version of IceNav.

The scroll bar specifies the image rotation angle in degrees with respect to the north or ship's head, depending on which one of those is selected.

Image extent
1024x1024
512x512

This is the size of the image. Only full-scale images (1024x1024) are now be used. However quadrants or scaled down images can be chosen in future.

The commands invoked by this dialogue box are described below.

- **Select MRI Server and set it Online**
  Windows Message received IDC_MRI_ONOFF
```
{
//   Invoke MRI select dialogue box
//   Select a MRI Server by its name
//   Set it on-line
      if (!SetTitanOnline(TargetMRI))                    // cannot turn it on
         MessageBox((hDlg),
                        "Cannot enable radar server.",
               "Information", MB_ICONEXCLAMATION | MB_OK);
//   Turn on Polling Task
}
```

- **Set MRI Server Offline**
  Windows Message received IDC_OFFLINE
```
{
//   Set radar off-line
     SetTitanOffline(TargetMRI);
//   Turn off Polling Task
// ELSE
```

- **Set OSCFAR mode**
  Windows Message received IDC_MRI_OSCFAR_ONOFF
```
{
// IF OSCFAR mode is on
//   Set OSCFAR off
// ELSE
//   Set OSCFAR on
// Send OSCFAR message command to TITAN via
if (!SetCFAR (fOscfar,TargetMRI))            // perform the setting on Titan
```

```
    MessageBox((hDlg),                    // something wrong
                "Cannot set OSCFAR.",
          "Information",MB_ICONEXCLAMATION | MB_OK);
}
```

- **Set PULSE FILTERING mode**
  Windows Message received IDC_MRI_PF_ONOFF()

```
{
// IF PULSE FILTERING mode is on
//   Set PULSE FILTERING off
// ELSE
//   Set PULSE FILTERING on
// Send message command to TITAN via
if (!SetPF (fPulseFilter,TargetMRI))     // perform the setting on Titan
    MessageBox((hDlg),                   // something wrong
    "Cannot set Pulse Filter.",
    "Information",MB_ICONEXCLAMATION | MB_OK);
}
```

- **Set SCAN AVERAGE mode**
  Windows Message received IDC_SCAN_AVG_ONOFF

```
{
// IF SCAN AVERAGE mode is on
//   Set SCAN AVERAGE off
// ELSE
//   Set SCAN AVERAGE on
//   Enable slider
// where 1= no scan averaging and maximum scan averages = 16;
// Send message command to TITAN via
if (!SetScans (cScans,TargetMRI))           // perform the setting on Titan
    MessageBox((hDlg),                      // something wrong
    "Cannot set Scans Averaging.",
    "Information",MB_ICONEXCLAMATION | MB_OK);
}
```

Windows Message received WM_HSCROLL

```
{
Set Scroll value
Set SCAN AVG VALUE
// where 1 = no scan averaging and maximum scan averages = 16;
// Send message command to TITAN via
if (!SetScans (cScans,TargetMRI))           // perform the setting on Titan
    MessageBox((hDlg),                      // something wrong
    "Cannot set Scans Averaging.",
```

```
    "Information",MB_ICONEXCLAMATION | MB_OK);
}
```

- **Set stream to tape mode**

  Windows Message received IDC_MRI_STREAMTOTAPE_ONOFF

```
{
// Instructs Titan Computer to stream Radar Images to Tape.
// A filename/archive name shall be passed to the Titan Computer.
// Send message command to TITAN via
GetTapeStatus (&TapeStatus,TargetMRI);          // request it from the server
if (TapeStatus.device_present     &     // if ready,
    TapeStatus.media_present      &
    (!TapeStatus.media_WP)        &
    TapeStatus.media_locked       &
    (TapeStatus.overall_status == OK))
    fStrToTape ? StartRecording(TargetMRI) : StopRecording(TargetMRI);
    // perform the required operation depending on function selected (start or stop)
else
  { MessageBox((hDlg),               // something wrong -
            "Cannot set/reset Stream-to-Tape mode.",
            "Information",MB_ICONEXCLAMATION | MB_OK);
}
```

- **Set range**

  Windows Message received WM_HSCROLL

```
{
// Set Scroll value
// Select a valid mode from the TITAN_MODES[16] structure array
// Send message command to TITAN via
SetDesiredMode(ModeNdx,TargetMRI);
}
```

- **Set update rate**

```
SetMRIUpdateRate()
{
// Set the Radar Frame Interval request from the client application
}
```

4.7.4. MRI Services Thread

As mentioned earlier, user application requests to the MRI server are not made directly via the MRI Client DLL calls, but are rather implemented as windows messages sent to another thread sharing system resources with the main IceNav process and started upon connection to the selected MRI server. The MRI Services thread works in an endless loop receiving messages, decoding them, and finally making the necessary MRI Client DLL calls. This approach liberates the main IceNav task from the network condition as well as server and radar response delays. Even if the MRI calls fail to respond immediately, the IceNav user can perform any other functions provided within IceNav. At the same time, the thread serializes MRI requests facilitates, so that requests do not overflow the server.

MRI Services Thread Functionality

The general scheme of the thread operation is as follows. When an application posts a message to MRI Services thread; windows places the message in a windows message queue. The thread which is running in a loop, "peeks and removes" the messages from its message queue. These messages are decoded in much the same way that regular dialogue messages are handled. The message type is decoded. The message is organized so that it includes some data which specify the parameters required by an appropriate MRI Client DLL call. The SRIC software message identification scheme identifies the message and makes a proper call to the MRI Client DLL routine using the parameters supplied.

When the MRI Client DLL makes its return, the return code is tested and a return message is sent to the main calling thread. This applies for all returns. The calling application then updates the appropriate GUI controls and parameters. In case of GetData call, which is invoked by the timer mechanism, the return message results in update of the image displayed in the Main Radar Window as well as an update of the Radar Mode GUI controls. This is because the operating parameters of the MRI are included in the header supplied by the MRI Server with each MRI image.

When GetData call returns, and the communications thread transfers an appropriate message to the calling thread, radar status flag is tested. If it appears that some other user had turned the radar offline, the program will attempt re-setting the radar online, so as to continue the started process of receiving radar data. If this attempt does not succeed, the timer will be turned off, the communications thread disabled, and the Radar Mode GUI updated so as to indicate that the radar is set offline.

The pseudo-code outlining the communications thread operation is presented below.

```
//      MRIDLLThreadFunction()

long MRIDLLThreadFunction(PMRITHREADBLOCKINFO pMRIThreadBlockInfo)
{
loop ever
    {
    if message has been sent to this thread
        {
        switch (thread message type)
```

```
{
case WM_SETMRI:
    switch(message parameters)
        {
        case IDC_MRI_OSCFAR_ONOFF:
            //call MRI
            goto POSTDLLRETURN;
        case IDC_MRI_PF_ONOFF:
            //call MRI
            goto POSTDLLRETURN;
        case IDC_SCAN_AVG_ONOFF:
            //call MRI
            goto POSTDLLRETURN;
        case IDC_MRI_STREAMTOTAPE_ONOFF:
            //call MRI
            goto POSTDLLRETURN;
        case IDC_NORTH_UP:
            //call MRI
            goto POSTDLLRETURN;
        case IDC_SHIP_HEAD_UP:
            //call MRI
           goto POSTDLLRETURN;
        case IDC_EDIT_ORIENTATION:
            // this is for the message actually caused by WM_HSCROLL
            //call MRI
            goto POSTDLLRETURN;
        case IDC_SLIDE_RENDER:
            // Update AGC
            // Post a different message  because parameters are different
            break;
        case IDC_512:
            goto POSTDLLRETURN;
        case IDC_1024:
POSTDLLRETURN:

        //post message back to radar mode window, indicate the result of the call
        break;
    }
    break;
case WM_GETMRI:
    {
    //Call MRI GetData();
    }
break;
```

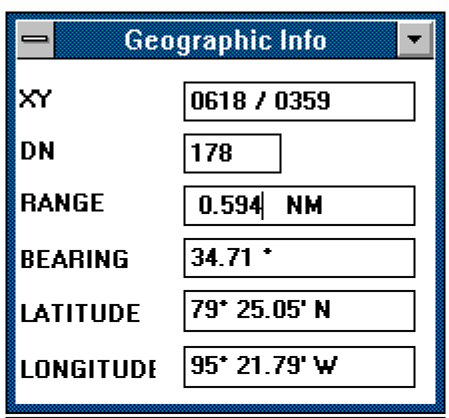
```
            }
        }
    else
        {
        if(msg.message == WM_QUIT)return (long) 1;
        }
    }
return(long)1;
}
```

4.7.5. Geographic Info

This option is provided to facilitate association of specific points in the image to their real geographic position. The basic information used to establish this association includes a reference point geographic and pixel coordinates and the whole image rotation angle with respect to true north. This information is taken from the data header supplied with the image. Reference point is the central point of the image (the common origin of the four quadrants).

<u>Geographic Info Functionality</u>

> The Geographic Info Dialogue is used to provide radar image geo- referencing information to the user. The range to cursor, bearing to cursor, latitude, and longitude of cursor are calculated and output to the assigned text boxes of the dialogue box shown in the figure below. This is updated for any point pointed to by the cursor within the image displayed in the Main Radar Window. The top line of the dialogue box contains the pixel coordinates of the point and the DN filed which stands for data number contains the value of the pixel.



Call-back function RangeBearing_CB() is responsible for this dialogue box and processes the following window messages:

WM_INITDIALOG: Initializes the "Position Fixing Information" dialog box.

WM_CLOSE: Closes "Position Fixing Information" dialog box.

WM_WINDOWPOSCHANGED: Deals with the case when the "Position Fixing Information" is moving around.

WM_USER+100: Get mouse position then calculate and display the following value: XY, DN, Range, Bearing, Latitude and Longitude.

- **Geographic Info**

Windows message received IDC_RADAR_RB

{
//Transfer control to RangeBearing_CB() call back function
//If in case of user defined message WM_USER+100:
// **GetPixel()**: Get the DN value
// **ComputeRadarRange():** Computer the Range and Bearing
// **CaculateLat/Lon()**
// **DisplayGeoInfo():** in the "Position Fixing Information" dialog box
}

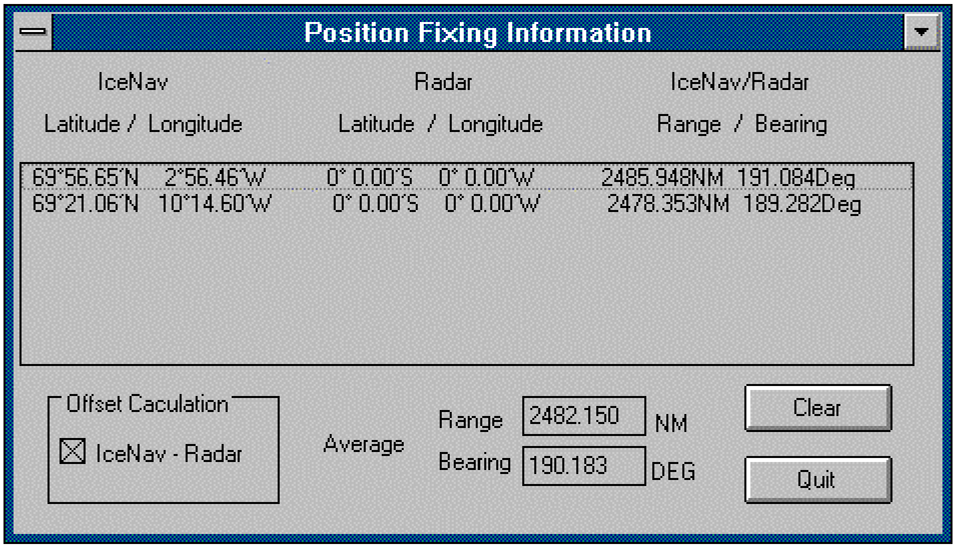
4.7.6. Position Fixing

Under the menu option "Position Fixing", there are two choices: Feature and Overlay.

<u>Position Fixing by Feature</u>

When this menu option is selected, IceNav enters position fixing mode and invokes "Position Fixing Information" dialogue box.

When in this mode, a user can select a group of paired positions (one from the displayed imagery of radar window and one from the displayed imagery of IceNav main window). The position fixing mechanism will calculate the latitude/longitude offset value for each "related position pair" and also the average offset vector. If GPS tracking is on and "Adjust GPS Vector" is enabled, this position fixing offset will be sent to the GPS as an adjusted GPS vector. At the same time, the vector will be displayed in "Position Fixing Information" dialogue box.



Position Fixing Information dialogue box

4.7.6.1. Position Fixing Information Dialogue Box Functionality

The Position Fixing dialogue box has the following three controls:

Offset Calculation

Allows the user to specify which of the images should be considered the reference one , i.e. which values should go first in the subtraction operation: those from the IceNav window or those from the Radar window. If the check box is selected, the subtraction scheme written beside it is in effect;

Clear

Clears the accumulated list of position fixing pairs of points as well as the average offset latitude and longitude values calculated for them;

Quit

Quits the Position Fixing mode;

Call-back function PositionFix_CB() is responsible for this dialogue box and processes the following window messages:

WM_INITDIALOG: Initializes the "Position Fixing Information" dialog box.
WM_CLOSE: Closes "Position Fixing Information" dialog box.
WM_WINDOWPOSCHANGED: Deals with the case when the "Position Fixing Information" is moving around.

WM_COMMAND: Quit: Quits "Position Fixing" mode and closes the "Position Fixing Information" dialogue box.

The dialogue box lists the following Information of the position fixing:
IceNav latitude / longitude: describes a position in the imagery displayed in IceNav window.
Radar latitude / longitude: describes a position in the imagery displayed in Radar window.
Offset range / bearing: the distance range of each position pair in IceNav and Radar windows and the bearing of the two points reference to true north.
Average Offset range / bearing: the average range and bearing of the position pairs selected by the user.

- **Position Fixing By Feature**

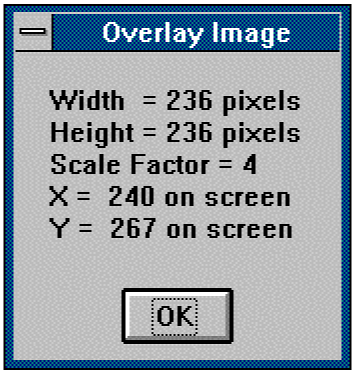
Windows message received IDC_PF

```
{
//If radar off line
//and no geo-referenced imagery displayed in the radar window
//    message: cannot do position fixing
//ELSE if radar on line
//    freeze radar imagery sending and go to POSITION FIXING
//ELSE if a geo-referenced imagery is displayed in the radar window
//    POSITION FIXING:
//        position pair checking(): user-selected positions must be in pairs
//        each time, one from IceNav window and one from Radar window
//        DrawSelectPosition(): draw on the screen
//        IceNavXY2LatLon()
//        RadarXY2LatLon()
//        CalculateOffset()
//        CalculateRange()
//        CalculateBering()
//        DisplayOffsets(): in the "Position Fixing Information" dialog box
//        IF GPS tracking on and "Adjust GPS Vector" enabled
//            UpdateGPSOffset()
}
```

The following factors may affect the accuracy of position fixing: human error in selecting the "same" position on two images, and the error introduced when computing (latitude, longitude) from (x, y).

<u>Position Fixing by Overlay</u>

When this menu option is selected, IceNav enters overlay position fixing mode. When in this mode, a dialogue box named Overlay Image will be displayed. Inside the dialogue box, the information of the Radar imagery overlaying on the IceNav imagery is displayed. For example, the following Overlay Image dialogue box shows that the overlayed Radar imagery is 236 pixels wide and 236 pixels height after scaled down 4 times, and its center position will be the point with x = 240 and y = 267 on the IceNav imagery.



After a user clicks the "OK" menu button in the Overlay Image dialogue box, the program will overlay the Radar imagery on IceNav imagery automatically. If the result is not satisfying, a user can adjust the overlaying center reference point by selecting the suitable point on the IceNav imagery by a mouse click. This point then will be the center point of the overlayed Radar imagery.

4.7.6.2. Overlay Functionality

- **Overlay**

Windows message received IDC_OVERLAP

```
{
//If radar off line
//and no geo-referenced imagery displayed in the radar window
//    message: cannot do overlay
//ELSE if radar on line
//    freeze radar imagery sending and go to Overlay
//ELSE if a geo-referenced imagery is displayed in the radar window
//    Overlay:
//        CaculateOverlayInfo()
//                {
//                OverlayPos()   // Calculate from the geo-info or from user input
//                ScaleFactor()
//                }
//        DisplayOverlayDlg():   // the Overlay Info dialogue box
//        PrepareOverlayDib()
//                {
//                SetColor(): // Set the DC background color
//                MakeOverlayDib()
```

```
//                  }
//        DibOverlay()
}
```

4.7.7. MRI Status Monitoring

Telemetry status from the MRI is received by using GetMRIStatus methods. A description of these procedures is given below.

- **Get Complete Status**

GetMRIStatus (MRI_STATUS *status, SHORT TargetMRI);

This function provides the user with the general information of the MRI features currently activated and in use.

- **Get Titan Hardware Status**

GetTitanStatus (PTITAN_DEBUG_HDR pStat, SHORT TargetMRI);

This function provides for the determination of the Titan hardware status in case of some failures for the purpose of obtaining the exact cause of the failure.

The status of the Titan hardware will also be requested on each MRI connection operation (see Radar Mode Dialogue Box) and on each image retrieval from the MRI server in case of some problems with data retrieval.

4.7.8. On-line Help

The on-line help is developed much like any other windows help file. The help text file is generated in a *.rtf (Rich Text Format) with Microsoft Word. This *.rtf file in conjunction with a help project file (*.hpj) are then compiled with the MS Help Compiler to produce a *.hlp file. This file is then run with the WinHelp executable when the help menu is selected.

IceNav_Radar

File Edit Bookmark Help

Contents Search Back History

IceNav Radar Module Menu Functions

When click the "View Radar Data" from IceNav's Mode menu, a radar image window will pop out. The radar image window has a menu bar and has the following functions:

File
- Open
- SaveAs
- Snap Shot
- Exit

Grid
- On
- Off

Mode

Set Up

Enhance

Geographic Info

Position Fixing

Help

5. CLIENT MRI FUNCTIONS

The list below is the non-parameterized set of routines with which the IceNav Applications must interface. The precise details of the routines can be found in the MRI Phase II Detailed Design Document. The ones marked with an asterisk indicate used by the SRIC Software. All others are used be either others applications or the MRISetUp Utility.

*SetTitanOnline();
*SetTitanOffline();
GetTitanCfgInfo();
ReadTitanCfgFile();
WriteTitanCfgFile();
SelectTitanCfgIndex();
SetDefaultCfg();
*GetTitanStatus();
*GetProcessing();
SetDesiredPlen();
*SetDesiredMode();
*SetScans ();
*SetPF();
*SetCFAR();
SetProcessing();
*SetGyro();
*GetData();
*GetTitanRanges();

StartRecording();
StopRecording();
StartPlayback();
StopPlayback();
GetTapeContents();
GetTapeStatus();
LabelTape();
SetCurrentAccessMode();
LockMedia();
UnloadMedia();
LoadNewTape();

SetGpsDefaultStatus();
GetGpsStatus();

EnableAGC();
DisableAGC();
SetAGCParameters();
GetAGCParameters();

GetAGCStatus();

StartExtraction();
StopExtraction();
SetExtractionParameters();
GetExtractionParameters();
GetExtractionStatus();
GetExtractedPlots();

SetBitmapParms();
GetBitmapParms();
Set1BitThreshold();
Get1BitThreshold();
SetPaletteBand();
GetPaletteBand();
SetPaletteIntensities();
GetPaletteIntensities();
SetPaletteThreshold();
GetPaletteThreshold();

*QueryNumOfMRIs();
*GetMRIStatus();
GetRPCStatus();
InitializeRPCSystem();
SetSimulationMode();
GetSimulationMode().

Appendix C

On-Line Help Manual

This appendix lists the **Help** files that are available on-line in the IceNav system.

ICENAV ON-LINE HELP MANUAL

IceNav Radar Module Help Index

IceNav Radar Module Overview

IceNav Radar Module is intended to enhance IceNav's functionality.

Hardware Requirements:

Environment:
Only IceNav_32 has Radar Module functions. IceNav_32 runs in Windows NT.

User Interface:
IceNav Radar Module provides a user friendly interface which controls the activity of the Modular Radar Interface Unit (MRI).

IceNav Radar Module Menu Functions

When click the "View Radar Data" from IceNav's Mode menu, a radar image window will pop out. The radar image window has a menu bar and has the following functions:

File
- **Open**
- **SaveAs**
- **Snap Shot**
- **Exit**

Range Rings
- **On**
- **Off**

Controls

Geographic Info

Image

Zoom

Enhance

Position Fixing

Feature

Overlay

Help

File

Function:

All functions in this module are concerning the radar imagery file management. The functions are:

Open
SaveAs
Snap Shot
Exit

Open

Function:

Open a radar imagery file stored in C:\radar directory:
-- Pick up the file name from listed box and then hit OK.
If you change your mind, hit CANCEL.

Save As

Function:

Save a coming radar imagery in a file which user defines its name.

Snap Shot

Function:

Save a coming radar imagery in a default file:
C:\ RADAR\Snap.BMP.

Exit

Function:

To quit Radar Module.

Range Rings

Function:

Enable or disable grid on radar image. This module has functions:

On
Off

On

Function:

To set Grid on the radar image.

Off

Function:

To set Grid off the radar image.

Controls

Function:

To display a Radar Mode Dialogue Box, which is used to control the radar mode.

Connect:

Select a Radar Server, set it on line.

Offline:

If the Radar Server is on line, set it off line.

OSCFAR:

If OSCFAR mode is off, set it on. If OSCFAR mode is on, set it off.

PULSE Filter:

If Pulse Filter mode is off, set it on. If Pulse Filter mode is on, set it off.

Scan Averaging:

If Scan Average mode is off, set it on. If Scan Average mode is on, set it off.
The scroll bar assigns the scan values, value can be 0..16.
The SCROLL CMD RENDER button set the value to Radar Server.

Stream To Tape:

If Stream To Tape mode is off, set it on. If Stream to Tape mode is on, set it off.

Update Rate:

Set the Radar Frame Interval request from the client application.

Freeze:

Stop updating radar imagery.

North Up:

If North Up mode is off, set it on. If North Up mode is on, set it off.

Ship's Head Up:

If Ship's Head Up mode is off, set it on. If Ship’s Head Up mode is on, set it off.

Correction:

The scroll bar assigns the Azimuth Angle values, value can be +/- 0..180.

512x512:

Set radar image width=512, and height=512.

1024x1024:

Set radar image width=1024, and height=1024.

Geographic Info

Function:

Displays the Geographic Info dialogue box displaying pixel coordinates for the current window cursor position as well as the values of range, bearing, latitude, and longitude of the corresponding point on the Earth, taking into account the image rotation with respect to true north.

Image

There are two functions in this group:

Zoom
Enhance

Zoom:

Zooms the displayed radar imagery to 25%, 50% or 100%.

Enhance:

Displays Radar Imagery Enhancement dialogue box to facilitate adjustment of image brightness, contrast and color (gray scale) range. The dialogue box has menu functions as follows:

Gain/Contrast
Linear Stretch
1-Bit Thrshld
Histogram EQ
Reset

Position Fixing

There are two functions in this group:

Feature
Overlay

Feature:

When this menu option is selected, IceNav enters position fixing mode and invokes the “Position Fixing Information” dialogue box.

When in this mode, a user can select a group of paired positions (one from the displayed imagery of IceNav main window). The position fixing mechanism will calculate the latitude/longitude offset value for each “related position pair” and also the average offset vector. If GPS tracking is on and “Adjust GPS Vector” is enabled, this position fixing offset will be sent to the GPS as an adjusted GPS vector. At the same time, the vector will be displayed in “Position Fixing Information” dialogue box.

Overlay:

When this menu option is selected, IceNav enters overlay position fixing mode. When in this mode, a dialogue box named “Overlay Image” will be displayed. Inside the dialogue box, the information of the radar imagery overlaying on the IceNav imagery is displayed.

The purpose of this function is to visually show how the ice condition is changed by overlaying the radar imagery (real time) on the top of IceNav imagery. By choosing the “Overlay” menu item, the program displays the “Overlay Image” dialogue box. Inside the dialogue box, the information of the radar imagery overlaying the IceNav imagery is displayed.

Click the “OK” button to close the dialogue box and the software will automatically overlay the radar imagery on the IceNav imagery. The user can adjust the overlay point by selecting the reference point with the mouse.

Help

Function:

To supply more information on IceNav Radar Module and describe how to use it.

Appendix D

ICENAV/MARINE RADAR INTERFACE (MRI)
Evaluation Kit

(Not available in electronic format/
Non disponible en format électronique)