11/82

RADARSAT REPORT 82-6
SURVEY OF USER REQUIREMENTS
FOR ICE AND OCEAN INFORMATION

PHILIP A. LAPP LIMITED
April, 1982

INTERIM REPORT
on Task 1 of the
Ice and Ocean User Requirement
Definition Study
for the
RadarSat Program

DSS CONTRACT NO.
OSR 80-00068

Philip A. Lapp
David J. Lapp

FORWARD

This report is based on extensive interviews, meetings and consultations with the user community representing both the private and government sectors. The emphasis was primarily directed towards the operational requirements of these various agencies. They have provided, coupled with the untiring effort of PHILIP A. LAPP LIMITED, the fundamental user requirements from which a comprehensive remote sensing system could be more easily defined. Based on the Surveillance Satellite (SURSAT) study which was the forerunner of the Radar Satellite (RadarSat) project, ice was clearly identified to be an ideal material for remote observation. Since there is an abundance of floating ice in Canadian waters which impacts on manmade activities, particularly the exploration and production of hydrocarbons and the marine transportation sectors, a need to better understand and predict its behaviour was a natural step for the RadarSat Project to pursue as its major objective. Expanding the view beyond the ice covered Canadian Seas towards the ice frequented areas of the northern and southern hemispheres and the open oceans of the world has provided an additional challenge to obtain global information useful to the operational community concerned with sea state, wind over the oceans and the possible effect of ice covered oceans on climate changes.

I would like to take this opportunity to thank the user community for being patient and understanding with the ongoing effort of the RadarSat Project to project the needs of users eight to ten years from now in an area experiencing rapid economic and political change.

Rene O. Ramseier
Scientific Authority
RadarSat Project

TABLE OF CONTENTS

TABLE OF CONTENTS(Cont'd)

LIST OF TABLES

LIST OF TABLES (Cont'd)

LIST OF TABLES (Cont'd)

RADARSAT PROJECT

USER REQUIREMENTS FOR ICE AND OCEAN INFORMATION

1. INTRODUCTION

1.1 Background

This report culminates a survey to define the requirements of users that need and make use of environmental information concerning ice and the oceans. Over the past 15 months, a broad community of users has been consulted who have a potential or actual need for data supplied by an orbitting radar equipped satellite. A preliminary report entitled "A Preliminary Statement of User Requirements for Ice and Ocean Information" (1) was issued in July, 1981 which presented the results of the survey to that time. The report was widely distributed to individuals and organizations in the user community for review and comment. Over the past several months many of the users have provided responses both written and oral which have been incorporated into this report.

The statement of user requirements is part of a larger project known as RadarSat (Radar Satellite), a polar orbitting satellite presently planned for launch in 1990 that will carry as its principal payload a synthetic aperture radar (SAR). In addition, there will be one or more secondary sensors of which a scatterometer similar to the one deployed on the U.S. SEASAT satellite is presently the baseline for the phase A design studies.

RadarSat is an outgowth of an earlier surveillance satellite project known as Sursat which involved aircraft and satellite experiments using the CCRS Convair 580 aircraft and the U.S. SEASAT satellite to evaluate the use of SAR for a range of remote sensing applications. A major activity in the Sursat project was the study of a C-Band radar described in, "A Conceptual Design Study for a Sursat Remote Sensing Satellite System - Main Report", Canadian Astronautics Ltd., March 28, 1980 (2). The system described therein has been used as the baseline design for RadarSat.

RadarSat is now midway through its phase A concept study and some design decisions have been made since publication of the preliminary statement of user requirements of ice and ocean information in July, 1981. A final mission requirements document has been completed by RadarSat project office (3) which included inputs from the ice and ocean teams. The report specifies desired specific parameters relating to the spacecraft payload of a SAR and a recommended secondary sensor for uses by designers of the satellite and ground systems. Two major recommendations from that report which have become baseline parameters are the frequency of the radar which will be C-Band and the inclusion of a steerable radar beam. The configuration calls for up to four selective beam positions which can alter the swath width of the radar over a 550 km wide strip. This additional feature permits daily coverage over selected areas north of 60^{o} with selective area coverage increased to two out of every three days in more southerly latitudes.

RadarSat is the subject of a bilateral study established through a Program Implementation Plan signed by the Department of Energy, Mines and Resources (DEMR) and the National Aeronautics and Space Administration (NASA) dated November 26, 1980 (4). The objective of the Bilateral SAR Satellite Mission Requirements Study is "to define the mission requirements that may support a bilateral NASA/DEMR program for the development, launch and exploitation of a SAR satellite system designed to satisfy U.S. and Canadian program goals and objectives".

The implementation plan calls for the establishment of jointly-chaired review and program boards, and the formation of bilateral study teams with co-chairmen designated by NASA and DEMR. The Ice and Ocean Mission Requirement Study, of which this report forms a part, supports the Canadian portion of the bilateral ice and oceans study teams.

The terms of reference for the Ice and Ocean Mission Requirements Study are as follows:

1. Define user requirements for ice and ocean information.

2. Develop suitable data presentation products to meet user needs.

3. Conduct an economic trade-off analysis which considers the best platform and sensor mix and communication systems for an ice and ocean information system. The analysis should also consider the role of forecasting.

4. Develop policy alternatives for levels, types and cost of an ice and ocean information service.

5. Develop a plan for phasing in services as system development and user needs dictate.

6. Conduct a benefit analysis of the various secondary sensor options available to RadarSat to determine which sensor would provide the greatest benefit for ice and ocean operations.

This report addresses the first term of reference and is a milestone document containing the results from the preliminary statement of user requirements modified by further discussions with and comments from various user groups.

An activity in parallel with the user requirements study was the convening of a committee to discuss the data products to be produced by an ice and ocean information system. Known as the RadarSat Information Standards Committee, its purpose was to define the required information products by activity, geographic area and time of year along with the desired product formats. The information products present many of the parameters listed in this report.

The discussion of information products is outlined in a separate report entitled, "Information Products Required for Ice and Ocean Operations" (5) and represents current thinking on the presentation of the parameters outlined in this report.

The deliberations of the committee also provided further insights into the user requirements for ice and ocean information.

1.2 Methods of Approach

The user community for ice and ocean information is very broad and heterogeneous. Consequently it was divided into seven groups according to priority:

1. Canadian Coast Guard and General Shipping
2. Oil and Gas Shipping
3. Offshore Drilling/Production
4. Fisheries
5. Defence
6. Research.

Oil and gas shipping was separated from general shipping because it is planned to operage LNG and oil tankers year round over fixed, environmentally sensitive regions of the Arctic. General shipping normally is confined to the Arctic summer. The other groups face differing operational constraints, and appeared to be natural subdivisions within the wide range of users. The first six groups have operational responsibilities in offshore activities. RadarSat is to be principally an operational demonstration project, and so while the research community should and will have access to data and be involved in the project, this study has focussed principally on operational users.

In order to structure requirements, a questionnaire was developed which addressed user needs in terms of:

- required parameters

- accuracy
- resolution and/or measurability
- repetition rate
- turnaround time from acquisition to end user
- geographical and seasonal dependence
- other requirements.

The quesionnaire was geared particularly to shipping activities where there has been some considerable thought put into future planning. It was followed up by a series of field visits and interviews with users across Canada. A total of 35 user agencies were visited, and 69 persons interviewed. A list of agencies and persons visited is contained in Appendix A.

In discussions with fishery users, it was evident that the original questionnaire was inappropriate and so a special questionnaire was developed for fishing fleet operators. The original questionnaire and the fisheries version are contained in Appendix B.

Following the field visits, the study team analysed the results of the questionnaire and interviews, followed up with telephone calls where necessary, and developed the set of tables that appear in Appendix C. Sources other than the questionnaire and interviews in the form of papers, reports, workshops and conferences also were used in compiling the preliminary set of user requirements. These references appear in Appendix D.

The resulting preliminary statement of user requirements was then circulated broadly among the user community for review and comment. Some written responses were received as well as comments over the telephone. Some further discussions were conducted with additional users not contacted during the initial survey as well as follow-up interviews with some organizations wherever the need arose.

As a result of the received comments, the report has been modified to correct inaccurate statements and the stated requirements were revised where necessary. Additional information was received from the Canadian Coast Guard and Defence departments which more closely reflect their ice and ocean information needs.

The definition of user requirements for ice and ocean information was also used as an input into Task 3 - The comparison of aircraft versus satellite (6) and into Task 6 - The benefit analysis for the secondary sensor on RadarSat (7). Each study required an analysis of the requirements listed in this report to develop the necessary baseline set of parameters and their specifications.

1.3 Organization of Report

Section 2 deals with the requirements of each of the above user groups in turn, leaving the detailed tables to Appendix C. The first three groups, which essentially cover shipping and drilling, were able to define their requirements quantitively under the headings of planning, strategic and tactical needs. While these three regimes had slightly different meanings to each group, they proved to be a convenient means of categorizing the timeliness of information required.

The remaining four groups - fisheries, meteorology, defence and research - were not as quantitative as the first three. Requirements are stated by parameter, and the user's specifications for each parameter under the headings accuracy, spatial resolution, repetition of coverage and turnaround time from acquisition to end user.

An analysis of ice and ocean information requirements is covered in Section 3 first collecting the cited parameters versus user group and then outlining reasons why and how these variables affect the decision making process involved in their diverse operations. The requirements by user group are then analysed identifying the most stringent requirement for each element of the parameter specification, and the user group responsible. Requirements also are summarized regionally and seasonally.

Section 4 summarizes the collective need of the user community and defines a realistic set of requirements that a public ice and ocean information system could provide to users.

Recommendations for continued liaison are also included. It is recognized the requirements listed in this report were solicited without consideration for the means of collecting the information. In short, these requirements are what users would ultimately like to have. It would not be possible for a public system to provide the total information package. Some of the requirements relate to site specific, close range activities where it will be the responsibility of the user to collect the necessary ice and ocean data.

1.4 Limitations of Study

The writers wish to emphasize the statement of user requirements represents the thinking of the user community to this point in time. Presumably the needs for ice and ocean information will change and will be a function of advances in technology as well as the success or failure of present and future oil and gas drilling activity. Thus it is to be expected that the parameter specifications will change both in numerical value and order of importance.

The requirements as specified by the oil and gas industry may also be overstated in their desire to obtain as detailed information as possible in order to demonstrate safe and environmentally secure operations.

Perhaps the fundamental question that cannot be answered in a study of this kind is when such information will be required. The timing of increased ice and ocean information need will be primarily a function of the timing and development of the major oil and gas development projects. The Beaufort Sea, Arctic Pilot Project and Hibernia oil fields are the pacing projects. None of these projects has been approved and, with the exception of the APP, must still clear the government environmental assessment and review process, followed by NEB approval. A positive conclusion to these processes coupled with a clear government policy on oil and gas development and production is required before any project can proceed. Only then can a definitive statement on the timing of increased information need be made.

The user requirements defined herein were used to formulate suitable data presentation products to meet user needs. These products form the basis of overall systems design including the satellite, earth stations and data handling, processing and communication systems required to place the appropriate final products into the hands of the user in a timely fashion and in a form that is most useful.

2. USER GROUP REQUIREMENTS

This section details parameter requirements and specifications for each of the seven user groups. In assimilating the information sources for each group, the most stringent specifications have been taken for each parameter recognizing that a system fulfilling such requirements would meet the needs of the other, less critical users. The parameters and their specifications for each group will tentatively define the critical parameter specifications for all users detailed in Section 3.

2.1 Canadian Coast Guard and General Shipping

The Canadian Coast Guard (CCG) has the primary responsibility to provide information and services that will insure the safe, regular and efficient passage of ships in Canadian waters. Under this umbrella is the provision of services for ship transits in ice-covered waters as well as in open sea conditions. CCG also provides for Lead Agency Management of ship source oil spills and acts as a Resource Agency for non-ship source spills. The following activities, services and responsibilities are provided for within Canadian Coast Guard policy:

(1) marine navigational aids
(2) icebreaking and escorting
(3) routing advice
(4) marine search and rescue

(5) marine emergencies/pollution control
(6) Maritime mobile communication services
(7) vessel inspection services
(8) vessel traffic management
(9) Maritime resupply administration and support
(10) pilotage
(11) training
(12) ice information for general shipping
(13) monitoring and enforcing sections within various shipping acts which cover safety and environmental concerns including:

  (a) Arctic Waters Pollution Prevention Regulations
  (b) Arctic Shipping Pollution Prevention Regulations
  (c) aspects of the Canada Shipping Act
  (d) aspects of the Navigable Waters Protection Act.

General shipping activities encompass all types of shipping besides oil and gas. Oil tankers now operate in southern ice-covered waters in the Gulf of St. Lawrence and off the East Newfoundland coast, and are treated the same as other ships with regard to the provision of ice information, routing advice and icebreaker escourt when required. In the Arctic, general shipping is limited to the transportation of cargo or natural resources including the resupply of settlements and bases, grain shipment out of Churchill and the transportation of minerals.

Also included within this user group is the Atmospheric Environment Service (AES) Ice Branch. This organization provides ice information and forecast services. They currently operate two ice reconnaissance aircraft, and since 1978 have had one equipped with side-looking airborne radar (SLAR). They patrol the Canadian Arctic in summer and the Eastern Seaboard in the winter. Periodic winter flights are also conducted in the Canadian Arctic. The primary function of the Ice Branch is to gather and present ice information from satellites, aircraft, ships and shore stations. This information is presented on daily and weekly ice charts. Forecasts for varying time periods are also prepared for users which provide an outlook on the growth, distribution and movement of ice within various geographic areas. The Ice Branch is a service organization which supports the CCG fundamentally as well as other users such as fishermen, researchers and oil company interests. Therefore its needs are dictated by others, primarily the CCG. The division of responsibility between AES and CCG is summarized in policy P23 of the MOT Arctic Marine Services Policy which states AES "shall be responsible for the provision of ice information and for ice forecasting, including iceberg tracking" while the Canadian Marine Transporation Administration (CMTA) "shall be responsible for the identification of ice reconnaissance and information services and requirements for the satisfactory performance of marine operators in the Arctic[8]."

A separate policy defines the division of responsibilites between AES and CCG for ocean information Policy P22 of the MOT Arctic Marine Service Policy identifies AES "be responsible for the provision of meteorological and sea state information" while "The Marine Administration shall be responsible for the identification of meteorological and sea state services and requirements for the satisfactory performance of marine operations in the Arctic."

2.1.1 Overview of Information Requirements

The objective of any general shipping operation is to transport its cargo in a safe and timely manner to its ultimate destination. The aim is to decrease transit time and consequently fuel costs while ensuring the safety of the vessel and its crew. CCG's role is to support general shipping in the achievement of its objectives as well as to monitor and control shipping activity and movements so environmental damage is minimized. CCG therefore has the dual role to provide service to users such as icebreaker escort or routing advice in the Gulf of St. Lawrence as well as to serve as an enforcing agency for rules and regulations covering the design, operation and deployment of vessels operating in Canadian waters.

CCG has separated its information needs into two parts; (1) meteorological and ocean information and (2) ice information. These needs have been articulated in a Memorandum of Understanding (MOU) between the CTMA and AES[9]. The MOU explains the roles of AES and CCG in providing marine services. Within the MOU are two draft annexes outlining CCG needs for ocean and ice information as well as a third draft annex from AES on the status of meeting these requirements. These annexes were a primary source of information for the tables of parameters and their specifications developed for the CCG and general shipping group.

The group's needs for ice and ocean information have been divided into the three levels of planning, strategic and tactical requirements. Ship operations differ for operations in open water versus ice-covered waters. Needs for ice and ocean information are mutually exclusive in most cases with the exception of icebergs which are present in both open and ice-covered waters. For example, in areas of high ice concentration, ocean information generally will be of less concern.

A further subdivision must be made for observational or nowcast versus forecast information. For a ship operator, it is more important to have a forecast of the area through which the ship must transit than the current information. However, the observational data has its importance in the provision of input data into forecast models. CCG in its requirements for ice, ocean and weather information make the important distinction between nowcast and forecast types of information.

Ice

Ice information for CCG planning purposes requires primarily the frequency, normals and extremes of various ice parameters which are outlined in the next section. Such information is needed for the following activities:

(1) utilization and deployment of vessels
(2) icebreaker construction and ice-strengthening of vessels
(3) marine insurance rates
(4) regulatory policies
(5) cost benefit studies as input into the feasibility of resource development requiring marine transportation through ice congested waters
(6) development of Arctic ports
(7) safety precautions
(8) pre-voyage planning and optimum ship routing
(9) safe navigation control

Ice information for planning is thus required for three main activites: design, development of regulations and pre-voyage planning.

Strategic ice information requirements are needed to plan or adjust plans for different phases of the voyage to take advantage of changing ice conditions. It is this level of information which needs both observation and forecast of parameters. Observations on ice conditions are needed on a day-to-day basis while forecasts of up to 2 weeks duration are required.

Tactical requirements relate to the Coast Guard and general shipping vessels' immediate operating area. Continuous information is needed to select the optimum routing in an ice covered area or for minor course changes in open ocean conditions.

Tactical ice information will also be needed for commercial vessels when not escorted by an icebreaker or under Coast Guard emergency conditions such as a search and rescue effort or a marine spill incident. The areal extent of tactical information required for shipping is the distance covered by the vessel within one day.

<u>Ocean</u>

There is a requirement for ocean information for planning marine activities, including:

(1) ship's track and optimum ship routing
(2) temporary extension of activities
(3) berthing and anchoring conditions
(4) safe navigation control

In addition, such information is needed to develop marine practices and modes of operation for regulatory purposes.

Strategic ocean information and forecasts support ship operations. This is needed during the voyage to permit plans to be made or changes to the route to take advantage of better meteorological and sea conditions as well as for the safety of the vessel and its crew. A forecast of future ocean conditions is the paramount requirement. Operators need not be told of present ocean conditions since they are already experiencing them. Observational data is required to produce the needed forecast.

Ocean information for tactical support has been assumed by the writers to relate to emergencies, marine spills in particular, as well as in the event of storms. For the latter, the CCG has a series of warning criteria for vessels related to forecasts of winds and waves:

1) waves - 1 meter for small craft
   3 meters for general warning
2) winds - 20 knots for small craft
   34 knots for gale warnings
   47 knots for storm warnings
   63 knots for hurricane warnings

Such events will require actual observations at site and frequent special spot and short term forecasts of conditions. The same requirement applies to major environmental marine accidents and spills.

2.1.2 Regional and Seasonal Needs

Based on present levels of shipping activity in the Canadian Arctic and East Coast regions, needs for ice and ocean information are very season-dependent. Arctic shipping is restricted in its operation by the technical characteristics of the ships and the particular times of the year when ships can enter certain geographic control zones through the Arctic Shipping Pollution Prevention Regulations (ASPPR)[10]. The regulations define 16 control zones which cover the entire Canadian Arctic as well as Hudson Bay and its approaches. Entry regulations relax with increasing zone number. Ships must conform to certain construction standards and have sufficient navigational and safety aids before entering the appropriate control zones.

General Arctic shipping has been limited to the traditional "open water" navigation season. Grain shipments, transportation of minerals and community resupply are the primary activities. Grain shipments through the port of Churchill have been limited to the summer navigation season. Grain has been exported through this port for the last 30 years and was the original basis for the establishment of Churchill. The CCG assists in this operation, placing navigational aids along the route in Hudson Bay and approaches at the beginning of the season and retrieving them at the end. While these ships ply the waters when ice conditions are easiest, more often than not they must deal with ice broken into floes which can include a percentage of old ice depending on the geographic area. The exception is in good ice years where many traditional shipping areas can be ice free. The incidence of ice damage to commercial ships confirms the ice environment as an important factor in planning and routing these vessels. CCG normally deploys six icebreakers into the Eastern Arctic waters during the navigation season to support these shipping activities.

According to forecasts made within the CMTA, the level of grain shipments will remain static through 1995 in light of development of facilities at Prince Rupert and Vancouver. Operations will remain restricted to summer months within Hudson Bay and its approaches.

In the Arctic, there are a limited number of mines which require shipment of ore. Two mines are operational: Deception Bay and Nanisivik; while a third is under construction on Little Cornwallis Island. This latter mine, a lead-zinc deposit known as Arvik, is scheduled to begin production in 1982 or 1983. The Nanisivik mine in Strathcona Sound began shipments of lead-zinc ore in 1977. Present reserves are sufficient to last for up to 15 years. The Asbestos Hill mine at Deception Bay has been operational since 1972 with present reserves to last to 1989. The production levels of these mines are such that the shipment of ore can be met by ships operating in the summer navigation season.

A major shipping activity in the Arctic is the resupply of communities and defence sites. Three major efforts are undertaken during the summer months to supply different geographic areas.

(1) Eastern Arctic
(2) Keewatin
(3) Western Arctic

Eastern Arctic resupply includes communities in northern Quebec, Baffin Island, Foxe Basin and the Arctic islands east of and including Resolute. The annual sea lift originates from Montreal. The Keewatin district on Western Hudson Bay is supplied by barges originating from Churchill. The Western Arctic resupply effort centres on the Mackenzie River Basin and the Western Arctic coastline to Spence Bay. Barges originate from Hay River. In addition to resupplying communities, cargo for gas, oil and mineral exploration activities is carried in fluctuating levels.

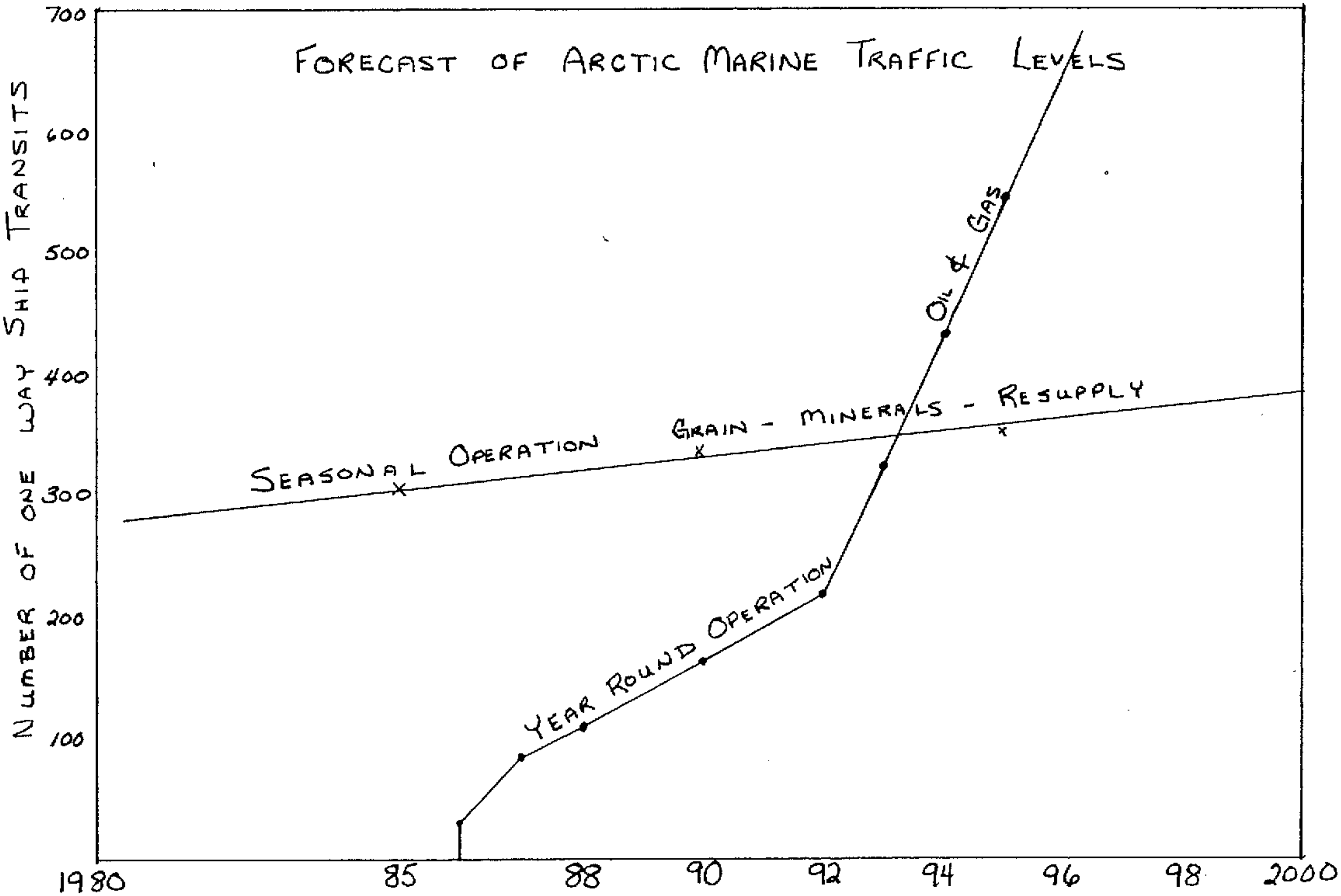
The CCG also routinely conducts a probe into Eureka Sound and/or Tanquary Fiord in the High Arctic in late August to early September depending upon ice conditions. The route tracing the resupply effort to Eureka takes CCG ships into Jones Sound, Norwegian Bay and Eureka Sound.

Operations in channels north of the traditional NW Passage are expected to remain limited to one or two trips to Eureka unless the oil and gas industry begins shipment of the hydrocarbons by vessels operating through any of the northern channels. The CCG interest would then expand appropriately.

Shipping in the Arctic will get an additional stimulus with the construction of oil and gas production facilities on Melville Island and in the Beaufort Sea.

Figure 2.1 shows a graph of projected seasonal and year round one way transits to 1995 taken from the MOT Arctic Marine Services Policy.

FIGURE 2.1


FORECAST OF ARCTIC MARINE TRAFFIC LEVELS
NUMBER OF ONE WAY SHIP TRANSITS
700
600
500
400
300
200
100
1980
85
88
90
92
94
96
98
2000
SEASONAL OPERATION
GRAIN - MINERALS - RESUPPLY
YEAR ROUND OPERATION
OIL & GAS

In the more southerly latitudes both on the West and East Coast, shipping is a year round activity. The Gulf of St. Lawrence and its approaches become the major focus for CCG activity during the winter months.

The CCG has a role to support the shipping operations summarized above. The wide range of activities and responsibilities of the CCG imply a diversity of information needs to support each one. In addition, these needs differ between geographic regions and time of year. Arctic shipping is limited to summer season when ice is minimized; however, the CCG is required to support these operations because the ice is still a factor and is still present in significant quantities in certain areas for the entire year.

The CCG has defined its present seasonal and regional requirements for ice and ocean information which are summarized in Table 2.1. General shipping regional and seasonal requirements lie within these specifications. The additional year round oil and gas shipping activity from the Beaufort Sea through the NW Passage, Baffin Bay, Davis Strait and points southwards will result in an expansion of the CCG interests for ice information in these areas. This expansion of information need will be required for VTM purposes as well as for operations of their own icebreakers.

The regional and seasonal needs expressed in Table 2.1 will thus expand at the time of startup of oil and gas shipping operations. However, until such time, CCG does not foresee any expansion of needs beyond what is stated.

Table 2.1

CANADIAN COAST GUARD AND GENERAL SHIPPING SEASONAL AND AREAL INFORMATION REQUIREMENTS

1. ICE INFORMATION

Area	Seasonal Requirement
Canadian Arctic East Coast north of 55° except for Labrador Sèa	June 1 - November 30
Hudson Bay and Approaches Labrador Sea north of 55°	June 1 - December 15
East Coast south of 55° Including NE coast of Newfoundland	December 1 - June 30
Gulf of St. Lawrence	December 15 - May 15
Great Lakes	December 1 - May 1
West Coast	no requirement

2. OCEAN INFORMATION

Area	Seasonal Requirement
Canadian Arctic East Coast north of 55°	June 1 - November 30
Hudson Bay and Approaches	June 1 - December 15
East Coast south of 55° Gulf of St. Lawrence, West Coast	year-round

2.1.3 Definition of Information Requirements

Planning, strategic and tactical requirements were recognized for both ice and ocean information. Strategic requirements were subdivided into strategic observation and strategic forecast. Some indication was also given for forecast information at the tactical level, although this was interpreted to be required primarily for marine spill incidents and under emergency conditions such as search and rescue incidents in ice-covered waters. Parameters were specified but with no numbers for accuracy or timeliness of information. The primary source of information for specification of ice parameters was obtained from the Cornwall* minutes[11] and from the presentation given on ice by Ramseier and Weeks at the U.S. - Canada RadarSat review meeting on June 5, 1981[12].

There are several points of consideration in reviewing ice and ocean requirements of this group:

(1) The CCG has the largest accumulated experience for ship operations in ice-covered waters.

(2) Present and future operations without the addition of oil and gas shipping and information requirements for ice-covered waters are highly seasonal and mutually exclusive between Arctic regions and the Eastern Seaboard.

(3) With anticipated increases in shipping levels, needs for ice and ocean information as required by the CCG will expand to match those of oil and gas shipping. Most noteable will be a year-round requirement in the Arctic. However the timing and exact level of activity is not known at present and is subject to the regulatory processes involved in getting projects approved.

---

* The first meeting of the Canada - U.S. bilateral ice study team took place as a workshop at Cornwall, Ontario in February, 1981.

(4) The parameters and system specifications outlined by the Coast Guard are of paramount importance in the discussion of critical user requirements. In order to carry out their mandate, their requirements must be met as a minimum for any ice and ocean information system.

Parametric requirements for CCG and general shipping are summarized in Table 2.2. Four support categories were identified: planning, strategic observation, strategic forecast and tactical.

Ice

Ice parameters of greatest relevance to shipping can be classified into three distinct groupings based on their relationship to shipping operations:

(1) those related to ice distribution
(2) surface and sectional characteristics
(3) ice hazards

Ice distribution parameters are required to minimize the time of interaction between ice and ship. This is particularly true for ships designed for open water use or with minimal ice capability. In particular coverage, edge location, concentration, motion, floe size and the location of landfast ice relate mostly to ice distribution. Knowledge of these paramenters will permit an operator to

Table 2.2

CANADIAN COAST GUARD AND GENERAL SHIPPING

Summary of Parametric Requirements

1. Ice

Planning	Strategic		Tactical (2)
	Strategic Observation	Strategic Forecast (1)	
1. Type-% by area 2. Coverage 3. Thickness 4. Landfast ice 5. Motion -patterns 6. Icebergs, bergy bits growlers -locations 7. Growth/ decay rates 8. Freezeup/ breakup 9. Ridge-height -width -spacing 10. Pressure character-istics convergence/ divergence 11. Leads -patterns	1. Type-% by area 2. Concentration -% by area 3. Thickness 4. Edge -location 5. Landfast ice -location 6. Motion -velocity 7. Icebergs, bergy bits and growlers -locations 8. Ridges -height -patterns 9. Floes-size 10. Leads-areal % patterns 11. Pressure -convergence or divergence 12. Ice Islands -size -location 13. Snow Cover -location -depth 14. Deterioration -% meltponds	1. Type-% by area 2. Coverage 3. Thickness 4. Landfast ice -location 5. Motion -pattern 6. Icebergs, bergy bits and growlers -motion 7. Leads -location -extent 8. Pressure -convergence	1. Type-% by area 2. Coverage 3. Thickness 4. Landfast ice -location 5. Motion -velocity 6. Icebergs, bergy bits, growlers -size -location 7. Ridges -height -point of easiest penetration 8. Leads -location -extent 9. Floes -size 10. Pressure -convergence 11. Ice Islands -size -location 12. Snow cover -location -depth

Table 2.2 (cont'd)

2. Ocean

Planning	Strategic Observation	Strategic Forecast	Tactical
1. Waves -height -direction -length 2. Swell -height -period 3. Windspeed 4. Wind direction	as for planning, but add storm locations and major fronts and troughs	as for strategic observation	as for strategic observation

1. Forecast requirements specified by Canadian Coast Guard only. Weekly forecast for 1-2 week periods required for these parameters. Forecast requirements for general shipping would be similar to CCG.

2. Also includes special spot forecasts of these parameters as needed by an on-scene commander for a marine oil spill incident.

avoid the ice entirely or steer a best course through it. Implicit in these parameters is the assumption that the ice cover is much less than solid and is likely made up of floes of varying concentration and size. Such a scenario exists for current general shipping in the Arctic. While limited to the normal June to November navigation season, there is always the possibility for such a ship will most probably encounter these ice conditions.

For some ship operations and in some geographic areas, ships must traverse regions with high concentrations if not continuous covers of ice. In this operating mode, the surface and sectional characteristics become the most important parameters. Ice type, thickness, ridges, leads, pressure, snow cover and the state of deterioration are the relevant parameters. They are needed to define ship/ice interaction and to determine a path of least resistance, given the high ice concentration or continuous ice cover. Ridges represent a major obstacle to a ship's progress. Considerable time and fuel can be spent attempting to penetrate ridges particularly ones with consolidated keels. Of equal concern is the location of multi-year ice which relates to ice type and thickness. Such ice is stronger and thicker than first-year ice. It presents an obstacle of similar magnitude to a pressure ridge. Detection and avoidance of multi-year ice is a desired goal in minimizing transit time. Meanwhile leads are a path of least resistance and an indicator of pressure within the ice. Pressure by itself can stop a ship if it is of sufficient magnitude.

The last group of parameters relate to ice hazards. Icebergs are mostly of concern during open water periods where their detection and avoidance is required, particularly when many ships cannot withstand an impact with an iceberg. The existence of multi-year ice pieces within a first year ice matrix is another significant ice hazard for ships not equipped to withstand an impact with the stronger and thicker multi-year ice.

Ocean

The need for ocean information is based upon the desire to optimize routing and therefore decrease costs. For example knowledge is needed on the location of heavy storms which can slow a vessel's progress significantly.

Ocean information also is needed in the event of a marine spill in order to monitor the movement of the slick, especially where slicks approach delicate shoreline areas. Under such circumstances, information needs increase significantly in detail and timeliness in order that preventative or cleanup measures can be enacted effectively.

2.1.4 Parameter Specifications

Planning

No parameter specifications have been imposed on the parameter listed under planning in Table 2.2. Frequency, normals and extremes are required for these parameters; information that would be obtained from climatological and ice atlases.

A requirement on planning of the ice and ocean information system would be the inclusion of an archiving scheme which would store and permit easy retrieval of historical data to use in making analyses and developing proper regulations and design criteria.

Strategic

Table C-2 in Appendix C lists parameter specifications for strategic ice information.

Accuracy and spatial resolution requirements for forecasts would be similar to strategic observation needs, while frequency and turnaround of information would be more stringent. Forecasts still depend on observational data but they also must be available early in their period of validity to be useful.

Tactical

Tables C-5 and C-9 in Appendix C list parametric specifications for ice and ocean parameters respectively.

Information needs for marine spill emergencies plus the criteria for small craft warnings were used as inputs for accuracy and resolution requirements.

Overall Statement of Need

Table 2.3 compares the parameter specifications for strategic and tactical needs. It is evident that, with the exception of icebergs, there is no difference in accuracy and resolution requirements between strategic and tactical modes. There are large differences in frequency and turnaround needs although this is a function of the time of year, geographic location and the parameter. For example, in strategic mode under frequency, all ice parameters except for type, motion and pressure are required on a once daily basis, while the latter parameters are wanted twice daily. These latter parameters define the changes in the ice distribution and its movement conditions which require more frequent updates. The frequency of need for ridges and old ice distribution information is less when the ice is consolidated, whereas after breakup, general ice conditions are less severe but the need for updates increases.

For tactical purposes the frequency of defining the various parameters becomes more divergent. The frequency can be viewed as a function of the magnitude of possible change in the parameters and their relationship to the ship operations. Thickness and landfast ice are two parameters which change slowly with time and so updates are not so frequent (12 hours and probably more). Motion, icebergs, leads and pressure are required much more frequently because of their direct impact on immediate operations and their rate of change.

TABLE 2.3

SUMMARY OF CCG AND GENERAL SHIPPING NEEDS FOR ICE PARAMETERS

PARAMETER	ACCURACY		RESOLUTION		FREQUENCY (hrs.)		TURNAROUND (hrs.)	
	S	T	S	T	S	T	S	T
TYPE	5%	5%	25m	25m	12	6	6	2
CONCENTRATION	5%	5%	500m	50m	24	3	6	2
THICKNESS	1m	1m	-	-	24	12	6	2
LANDFAST ICE	<500m	50m	500m	500m	24	12	6	2
EDGE LOCATION	100m	-	100m	-	12	-	6	-
MOTION	0.1m/s	0.1m/s	25	25	12	3	6	2
ICEBERGS SIZE	20m	5m	100m	5m	24	3	3	2
LOCATION	20m	20m	100m	100m	24	3	3	2
RIDGES HEIGHT	2m	2m	25m	25m	24	6	6	2
FLOE SIZE	20m	20m	20m	20m	24	12	6	2
LEADS	10%	10%	20m	20m	24	3	6	2
PRESSURE	+ve	+ve	$10km^2$	$10km^2$	12	3	6	2
ICE ISLANDS								
SIZE	20m	20m	100m	100km	24	12	6	2
LOCATION	20m	20m	100m	100km	24	12	6	2
SNOW COVER THICKNESS	0.2m	0.2m	-	-	24	3	6	2

The required turnaround time of strategic information averages 25% of the update time, while for tactical purposes the turnaround required is 2 hours regardless of parameter. However for emergency situations the turnaround requirement could be even less than 2 hours.

2.2 Oil and Gas Shipping

The oil and gas shipping group represents a major potential user of ice and ocean information. Currently there is no shipping of oil and gas from Canadian frontier regions. However, discoveries of oil and gas in the Beaufort Sea, Arctic Islands and Grand Banks have stimulated plans and programs to extract and transport these resources to southern markets on the East Coast which has the highest dependence on foreign oil.

The remoteness of the oil and gas fields necessitates a costly transporation system for delivery of these products. Transportation from the Arctic can be either by pipeline or by tanker. Required threshold levels and costs of pipelines may prohibit the former method based on present known reserves; therefore tanker shipping appears to be the preferred method at this point in time.

There are two major projects currently planned which will require tanker shipping and hence ice and ocean information. The first project is to liquify and transport on a year-round basis, liquified natural gas (LNG) from a terminal located on Melville Island at

Bridport Inlet to a southern terminal. Known as the Arctic Pilot Project (APP), the initial effort will comprise two class 7 icebreaking tankers which will follow part of the Northwest Passage through Parry Channel and Lancaster Sound to a terminal located at Gros Cacouna, Quebec; Melford Point, Nova Scotia or perhaps a point in James Bay. The project is scheduled to commence in 1987. Production is estimated to be at a rate of 250 million cubic feet of gas per day. The project is truly pilot in nature and this formed the basis for its approval at the Environmental Assessment Review Panel (EARP) hearings on the project held in April, 1980[13]. The project will test the feasibility of transporting gas and oil in ships from the Canadian Arctic on a year-round basis.

The second project is that of Dome Petroleum Ltd. which has been exploring the Beaufort Sea since 1976 using ice-reinforced drillships. Two major oil finds by the company in the Beaufort Sea have stimulated plans to design and build ice-strengthened Class 10 tankers which would operate year round. Their destination would also be a port on the East Coast although there is a possibility for a western route through the Bering Strait. The eastern route would follow the Northwest Passage through Prince of Wales Strait eventually overlapping with the APP route. Dome's development scenario sees some of these oil fields in production by 1986.

In the Grand Banks area, a major oil discovery at Hibernia has stimulated plans for its production. However, the final production system has not been decided upon as yet, and it is not yet known whether tankers will be the method of transportation to the shore.

Oil and gas shipping will be the major stimulus to Arctic shipping in general. The impact of such activity will be the expansion of shipping from a traditional summer navigation season to a year-round operation. This has not been done before, with the exception of the brief voyages of the 100,000 dwt Manhattan tanker during the winters of 1969 and 1970. The size of the proposed vessels (150,000 - 200,000 dwt) is much larger than any conventional vessels that have operated in the Arctic.

2.2.1 Overview of Information Requirements

As with general shipping, the objectives for oil and gas shipping are similar. The ships will be designed to withstand severe ice pressures and forces, but nevertheless the optimization of the route by selecting the easiest passage through the ice will be a primary objective. Routing of the vessel must also take into account biological concerns and other regulatory requirements.

The definitions of strategic and tactical support for oil and gas shipping are similar to CCG and general shipping. The larger tankers will require tactical ice information for a greater distance ahead of the ship since more distance can be covered in one day. These ships will not try to avoid ice if it requires a major deviation from the usual route as might smaller cargo vessels. Tactical ocean information will relate only to the short-term need for small adjustments in routing to take best advantage of prevailing weather and sea conditions.

Both the APP and Dome Petroleum stated the need for observational and forecast information for ice, ocean and weather conditions. The major application of forecast information would be for ship routing purposes. The "path of least resistance" through an ice covered area would be a principal output of such forecast models.

2.2.2 Regional and Seasonal Needs

The APP and Dome Petroleum tanker operations plan to operate on a year-round basis over a wide geographic area. The ship routes will cover a wide geographic area including the Beaufort Sea, Northwest Passage and East Coast waters. The year-round need for ice and ocean information stated by this group exceeds the standard CCG shipping season requirements presently in effect.

While a year round requirement for information is specified, it will vary in frequency and turnaround between regions. For example, the interior channels within the Canadian Arctic Archipelago freeze fast and the ice remains static during the winter months. Once the initial ice distribution known, there is much less frequent need for information, since conditions with the exception of thickness do not change much. However, in the earlier phases of these projects, observations of the ship's track will likely be necessary during the winter passages to determine the dynamic and longer term impact of the vessel's pathway through the ice.

As well, the regional and seasonal need for ice information for the initial stages of these projects will be extensive because of the need to demonstrate the safe and efficient passage of vessels to regulatory agencies. Once further experience is gained in year round shipping and the traffic levels grow, the information need in certain areas and times of year will decrease. An increasingly important source at information will be the ship-to-ship communications to let fellow masters know the expected conditions throught the region just passed.

2.2.3 Definition of Information Requirements

The definition of ice information requirements for oil and gas shipping has been obtained primarily from two source documents.

(A) "LNG Carrier Strategic Routing Study" - proprietary report prepared for the APP by Viatec Resource Systems Inc. of Calgary and Leigh Instruments Ltd. of Ottawa, April 1981[14].

(B) Technical Development of an Environmentally Safe Arctic Tanker - paper presented by Johansson et. al. at the Ice Tech Symposium, Society of Naval Architects and Marine Engineers (SNAME) Spring meeting, Ottawa, June 1981[15].

The first study defined ice information requirements for strategic routing of the APP LNG tanker. The latter paper defines ice requirements for tactical and strategic support considering what is available from and can be provided by remote sensing systems.

Both organizations stated the need for forecast information of some of the ice and ocean parameters. Dynamic parameters such as movement, concentration, and icebergs are all features which at certain times of year can change appreciably in the time span of hours.

Forecast information is more particularly needed for winds and waves off the Labrador and Newfoundland Coasts as well as for Baffin Bay/Davis Strait whenever ice is absent or in low concentrations.

Table 2.4 lists the parametric requirements stated by Dome and the APP.

An archived data base of ice and ocean data is required for design purposes including means and extreme events. While some of this information is, and will be, available through public archives, it will be the oil and gas shipping operators themselves who will collect and archive data on ice properties and mechanical behaviour needed for design. The APP ranked its ice parameters in a descending order, recognizing all the parameters and associated specifications could not be met at all times nor would they always be wanted:

(1) thickness
(2) ridges
(3) ice pressure
(4) concentration
(5) type
(6) leads, polynyas
(7) surface characteristics (rubble fields)
(8) icebergs
(9) ice edge

Dome did not prioritize its ice parameter needs. The submitted list represented the ice conditions of greatest relevance that could be obtained using remote sensing systems. Their list of ice parameters included:

Table 2.4

OIL AND GAS SHIPPING

Summary of Parametric Requirements

1. Ice

	Strategic Observation	Strategic Forecast (1)	Tactical(5)
	Ridges-height -density -orientation -separation -type	Ridges-height -separation	Ridges-height -separation
	Thickness	Leads -width -separation	Leads-width -separation
	Pressure -convergence	Icebergs -size -height -location (2)	Icebergs-size -height -location
	Concentration -% by area	Floe-size	Floes-size
	Leads -orientation -% by area -width -separation	Type -% by area	Type-% by area
	Surface (3) characteristics	Concentration -% by area	Concentration -% by area
	Icebergs -size -height	Ice Accretion	
	Edge -location		
	Floes -size		
	Ice Island (4) fragments -area -height		
	Snow Cover		
	Ice Accretion		

2. Ocean

Planning (Historical)	Strategic Observation	Strategic Forecast	Tactical
Waves -height -direction -length -period Swell -height -period Windspeed Wind direction	Waves -height -period Windspeed Wind direction	as for strategic observation	as for strategic observation

1. Dome Petroleum indicated a forecast need for ice and ocean information. The list of ice parameters was taken from their table of remote sensing needs.

2. Predicted location of icebergs was not specified by either Dome or Melville Shipping. However, it is the writer's view that location of bergs would be an important forecast parameter.

3. Surface characteristics include the identification of rubble piles and multi-year hummocks.

4. Beaufort Sea only.

5. Tactical requirements based on Dome's list of ice conditions of greatest relevance.

(1) icebergs
(2) ice type and concentration
(3) floe size
(4) ridges/rubble fields
(5) leads
(6) ice island fragments
(7) snow cover and melt conditions

The list of ocean parameters was taken from the corresponding CCG and general shipping list. Needs for ocean information will be similar for all vessels regardless of their size or cargo.

2.2.4 Parameter Specifications

Strategic

Table C-3 in Appendix C shows the parameter specifications for strategic ice information. They are a compilation for Dome and APP needs. Frequency of coverage for most parameters is as frequent as once every 6 hours while the turnaround time averages to 2 to 3 hours.

Tactical

Tactical ice information requirements are listed in Table C-6 in Appendix C. Dome Petroleum further divided the tactical support mode into two parts:
close- tactical and tactical. The latter fits the

definition stated for CCG and general shipping. Close-tactical is defined as the operating area near the ship, from 1 to 10 km ahead. Close-tactical support requires continuous coverage and instantaneous turnaround of ice information. Tactical parameter specifications are less stringent though not greatly. Near real time turnaround of information (down to 5 minutes) is needed depending on circumstances. Frequency of coverage for taçtical support is specified to be 12 hours minimum or as required.

The table of tactical ice information for oil and gas shipping shows the more stringent repetition and timeliness requirements for close-tactical support.

Strategic and tactical ice parameter specifications are compared in Table 2.5. It is clear that the frequency and turnaround requirements for close-tactical support are beyond what could be supplied by a public ice and ocean informations system. For the parameters that are wanted at both levels, the same trend in specifications is evident as for the CCG. Accuracy and resolution are the same between strategic and tactical levels, but the tactical frequency and turnaround times are much more stringent. Most of the stated tactical parameters relate to features which are of concern within the immediate operating area and are needed for subtle routing changes in the ship.

Frequency and turnaround specifications for strategic support are more rigorous than for CCG and general shipping. This is probably due to a tendency to

TABLE 2.5

SUMMARY OF OIL AND GAS SHIPPING ICE REQUIREMENTS

PARAMETER	ACCURACY S	ACCURACY T	RESOLUTION S	RESOLUTION T	FREQUENCY (hrs.) S	FREQUENCY (hrs.) T	TURNAROUND (hrs.) S	TURNAROUND (hrs.) T
TYPE	MY,FY thin, O/W	MY/FY thin, O/W	-	*	6	C	2	I
CONCENTRATION	10%	10%	2km	*	6	C	2	I
RIDGES HEIGHT	1m	1m	-	-	6	C	2	I
DENSITY	10%	-	-	-	6	-	2	-
ORIENTATION	10%	-	-	-	6	-	2	-
SEPARATION	20m	30m	20	30	6	C	2	I
TYPE	FY/MY	FY/MY	-	-	6	C	2	I
THICKNESS	0.2m	-	-	-	24	-	8	-
PRESSURE CONVERGENCE	+ve sign	+ve sign	2km	*	6	C	2	I
LEADS WIDTH	50m	50m	50m	50m	12	C	3	I
SEPARATION	500m	500m	500m	500m	12	C	3	I
% AREA	10%	-	2km	-	6	-	2	-
ORIENTATION	10°	10°	-	-	6	C	2	I
ICEBERGS								
SIZE	5m	5m	20m	20m	12	C	3	I
HEIGHT	1m	1m	3m	3m	12	C	3	I
ICE EDGE LOCATION	2km	-	2km	-	6	-	2	-
SNOW COVER	yes/no	-	-	-	12	-	3	-
FLOE SIZE	100m	100m	100m	100m	12	C	3	-
SURFACE CHARACTERISTIC	$10m^2$	-	$10m^2$	-	6	-	2	-
ICE ISLAND FRAGMENTS								
SIZE	20m	-	20m	-	12	-	3	-
HEIGHT	1m	-	1m	-	12	-	3	-

Code: S - strategic
T - tactical (and close tactical)
C - continuous
I - instantaneous.

*within vessel's immediate operating area of a few kilometers overstate requirements because of a lack of operational experience. The desire to have as much information as possible to demonstrate a safe and officient operation of the tankers in the interest of project success is another motivation. Increasing ship traffic probably will decrease the frequency requirement since ships will communicate to each other more pertinent information on ice conditions being encountered.

2.3 Offshore Drilling/Production

Offshore drilling and exploration for hydrocarbons is an ever-increasing activity within the Canadian marine environment. Both Arctic and sub-Arctic areas have been explored and considerable success has been reported. While technology has advanced considerably for offshore exploration systems, to date there have been no production platforms put into operation. However, production system designs are underway and some will be implemented within the next five years.

Offshore drilling and production of hydrocarbons embrace a wide range of activities based around different phases in development which include:

- exploration drilling
- field delineation drilling
- actual production (year round and seasonal)

There are a number of activities which support these operations or form part of the process needed to put the exploration or production platforms into place:

- work and supply boat support
- helicopter and fixed wing support
- storage and loading vessel operations
- offshore exploration/production system construction
- offshore exploration/production development
- shuttle tanker operations
- pipeline laying (where applicable)

Such a diverse range of activities implies widely varying needs for ice and ocean information. Much depends on the activity currently underway versus prevailing ice conditions. For example, the requirement for an ice or ocean forecast may not be as severe for drilling activity as it may be for a subsea installation of blowout preventors.

2.3.1 Overview of Information Requirements

The essential objective within an offshore hydrocarbon program is to explore for and produce hydrocarbons that are within hostile marine environments in the safest and most economic manner possible. To achieve this objective requires considerable environmental information at the three levels of planning, strategic and tactical support. For the purposes of the statement of user requirements for this group, information to assist in the planning phase relates to design only. The design phase for offshore operations suffers from a lack of information on the influence of the environment on structures, particularly for the production phase where there are no production systems in place either in open water or ice-covered conditions within Canadian waters. Limited experience has been gained with man-made islands which are presently an exploration platform only. Design criteria await the emplacement of the first fixed structure into an ice environment and its subsequent performance monitored through extensive instrumentation.

Strategic support for offshore operations relates to deployment of vessels and systems as well as to monitoring conditions in the medium timeframe, in excess of one day.

Tactical support for a fixed site implies short time periods of less than one day and limited geographic extent, in the neighbourhood of 75 - 100 km.

Many of the support activities will require both strategic and tactical information albeit at different stages and in relation to prevailing environmental conditions.

2.3.2 Regional and Seasonal Needs

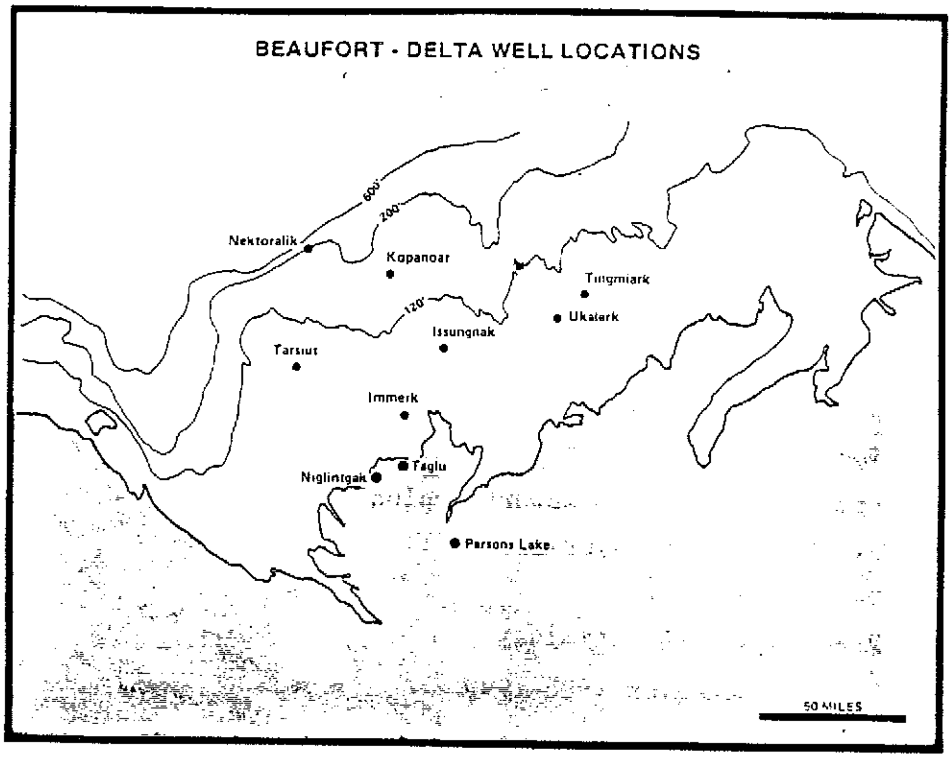
Offshore drilling and exploration has been conducted in both Arctic and sub-Arctic waters within Canadian jurisdiction. In particular, the following offshore areas have been presently determined to be important for hydrocarbon development:

(1) Beaufort Sea/Mackenzie Delta
(2) Sverdrup Basin, particularly King Christian Island, Melville Island (Sabine Peninsula) and more recently Lougheed Island
(3) Eastern Lancaster Sound, Davis Strait
(4) Labrador Sea
(5) Grand Banks (Hibernia)
(6) Scotia Shelf

Offshore operations for resource development have concentrated around exploration drilling and, to a lesser extent, field delineation drilling.

Drilling activity has been underway in the Beaufort Sea and Mackenzie Delta since the early 1960's. Three principal operators have been active in the region: Dome Petroleum, Imperial Oil (now Esso Resources) and Gulf Canada Ltd. These companies now have been charged with preparing an environmental impact statement (EIS) for the eventual production of hydrocarbons from the Beaufort Sea/Mackenzie Delta. Gulf Canada drilled the first exploratory well in 1965 in the Mackenzie Delta. Offshore exploration drilling in the Beaufort Sea commenced in 1972 when approval was given to Imperial Oil Ltd. to drill in shallow water from a man-made island. Significant gas discoveries were made within the shallower depths from subsequent man-made islands which remain untapped to this time. Since 1976, Dome Petroleum has conducted an intensive exploration program in deeper waters using ice-reinforced drillships. Twelve wells had been drilled from drillships by the end of 1980. Oil discoveries have been reported at three sites - Nektoralik, Kopanoar in 1979 and Tarsuit in 1980 with gas discoveries at Ukalerk, Tirgimiark and Nektoralik wells. The location of these wells and others is shown in Figure 2.2. Another oil discovery was made by Esso Resources at their Issugnak well in 1980. A directionally-drilled delineation well was begun at the wellsite in October 1981.

Figure 2.2



Source: (17)

Dome, Esso and Gulf have presented a number of development scenarios for oil development [17]. Projections to 1990 suggest most of the oil would be produced from the Kapanoar and Tarsuit or Issugnak fields. These operators have divided the development phases into three stages: pre production (1981-1985), early production (1986-1990) and long-term production (1990-2000). Separate scenarios for tanker and pipeline transportation have been developed. Between 1981 and 1985 projected activities include 30 offshore exploration and delineation wells drilled of which 5 would be from artificial islands, 5 offshore islands would be constructed and up to 15 development wells would be drilled. Either one Arctic tanker with an offshore terminal would be built or construction of an oil pipeline would begin with an onshore terminal. The early production phase (1986-1990) would include drilling 40 exploration and delineation-wells; 5 exploration and 4 production islands would be constructed; one deep water artificial island for development may be built and about 160 offshore production wells would be drilled. Production rates could reach 500,000 barrels/day. For transportation of the oil, about 11 Arctic tankers would be operating or subsea pipelines linking up to two offshore fields to the onshore terminal would be built. As well, the Mackenzie Valley pipeline would be completed.

Beyond 1990 development scenarios become less defined although projections and scenarios have been made.

In the High Arctic, exploration drilling over the past several years has been conducted by a consortia of companies (Esso, Texaco, Gulf) with Panarctic Oils as the principal operator. In recent years, drilling activity has moved offshore through the use of artificially-thickened ice platforms which permit the fixing of a derrick directly on the ice surface. Such drilling begins from the stage where the ice is thick enough, usually in January, to where significant melting commences around mid-May. Significant gas discoveries have been made at King Christian and Lougheed Islands with the largest and most developed gas field at Drake Point on Melville Island. This gas will be liquified and shipped by tanker to southern markets as part of the Arctic Pilot Project. Oil has been reported by Panarctic to flow in significant quantities in an offshore site east of Lougheed Island.

Offshore exploration along Canada's East Coast up to Davis Strait has been conducted principally during the open water season with the exception of Mobil's Hibernia and Scotia Shelf operations which operate as the waves and ice permits. Aquitaine, Esso and others have undertaken drilling in Davis Strait while Petro Canada has become the operator for the Labrador Sea. Seasonal (July to October) exploration has been conducted there over the past decade with some 50 wells drilled. Production is not expected until the end of this decade or later. Even then, it will likely be a seasonal operation (July-October) with perhaps some extension to December. The most successful area to date has been the site at Hibernia on the Grand Banks. A consortium of Mobil Oil, Gulf Canada and others with Mobil the principal operator has discovered oil in commercial quantities. Up to 2 billion barrels have been estimated. Mobil is continuing its exploration program with stepout wells to determine the field's size. Production of the field is scheduled to commence within the next five years; however, this is dependant on political and economic developments. Their production system has not been decided upon as yet.

Offshore drilling for hydrocarbons then, is presently in the exploration stages of development for most marine regions. Most operations in the Eastern Arctic and East Coast are seasonal with limited capability for pack ice and will remain so for some time to come. Production drilling and system emplacement will occur within the next several years at Hibernia and the Beaufort Sea. Most other areas mentioned will not be producing until the 1990's at least however, increasing exploration drilling activity is foreseen before then in these areas.

2.3.3 Definition of Information Requirements

Information requirements for the offshore drilling and production group have been divided into the three stages of planning, strategic and tactical support. Separate tables were created for ice and oceans. This group expressed a strong requirement for ocean information, actually prioritizing it over ice information in the context of present operations on the East Coast.

Several points of consideration should be considered when reviewing the requirements of this group:

1) Offshore drilling and production operations are in a fixed site with a limited geographic area. This implies a low requirement for extensive areal coverage on a daily basis. It also implies a need for more detailed and accurate information with timely turnaround from acquisition to delivery to the user.

2) Present and future operations cover a wide range of geographical areas. While the needs of any one site are minimal, the collective need for coverage will be great.

3) Information requirements will be limited seasonally to open water periods for the Eastern Arctic including Labrador until the end of the decade at least.

   Ocean information, with the exception of icebergs, is more urgently needed in these areas. However, the need to know when it is feasible to commence and finish season operations will be subject to prevailing ice conditions and therefore ice information will be required at these times.

4) The waters off the East Coast of Newfoundland and the Scotian Shelf require ocean and iceberg information on a year-round basis. Because of the continuing presence of ice and the short fetches on most marine channels, needs for ocean information in the Canadian Arctic Archipelago as defined in this study are minimal.

5) Plans for year round production and exploration systems in the Arctic are most advanced in the Beaufort Sea area. Dome's plans for tanker navigation by 1986 imply production systems already in place by that time.

6) Information needs and requirements will vary considerably between the exploration and production phases. Their value and necessity will be much greater during the production phase. Users have stated their site specific coverage needs will increase in the production phase. Larger regional ice and ocean requirements will remain unchanged between exploration and production.

7) There has been considerable experience gained with existing technology (drillships, semi-submersibles) for exploration drilling. Very little experience has been acquired for production systems in Arctic environments. Information needs are primarily based on theoretical calculations rather than practical experience.

8) There will be a need for timely forecasts of ice and ocean parameters required to make operational decisions. Forecasts of wind and waves are considered to be the highest priority ocean items. Present Labrador Sea drilling operations are limited seasonally by

severe weather and wave conditions in the fall rather than any influx of ice. Operations will already have their own data acquisition systems such as waverider buoys which will provide more timely site-specific wave information than a public system could ever supply.

9) The relative importance of parameters varies considerably with geographic area. For example, leads and ridges are less significant in more southerly latitudes because of continuous ice motion and broken as opposed to consolidated ice conditions. Icebergs are an East Coast Concern, while ice islands and ice island fragements are found almost exclusively in the Beaufort Sea.

10) Need for site specific and regional ice dynamics models.

Table 2.6 summarizes the parametric requirements for ice and ocean information for planning, strategic and tactical support. No priority has been placed on the parameters because of the changes from operation to operation and with location. Some said the observational information would be input into their own forecast models.

TABLE 2.6

OFFSHORE DRILLING/PRODUCTION GROUP

Summary of Parametric Requirements

1. Ice

Planning	Strategic	Tactical
Type-FY/MY	Boundary/edge	Boundary/edge
Floes-size	-location	-location
-type	Concentration	Concentration
-thickness	Type-FY/MY	Type-FY/MY
Ridges-density	Floes-size	Floes-size
-height	Ridges-density	-type
-width	-height	Ridges-density
-length	Motion-margin	-height
-keel depth	-magnitude	-width
Motion-magnitude	Leads-width	-type
Leads-% area	-% area	-keel depth
-pattern	-pattern	Motion-margin
Surface temperature	Icebergs-location	-direction
Local deformation patterns	-geometry	-magnitude
Height of deformations	Ice Islands-size	Leads-width
Block size	-location	-% area
Large scale deformation	Thickness	-pattern
		Icebergs-location
Pressure buildup	Ice Accretion	-movement
Thickness		-geometry
		Ice Islands-size
Freezeup and breakup prediction		-location

2. Ocean

Strategic	Tactical
Sea state-height	Sea state-height
-period	-direction
Wind-velocity	-period
-direction	Sea state spectra
Sea surface temperature	-% energy
	-direction
	Wind-velocity
	-direction
	Surface current

2.3.4 Parameter Specifications

Planning

For offshore drilling and production, planning requirements relate to design only. These are shown in Table C-1 in Appendix C. Planning/design requirements need accurate, regular gathering of information, but with a relaxed turnaround time. The measurement of several parameters such as local and larger scale deformation patterns, block size, pressure buildup and height of deformations for use in other designs, is possible only at the surface at each site.

Strategic and Tactical Needs

Tables C-4 and C-8 of Appendix C detail the strategic and tactical ice requirements. Tables C-8 and C-10 in Appendix C show the strategic and tactical requirements for ocean information.

Enough information was collected from discussions with users within the offshore drilling group to develop a table of forecast needs by geographic area, time of year and parameters required. Table 2.7 lists these forecast requirements for the drilling areas of interest. It can be seen that the requested forecast ice parameters are limited to type/concentration changes, ice movements and pressure buildup as well as ice edge location. Ice accretion is also needed for part of the year in eastern locations. Ocean forecast parameters are significant wave height, windspeed and surface currents.

TABLE 2.7

FORECAST NEEDS OF OFFSHORE DRILLING/PRODUCTION
FOR ICE AND OCEAN INFORMATION

LOCATION	TIME	PARAMETER	DURATION	FREQUENCY
BEAUFORT SEA	JAN/APR	CONCENTRATION TYPE EDGE LOCATION MOTION PRESSURE	12-48 hrs.	Daily
	MAY/JULY	MOTION PRESSURE EDGE LOCATION CONCENTRATION TYPE	12-48 hrs.	Daily
	AUG/SEPT	EDGE LOCATION CONCENTRATION TYPE WAVE HEIGHT	12-48 hrs.	Daily
	OCT/DEC	EDGE LOCATION CONCENTRATION TYPE MOTION	12-48 hrs.	Daily
BAFFIN BAY/ DAVIS STRAIT	JUNE/JULY	EDGE LOCATION CONCENTRATION TYPE	72 hrs.	Twice weekly
		SIGNIFICANT WAVE HEIGHT WINDSPEED CURRENTS	24 hrs.	Daily
	AUG/OCT	EDGE LOCATION CONCENTRATION TYPE	72 hrs.	Twice weekly
BAFFIN BAY/ DAVIS STRAIT	AUG/OCT	CURRENTS SIGNIFICANT WAVE HEIGHT WINDSPEED	24 hrs.	Daily
LABRADOR SEA	JAN/APR	EDGE LOCATION CONCENTRATION TYPE ICE DRIFT ICE ACCRETION	Week	Weekly

TABLE 2.7 (Cont'd)

FORECAST NEEDS OF OFFSHORE DRILLING/PRODUCTION
FOR ICE AND OCEAN INFORMATION

LOCATION	TIME	PARAMETER	DURATION	FREQUENCY
		SIGNIFICANT WAVE HEIGHT WINDSPEED CURRENTS	24 hrs.	Daily
	MAY/DEC	SIGNIFICANT WAVE HEIGHT WINDSPEED CURRENTS ICE ACCRETION	24-48 hrs.	Daily
GRAND BANKS	JAN/APR	EDGE LOCATION CONCENTRATION TYPE DRIFT	12-48 hrs. up to one week	Daily-weekly
		ICE ACCRETION	12-48 hrs.	Daily
		SIGNIFICANT WAVE HEIGHT WINDSPEED CURRENTS	12-48 hrs.	Daily
	MAY/DEC	ICEBERG LOCATION	12-48 hrs.	Daily
		SIGNIFICANT WAVE HEIGHT WINDSPEED CURRENTS	12-48 hrs.	Daily
SCOTIAN SHELF	JAN/APR	SIGNIFICANT WAVE HEIGHT WINDSPEED ICE ACCRETION	12-48 hrs.	Daily
	MAY/DEC	SIGNIFICANT WAVE HEIGHT WINDSPEED	12-48 hrs.	Daily

In certain areas for certain times of year, there is a stated need for longer-term forscasts of up to one week's duration for ice parameters. The implication is that the forecast models must extend to periods beyond one day. Ice accretion has been added to the parameter lists since the preliminary user requirements report.

The most severe system requirements are for ice motion information (edge, floes or bergs) as well as sea state and wind. Such information would be needed with the close proximity of any one of these ice features.

Overall Statement of Need

The same trend of identical accuracy and resolution requirements between strategic and tactical support modes as observed for CCG and oil and gas shipping is also evident for drilling as shown in Table 2.8.

Frequency and turnaround times become more severe for tactical support, particularly for ice movement and iceberg parameters. These parameters can be considered a significant hazard to present seasonal drilling operations so their location and progress must be constantly monitored within a certain operating radius around the site. Incursion of ice or icebergs into the operations area will initiate procedures at the drillsite, and at other operational centers depending on the distance of the hazard from the site. Within certain range limits, observation and tracking will become continuous activities. Although numbers have been given for frequency and turnaround time for tactical support, they will change in accordance with the environmental conditions and support vessel availability at the time.

TABLE 2.8

SUMMARY OF OFFSHORE DRILLING/PRODUCTION
ICE INFORMATION REQUIREMENTS

	ACCURACY		RESOLUTION		FREQUENCY (hrs)		TURNAROUND (hrs)	
PARAMETER	S	T	S	T	S	T	S	T
ICE EDGE	2%	2%	2%	2%				
LOCATION	conc.	conc.	conc.	conc.				
MOVEMENT	or	or	or	or				
	5km	100m	1km	100m	6	1	6	I
	1km/d	1km/d	1km	1km	24	C	12	I
ICE TYPE	5%	2%	25m	25m	7 days	3	12	3
CONCEN-TRATION	5%	5%	10m	10m	12	3	12	3
FLOE SIZE/AREA	10m	$10m^2$	20m	20m	7 days	24	12	24
MOVEMENT	1km/day	1km/day	1km	1km	24	C	12	I
ICEBERGS	200m	200m	200m	200m	12	1	12	1
LOCATION								
GEOMETRY		5m	10m	5m	12	1	12	1
MOVEMENT	-	5°	-	5°	-	1	-	1
DIRECTION								
ICE ISLANDS								
SIZE	25m	25m	25m	25m	24	24	24	24
LOCATION	1km	1km	1km	1km	24	24	24	24
THICKNESS	1m	-	-	-	7 days	-	6	-
RIDGES -								
DENSITY	5%	5%	20m	20m	12	12	12	12
HEIGHT	2m	0.25m	10m	1m	7 days	12	12	12
WIDTH	-	1.0m	-	10m	-	12	-	12
LEADS -								
% AREA	2%	2%	25m	25m	12	3	12	3
WIDTH	25m	25m	25m	5m	12	3	12	3
PATTERN	-	-	-	-	-	3	-	3

Code: S - Strategic
T - Technical
C - Continuous
I - Instantaneous

2.4 Fisheries

Fisheries encompass the execution of two main activities: fishing operations and fisheries research to support the management and control of fishing stocks. There is a diversity of information needs for these respective activities and hence they are considered as separate entities of the fishing group in this report.

Fishery operators on the East Coast can be subdivided into inshore fisheries and the offshore, and deep sea, fleet. In general, inshore fisheries are composed of individual or small company operators with a maximum of 5 - 10 boats. The offshore fishing fleet is owned principally by three companies operating larger vessels. The three companies are Fisheries Products, National Sea Products and Lake Group. The types of boats operated on the East Coast by both inshore and offshore fisheries include scallop draggers, groundfish stern and side trawlers, lobster and herring boats, shrimp vessels and smaller groundfish boats. The fishing fleet on the West Coast principally fishes for salmon and herring, mostly from trawlers and purse seiners. Some 2,000 boats ranging in size to 70 feet comprise the salmon and herring fleets.

Fisheries researchers are primarily within the federal government conducting research programs on the East and West Coasts. Their main interests are the relationship of physical oceanography to fish distribution. For example, sea surface chlorophyll is an important factor in the primary productivity of some fish, as evidently is sea surface temperature.

2.4.1 Regional and Seasonal Interests

Fishing is a highly regulated industry in terms of the types of boats that can be operated, the fish that can be caught and the methods of harvesting them. The Atlantic Fishery Regulations [18] cover the management and allocation of fishery resources on the Atlantic Coast of Canada. Within these regulations are a set of fish quotas that are amended each year to meet fluctuating stocks. These quotas are set for individual fish species within each geographic area defined by the North Atlantic Fisheries Organization. The Canadian Atlantic Fisheries Scientific Advisory Commission also contributes to fishery management policies. Twenty different subregions are defined within an area bordered by 39 - 61°N by 42°W - 71° 40'W. Some of the zones are illustrated in Figure 2.3. As well, the regulations specify the fishing season for each species for each subregion. Regulations are gradually forcing the larger boats to leave the inshore fisheries. The smaller inshore fishery boats are taking over in the Gulf of St. Lawrence in particular. The Atlantic Fishery Regulations also stipulate what types of vessels and methods of catching are permitted for each subregion along with any seasonal restrictions.

It has been found from the respondents to the Fisheries' questionnaire that inshore fishermen do not fish in the winter months. For those few that do, their operations are south of the Strait of Belle Isle from December to May. While many boat operators do not operate in ice-covered waters, some boats have been ice reinforced.

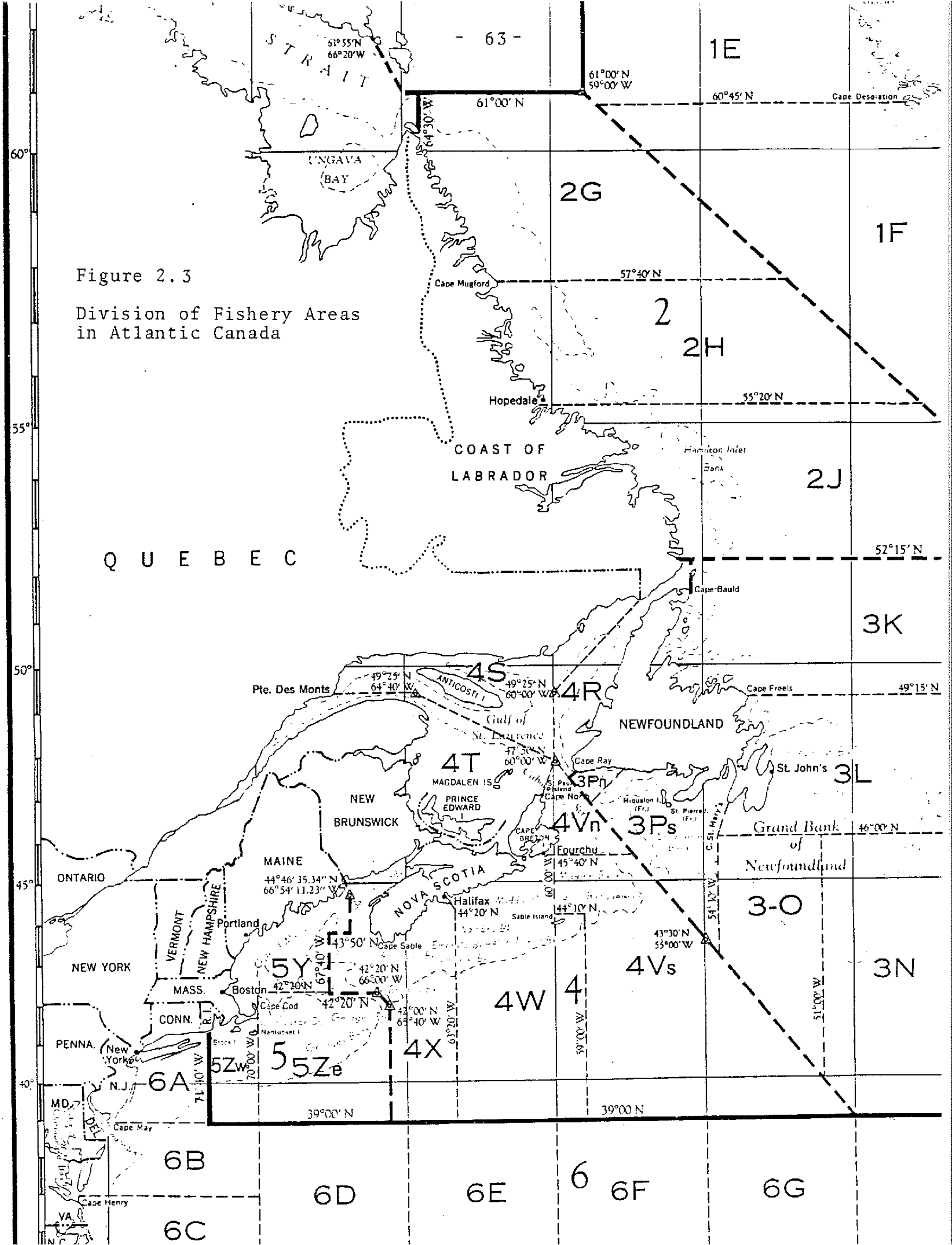


Figure 2.3

Division of Fishery Areas in Atlantic Canada

The larger offshore operators however are extending their operations to the winter months when ice is a major factor. The companies have found in their course of operations that there is a positive correlation between the location of ice and the abundance of fish. It has been reported by ship captains that an abundance of fishing stocks are located within the ice pack which seem to move with the ice. As well, the quality of fish is superior in the winter months. A major area where significant fish stocks are located is Hamilton Bank. Located off the Labrador coast around 54^{O}N latitude, the area has become increasingly important to the deep sea fishing fleet both in summer and winter months. Several people stated Hamilton Bank will experience increased fishing activity in the future.

The apparent correlation between ice and fish has spurred the offshore operators to refit their ships for ice capability, or to buy ice-strengthened vessels. National Sea Products now operates six ice-strengthened vessels out of St. John's and nine out of Halifax. Fisheries Products operates up to 40 trawlers in the north. Despite the purchase of ice-strengthened boats, there have been some mishaps with ice. A boat was lost in 1980 at a cost of $8 million when it struck a piece of multi-year ice along the Labrador Coast. There are a number of ships which are damaged by ice each year.

The timing of Atlantic salmon runs is thought to be influenced by the amount of ice around the coast. However this hypothesis has not been tested due to the lack of good archival data quantifying ice amount and distribution.

It can be seen that the regional and seasonal interests for the East Coast offshore fisheries are changing to include more winter operations in ice covered waters. As well, fishing activity is moving northward from the Grand Banks, Gulf of St. Lawrence and Scotia Shelf to areas off the Labrador Coast.

Fishing on the West Coast is limited to salmon, tuna and herring. The salmon season is from April to October while the herring season is from February to April.

2.4.2 Definition of Information Requirements

Information requirements differ significantly between fishery operators and fishery researchers.

Fishery Operators

Regulations must be consulted first before a fishery operator decides on the location of his fishing efforts. The fishery subregions that are open and the type of fish currently available will be the first criteria in his decision making. Only then will environmental information be consulted.

Fishery operators require ocean and will increasingly require ice information for planning and strategic modes although the definition of these terms will differ between fishermen. Inshore fisherman and day operators would require information on a daily basis to decide whether conditions are worthwhile to fish on a particular day. Offshore operators will have a need for longer term information for planning and routing purposes since their voyages are generally of longer duration. They also will need longer term "strategic" forecasts to plan their voyage to the particular fishing location.

Despite the provision of better quality and more timely information to the fishermen, the impact remains to be seen on their methods of operation. Provided the cost of receiving and recording equipment is low enough, they may be prepared to install a FAX receiver to accept charts showing ice information. However it is probable that many fishermen will still rely on narrative transmissions of forecast information in particular. Improved ice distribution and prognoses must first be shown to be of value the individual fishery operator before he will accept it. In most cases he will still rely mainly on his own past experience.

Larger operators that can more afford to acquire such information can be expected to exhibit greater interest. The parameters are required to plan and run their operations and, with incresing fishing success near or in ice-covered areas, their ice information needs should increase.

In general, the fisheries group has not placed severe requirements on the ice and oceans information system. Their requirements are generally less than the first three groups although the form of distribution may differ because of their more limited options in receiving information.

Fisheries Research

Fisheries research does not require information in the context given to operations. There is requirement for repetitive coverage but most importantly there must be easy access to the data.

Fisheries researchers require ocean information to support a number of various studies examining the relationship between physical oceanography and the behaviour, distri ution and productivity of various fish species. Such studies assist in the understanding of fish behaviour patterns and help government departments determine the status and quotas of fish species.

Overall Statement of Need

A list of parametric requirements for both fishery operators and researchers is given in Table 2.9. These parameters were obtained mainly from interviews with relevant people and organizations as well as from the limited response received for the fisheries questionnaire. No attempt was made to match these parameters to a strategic or tactical support mode; however, the need for these parameters would depend upon prevailing conditions. Fishery operators stated a preference for forecasts of these parameters rather than observations.

Based on a limited sampling from the fishery questionnaire, operators wanted wind and wave information on a once daily basis and forecasts of sea state ranging from 3 - 12 hours.

Table 2.9

Fisheries Group
Summary of Parametric Requirements

A. Fishery Operators

Ice	Ocean
Thickness	Wave - height
Distribution	- period
Edge - location	
Type	Winds - speed
Leads - direction	- direction
- location	
Icebergs - location	Sea surface temperature
- size	
- movement	
Time of freezeup and breakup	
Ice Accretion	

B. Fishery Researchers

Ice	Ocean
Distribution	Sea surface temperature
	Chlorophyll
	Surface currents
	Water colour
	Salinity
	Fishing vessel locations

Fisheries researchers wanted their ocean information collected on a weekly basis with a 2-day turnaround time.

2.5 Meteorology

The present AES data gathering network does not include permanent offshore data collection points - even Weather Station Papa has disappeared - and so it must rely on ships of opportunity, fixed and drifting buoys with suitable instrumentation, and the occasional drilling rig. Basic observational coverage is limited to these few fixed points and along the major shipping lanes. Off the West coast, the U.S. have placed a few large data buoys along the tanker route to Alaska. Papa is being replaced by the Papa Alternate Data System (PADA) which will be a network of drifting buoys that provide surface pressure and water temperature. Ships of opportunity generally do not have a meteorological instrument package, but use the officer of the watch and radio operator; the latter often is not on duty at night so that some of the required synoptic data is not available. The density of the buoy and ship network is quite low compared to what a satellite scatterometer could provide.

Unfortunately, data which would come from a satellite scatterometer generally is asynoptic and so it is difficult to incorporate such data into AES numerical models. However, these data can be used to provide the initial conditions needed by forecast models. Regional models operate down to 30 km gridspacings, depending on the model and use the CMC data as boundary conditions. Such models can use satellite scatterometer data for initialization purposes.

AES experience using the Seasat scatterometer for a manual analysis showed "that Seasat added considerably to the overall data coverage, and that this coverage modified the analysis in a number of areas - particularly in the placement of features (lows, cols and fronts) and in the intensification of pressure gradients (19)."

In putting forth the mission requirements for meteorology, we have drawn from the draft report - "Weather and Ocean Experiments", Sursat Project Report, Fall, 1981, edited by Dr. S. Peteherych (20). The requirements for oceans regions are as follows:

1. Wind - accuracy 2 m/sec. of 10%, whichever is greater, at a frequency ideally of every 6 hours, and turnaround time of less than 1 hour.
2. Water vapour - content and vertical distribution to an accuracy better than 20%.
3. Sea surface temperature - relative accuracy $\pm 0.5^{\circ}C$ and absolute accuracy $\pm 1^{\circ}C$.
4. Climate - archiving of the above three parameters.

Hydrometeorologists have a particular need to know water vapour content which can be determined using infrared and microwave radiometry. Such instruments on other spacecraft have been used experimentally for snow mapping, and now also are being used for lake temperature mapping.

Ice and ocean information on a broader, global scale has been specified by the Canadian Climate Center (CCC) branch of the Atmospheric Environment Service. The CCC has responsibility for archiving meteorological data including marine climatology and wave statistics. Its interest is non real time archiving of derived products such as percentage ice cover of major ocean areas. One of its prime interests is to determine the ratio of ice and open water on a global basis. This ratio is needed for climate modelling and forecasting.

The scale of Radarsat data is very small compared to what CCC requires. A coarser resolution in the order of kilometres or tens of kilometres would be more suitable. These broad scales are much more compatible with the output of a microwave radiometer.

CCC is also a participant in the World Ocean Circulation Experiment for which geoidal data is important. The shape of the geoid is needed as an input for ascertaining circulation patterns. If an altimeter were part of the Radarsat sensor package, CCC could be considered a customer for the data.

Climate Research

As a result of the World Climate Conference in 1979 held under the auspices of the World Meteorological Organization (WMO) the World Climate Research Programme was established. A workshop on the topic was held at AES Headquarters in Downsview on March 10 and 11, 1980 which reviewed and made recommendations on the Canadian input to the programme. A document entitled "Report of the CCO Climate Workshop" (21), was drafted listing the recommendations for the Canadian contribution towards the World Climate Research programme which has the following short term objectives:

(1) continue the development of climate models with particular attention to improving the modelling of atmosphere-ocean interactions;

(2) through experiments and diagnostic studies, to advance the knowledge of climatic processes, particularly those which are most relevant to Canadian interests, and those which are crucial to overall progress;

(3) to increase the quantity, quality and availability of atmospheric and oceanic data in the Canadian area which is important for climate monitoring and research.

The report provides a set of recommended actions towards climate research which covers modelling, diagnostics, process studies, observing system development, climate monitoring, data bases and institutional arrangements. Of these, observing system development and climate monitoring have most direct bearing on RadarSat particularly if a scatterometer were part of the sensor package. Under these two items the report states:

> "Canada should be involved in developing parts of the global climate observing system. Particular emphasis should be placed on the development of new concepts and instrumental systems for observing the oceans near Canadian coasts and the Arctic ice-covered regions. These observing systems should include an appropriate combination of buoys, ships of opportunity and satellite observation and communication systems."

The inclusion of a scatterometer and/or a radiometer on RadarSat would make a significant contribution to such a goal, particularly since it is a proven sensor.

The report addreses the question of data archiving which for a satellite system presently "...high time and space resolution yields quantities of data too large to be archived digitally without real-time processing to reduce the data volume. At present other data are available as images or unprocessed signals, both of which require considerable analysis and interpretation before they can be included in a climate research program." These questions are also of relevance to operational needs, particularly since an archived data base of ice and ocean information will be necessary for design purposes.

2.6 Defence

As with Transport Canada, AES provides basic weather support for all weather-sensitive activities of the Department of National Defence (DND). The special needs of DND are met by the Canadian Forces Weather Service (CFWS), which satisfies the meteorological and oceanographic requirements of the Canadian Forces. Under an agreement between DND and DOE, professional meteorologists are seconded to DND; and AES provides climatological services and meteorological equipment, and its national weather communication system delivers basic and processed meteorological information, obwervations, analyses and forecasts to the CFWS. In turn, CFWS provides AES with weather and oceanographic observation from its units and from military vessels, and undertakes certain civil commitments using AES meteorological standards and operating procedures. For example, AES discharges most of its wave analysis and forecasting commitments throught the CF Meteorological and Oceanography (METOC) Centres. The CFWS is now staffed with some 100 meteorologists and other civilian employees, and with 320 Canadian Forces meteorological technicians.

Information pertaining to DND requirements was acquired mainly from two interviews - one at DND headquarters with the Directorate of Meteorology and Oceanography (D METOC), the other at the Atlantic METOC Centre in Halifax. In general, DND has no short or long range plans to operate marine vessels in the Arctic, and none of their fighting vessels are ice-strengthened. The Canadian Forces do maintain bases in the Arctic and conduct routing flying operations there. However, because ice can be encountered in waters where it operates, DND requires and receives ice information made available through regular AES/CCG facilities.

Ice is of interest in anti-submarine warfare (ASW). It is important to know and understand the effects of ice on background acoustic noise generation, and how it differs from other background noise sources in contrast with target signals. The noise properties are related to the type, movement and location of the ice, and the wave structure in and around the ice.

DND's principal interest is in ocean and weather information - particularly waves, winds and temperature profiles in the water column. Waves and winds are required for ship routing and mission planning purposes. Sea state is particularly important when planning ASW exercises and other wave-sensitive activities. Ship routing or maximum fuel economy is developing into a major impetus in the face of rising fuel costs.

DND does not plan operational exercises in waters containing sea ice and icebergs. However, Maritime Command does conduct ship deployments in these waters to support fisheries surveillance. DND and the CCG jointly man the Rescue Coordination Centre (RCC) which coordinates all search and rescue operations. Should an emergency arise, ice and ocean information, both nowcast and forecast, must be readily available. Such emergencies also include responding to environmental accidents such as oil spills. DND's ice information requirements are very activity-dependent, but there is a general need for most of the ice information products produced by the system. Essentially, DND will accept whatever can be provided, and recognize its ice information needs would be met by any system driven by users with more stringent requirements.

Table 2.10 lists DND's seasonal and areal ice and ocean information requirements. Perhaps the major additional need compared to the other groups is an expanded area of interest for information to include extended regions of the Atlantic and Pacific oceans.

Table 2.10

DEPARTMENT OF NATIONAL DEFENCE

SEASONAL AND AREAL INFORMATION REQUIREMENTS

1. ICE INFORMATION

Area	Seasonal Requirement
Gulf of St. Lawrence	December - April
Labrador Sea, East Newfoundland	Year - Round
Eastern Arctic	July - September

2. OCEAN INFORMATION

North Atlantic, North Pacific	Year - Round

METOC wave forecasts (12, 24, and 36 hr.) are considered to be a good product. It has been evaluated through a user questionnaire, and a report has been prepared entitled "CF METOC Wave Program Evaluation" by B.D. Brodie and D.J. Russell, April 10, 1081. Responses received from 119 clients, mainly civilian, were quite positive. The principal users of METOC wave information products are:

- Canadian and other military operators
- container ships and other domestic and foreign commercial ship operators
- rig operators and consulting firms to rig operators
- Canadian Coast Guard
- research community

While the wave forecasts are considered to be a good product, they do lack the detail from ships of opportunity, oil rigs and wave rider buoys dispersed around rigs and other strategic locations by rig environmental consultants and DFO. Direct measurements from a satellite-borne radar altimeter could provide more reliable data of higher density and predictable regularity and could improve the detail in the present charts.

Although the METOC products are used by private organizations, there are no plans to create, improve or alter the format of the present products. D METOC considers itself solely a supporting agency for defence activities.

Wave forecasts also rely on wind data which is sparse and unreliable in most offshore regions of Canada. Scatterometer data would be of great benefit in improving wave forecasts according to METOC personnel, but unfortunately, the surface winds only reveal a part of the story. Upper air movements and temperatures are also needed to forecst weather and waves, but research only now is trying to prove the efficacy of satellite sensors for measuring such parameters.

METOC can be considered both a user and a provider of ocean information. Its main interest is in acquiring data reduced to geophysical parameters to run predictive models and forecasts which are, in turn, used by defence and other interests. It stated a turnaround time requirement for such data of 2 hours after observation. Ice data was wanted on a daily basis within 2 - 6 hours of acquisition.

Sea surface temperatures (SSTs) are useful for ASW work; however, the accuracy from a passive microwave radiometer ($\pm 1.5^{\circ}$C) is not sufficient for DND's needs which are $\pm 0.5^{\circ}$C. NATO documents specify $\pm 0.25^{\circ}$C for SST. Moreover, temperature profiles throughout the water column are needed which are not possible to measure from a satellite. The twice weekly SST contour charts put out by METOC, which now use satellite data, were considered by DND to be adequate given the complexity of surface temperatures. If the data were to be improved, it is not known whether greater use could or would be made of the charts.

In times of war or national emergencies, ice, ocean and weather information will be controlled. Such a provision needs to be incorporated into any plan for a Canadian environmental information system.

Under the present circumstances of fiscal restraint, it is not likely that DND would place high priority on improving environmental information unless it becomes critical to operational effectiveness. Undoubtedly the department would use data provided by the RadarSat sensor package if and when it becomes available, but it is unlikely to be motivated sufficiently to become directly involved in the program.

2.7 Research

The research community associated with ice and oceans covers a very broad range of interests which includes the investigation of natural phenomena, the gaining of a deeper understanding of the physical, chemical and biological processes associated with ice and oceans, and research on new or improved sensors to measure phenomena of interest.

While most researchers are located within the universities and in governments, increasing numbers are working in the private sector - in the major resource companies and in service companies established to serve industry and governments. The manufacturing industry conducts R and D on sensors. For the purposes of this study, we have divided the research group into two parts - one that deals principally with ice, and another that is concerned mainly with oceans. While RadarSat is an operational demonstration satellite, it will produce data which will be of interest to the research community.

2.7.1 Ice Research

Ice research interests can be subdivided into two areas - operational concerns, where the objective of the research is to gain further insight and understanding of ice phenomena as they relate to specific operations, and science concerns, which study the circulation of the ocean and the atmosphere, related climatology and the properties of sea ice as a material.

Sea ice is an important component of the global climate system and an accurate description of the ice cover, particularly concentration changes and related ice movements, are important to an understanding of the relationship between ice and climate. For example, it is thought that accurately monitoring the proportion of the oceans covered by sea ice may be an indicator of the effect of increasing carbon dioxide in the atmosphere. The scientific study of sea ice emphasizes more global coverage, as opposed to other characteristics of ice information including turnaround time.

Operational research on sea ice is geared to the development of techniques to determine the exact nature and location of ice hazards such as icebergs and multi-year ice floes, as well as sea ice growth and movement. An intensive activity underway is to formulate computer driven models for predictions of ice behaviour. The eventual goal is to implement these models operationally into the ice information system for better forecast information products.

The principal source of information on the requirements for ice research was the minutes of the first Canada - U.S. Ice Study Team Workshop for Ice Mission Requirements held at Cornwall, Ontario, in February, 1981. In contrast with operational users where the needs of most members of any particular operational group are more or less alike, the quantitative requirements will vary from one researcher to the next. Therefore it would be misleading to place numerical specifications on the parameter accuracy or resolution requirements. In general, the requirements stated by researchers at the Cornwall conference were those needed for research in support of operational missions.

Data received from the satellite sensors needed to support operational missions will be determined by those missions, and research users will not likely be able to exert much control on the acquisition or processing of such data. A significant component of current ice research is to demonstrate the value of remote sensing from aircraft and satellite platforms, and to show that such data is valuable for engineering design decision making, planning, strategic and tactical operations associated with ice-covered waters.

Another major research objective is to improve the ability to forecast ice conditions. Forecast models that integrate remotely-sensed data on ice and meteorological parameters are needed to provide future information products of significant value to ice-related operations.

Finally, there is still some doubt as to the resolution requirements of imaging sensors to detect an object or characteristic, and to measure it. Continuing remote sensing research and related ground truthing is needed to put this issue to rest, and to permit reasonable specifications to be placed on the resolution requirements of future remote sensing ice surveillance systems.

Research requirements have been grouped under the following headings:

A. Ice Type and Ice Feature Identification

- ice type classifications - distinguish ice islands, multiyear, first year (smooth and rough), grey, nilas, grey/frazil, open water.

- ice features - distinguish melt ponds, icebergs, pressure ridges, thin ice, leads/ polynyas and marginal ice zones

B. Parameter Identification

Automated techniques are needed for interpreting imagery in timely fashion. The following parameters need to be extracted:

Boundary

- ice edge
- marginal zone
- pack

Concentration

- ice in water
- ice type distribution

Albedo

Motion

- pack
- floe
- margin

Ridges

- detection
- density
- orientation
- height
- width
- type

Icebergs

Snow Pack

- percent cover
- water content

Ice Type

- multiyear
- first year - thick, thin
- young
- slush
- seasonal variation
- frozen melt ponds
- geographic variations

Leads

- fractional area
- orientation
- width
- frozen/open
- detection

Floe

- position
- type
- size

Melt

- stage
- aerial extent

Surface Temperature

Ice Thickness

C. Ice Dynamics and Thermodynamics

D. Engineering Problems of Ice Mechanics

There is a need to know ice loads on fixed structures and vessels for design and certification purposes. Information required includes:

a) Environmental statistics - over as long a time span as possible up to 100 years

b) Ice properties

c) Ice features (geometry, bulk properties)

d) Environmental driving forces (principally wind and currents)

e) Ice movements

Remote sensing can provide parameters b) to e) above, and the following mission requirements have been stated:

Item	Desired	Minimum Adequate
Spatial resolution	10 m	20 m
Temporal resolution	6 hr	24 hr
Area of interest	2 km 2km	-
Absolute position between passes	0.25 km	1 km
Ice type identification	FY, MY, Glacial	FY, MY Glacial
Ice feature identification	Ridges, Rubble Floes, Leads	Ridges, Rubble Floes, Leads
Turnaround	2 mos.	6 mos.

E. Icebergs and Ice Islands

Location, size and motion of icebergs, ice islands, bergy bits and growlers on a daily basis and disseminated within 24 hours are required by researchers. Source areas include east, north, west Greenland, Melville Bay, Lancaster Sound, Baffin Bay, Labrador Sea, Beaufort Sea and the Antarctic convergence.

F. Ice Shelves, Ice Tongues and Channel Plugs

Location and berg production rate information is needed for Arctic and Antarctic shelves and tongues, Alaska calving bays and plug channels such as Nanson, Sverdrup and north Greenland. Location data should be collected once per year, but particular events such as berg production need to be monitored more frequently, depending on production rates.

Some parameter specifications for icebergs, ice sheets and ice shelves were specified in the Ice and Climate Experiment (ICEX) document[32]. The ICEX group was established in February, 1979 to review and make recommendations on the requirements for satellite sensing of ice parameters and ice processes, research, climate studies, resource extraction and ocean operations as well as needs for field projects complimentary to the satellite observations. System implementation options were also considered. The specifications stated by this working group for icebergs, ice sheets and ice shelves can be considered the most up to date definition of research needs at this time.

In recognition of the role that could be played by RadarSat, the Oceans Working Group of the Canadian Advisory Committee for Remote Sensing formed a RadarSat Oceanographic Study Team containing representatives from government, industry and the universities. A preliminary report was filed with the RadarSat Project Office dated May 29, 1981 (23). The report, prepared by a group under the Study Team's chairman, Dr. C.S. Mason, forms the basis of the following paragraphs.

At present, there is only a very low level of research activity in Canada in which remote sensing is used in application-oriented marine studies. The team pointed out that significant and lasting results from a RadarSat program in the oceans area will require continuing funding for research studies beyond 1982. The team rcommended a figure of $4 million per year to sponsor processing, interpretation and application-oriented research in conjunction with a Canadian microwave remote-sensing program.

The team addressed quite specifically the potential applications of SAR, and identified five:

- directional wave spectra and wave climate studies
- surface winds
- internal waves, fronts and eddies
- wave refraction and shoaling
- surface water velocity

The team's report to the RadarSat Project Office outlined seven experiments exploiting the above SAR applications, and further proposals have been received by the team concerning internal (Leblond, UBC) and surface currents (Greenberg, BIO).

It should be emphasized, however, that SAR is not necessarily the most important sensor to the oceanographer. Much more development work needs to be done before SAR can be proven useful. In the words of one oceanographer (F.U. Dobson, BIO), "it is low on the priority list for oceanographic research". According to Dobson, four measurements stand out as the first-priority interest: surface wind stress, ocean colour, sea surface temperature and sea surface topography.

Parameters such as these rely on a variety of different sensors. Surface winds require a scatterometer or passive microwave radiometer - Seasat proved these sensors were capable of measuring surface wind velocities to within m/sec or 10%, and direction to within 20°.

Ocean colour monitors have been developed for coastal sedimentation and biological studies.* Sea surface temperature can be measured to within $0.5^{\circ}C$ by infrared radiometers, and eventually using passive microwave radiometry. Surface topography requires a radar altimeter on board the satellite and more accurate measurements of the earth's gravity field (geoidal height). Accuracies of a few centimetres are required, and may exceed the unclassified state of the art for some time.

---

*For example, a fluorescent line imager using a 400-500 CCD array at the chlorophyl 685 nm fluorescent line is being developed in Canada for ultimate use in space.

In broadening the statement requirements for oceanographic applications to include sensors other SAR, we have turned to material prepared by Dr. S. Peterherych of AES. It appears as Table C-11, in Appendix C. The best sensor is shown in the right-hand column, from which it is evident that a scatterometer ranks very highly if wind data is important. Section 2.5 dealing with meteorology emphasized the importance of offshore wind data which reinforces the oceanographer's needs for wind stress.

As stated earlier, there are no major operational oceanographic programs at present, although some planning decisions are being contemplated by DFO. If a directional wave forecasting and climate modelling program is created, SAR-derived data on surface waves, internal waves, fronts and eddies and other small-scale roughness patterns will be required at regular geographical and temporal intervals.

Finally, in a communication from J.F.R. Gower, IOS (24), it was suggested that if the team were to broaden its concerns beyond the SAR sensor to the type of sensor suite planned for NOSS, "then there should be coordination with the previous NOSS planning effort". The writers strongly endorse this view.

3. ANALYSIS OF USER REQUIREMENTS

In analysing user requirements for ice and ocean information, it was evident that the needs varied considerably between the various user groups. The motivation for information needs of those groups which routinely conduct operations in Canadian waters can be divided into four main groupings:

(1) Safety and hazard avoidance
(2) minimizing environmental risks
(3) optimization (economics)
(4) emergency situations.

These factors affect industry and government in related and different ways, particularly in the roles that each plays in shipping and hydrocarbon development. While government requires ice and ocean information to conduct its own shipping operations such as in the Canadian Coast Guard and National Defence, it also has the responsibility to develop and enforce appropriate regulations for shippers, drillers and fishermen to ensure safety of their operations. Industry in turn must adhere to the regulations and be responsible for the safety and low environmental risk of their activities. Industry has and will be strongly motivated to optimize their operations to minimize operating and capital costs. Appropriate and timely information and forecasts are required to respond properly to emergency situations.

An assessment of requirements for ice and ocean information at the planning, strategic and tactical support levels for user groups is very strongly a function of the time of year, geographic location and, for present or future operational scenarios, a function of their respective capabilities in coping with environmental conditions.

The analysis of user needs was viewed from two different levels. First, the parameters cited by each user group were compared to establish where the differences are and to provide insight into the varying reasons for wanting the information. Second, the specifications of the parameters were matched to determine the most stringent requirements for accuracy, spatial resolution, repetition of coverage and turnaround of information taken from the various summary tables in Appendix C of this report. Included in the summary tables are the number of user groups setting numerical specifications. From the information received in the study, it was evident that the first three groups, 1) CCG and general shipping, 2) oil and gas shipping and 3) offshore drilling and production were the most conprehensive and specific in their ice and ocean information needs. In summarizing the parametric specifications for strategic and tactical support levels, these three groups formed the basis for almost all critical requirements.

Parameter specifications for planning support were available only from one user group: offshore drilling and production. Other groups such as the Canadian Coast Guard and general shipping recognized and identified parameters for planning support; however, no specifications were imposed beyond the need for frequency, normals and extremes. Such information would be obtained from a historical data base or atlas.

An archived ice and ocean data base is needed to create and improve probabilistic models of ice and ocean phenomena for design and regulation purposes. Several statutes such as the Canada shipping Act, Arctic Waters Pollution Prevention Act, Fisheries Act and the Canada Water Act are examples already in place to provide regulatory measures. However, many future developments are in areas where ice and ocean characteristics are not well known over a long time period. The complete definition of the environment requires years of data to define the necessary means and extremes.

A lack of complete understanding of the environment can lead to the overdesign of structures and ships with economic consequences ranging into millions of dollars. A more complete knowledge of the wave climate with accompanying extreme events for example, may lead to the lowering of the height above water for an offshore structure resulting in significant savings.

A summary list of parameters and specifications for each geographic region beyond some obvious observations is difficult because of the diversity of needs. Beyond lists of parameters applied to geographic regions as the Canadian Coast Guard has done, no geographical differences in specifications were possible. The importance of any parameter and its specifications will largely depend on the environmental situation at the time, the vessel or offshore platform capability as as the attitude and motives of the user. Specifications will change from location to location and with the time of year. The Arctic Pilot Project, in its strategic routing study, subdivided the route into two areas, each with its own specifications of the same parameters. These differences, however, relate only to frequency of observation and turnaround of information.

3.1 Analysis of Cited Parameters - Their Role in User Functions

It was not possible nor practical to compare all the user group requirements for ice and ocean information to the specific details of accuracy, resolution, frequency and turnaround to cover all the possible activities of the whole community. Some groups could not be more definite in their needs beyond citing parameters of interest, either because the requirement is so much a function of the prevailing conditions or their present system for receiving information is deemed adequate based on present activities. In the latter case, such as fisheries, any improvement in the present data/forecast dissemination system would be acceptable. Presently, they now feel more confident in their own evaluation and experience.

A more complete listing of parameters for each user group was assembled than was used for the accompanying specifications. Leaving aside the questions of turnaround, frequency and resolution, it was useful to discuss in a general way the role the parameters play in the operations and functions of the user groups.

3.1.1 Ice Parameters

Table 3.1 shows a compilation of the parameters cited by each of the six operational user groups for strategic purposes. It can be seen that the number of parameters decreases somewhat from left to right reflecting the approximate priorities of user groups for ice information. The first three groups, CCG, oil and gas shipping and offshore drilling/production wanted the largest number of parameters because of the geographic range of their activities and the diversity of conditions they will encounter. The number and order of importance of parameters will also be a function of the time of year.

The relationship between parameters and the activities of the user groups differs for each and every one. The main activities can be divided into three groupings. First, the meteorology group has some interest in the distribution parameters but more from a global viewpoint for climatological modelling purposes. The second group relates to the operation of ships and boats which embraces the CCG, oil and gas shipping, fishing and defence. The third and final group is offshore drilling and production, which is distinguished from the others primarily because of its concern with the immediate operating area.

Ice Edge Location

All six operating groups stated a need to know the location of ice edges. For shipping activities, the importance of ice edge is dependant upon the capabilities

TABLE 3.1

OPERATIONAL USER GROUP VS. CITED STRATEGIC ICE PARAMETERS

PARAMETER	CCG	OIL & GAS	DRILLING	FISHING	METEOR-OLOGY	DEFENCE
TYPE - % OF AREA	*	*	*	*		*
CONCENTRATION % OF AREA	*	*	*	*	*	*
THICKNESS (m)	*	*	*	*		
ICE EDGE - LOCATION	*	*	*	*	*	*
- MOVEMENT	*		*			*
LANDFAST ICE - LOCATION	*					
ICEBERGS - LOCATION	*	*	*	*		*
- SIZE		*	*	*		*
- MOVEMENT				*		
RIDGES - HEIGHT	*	*	*			
- WIDTH		*				
- SPACING		*				
- PATTERN	*	*	*			
LEADS - % COVERAGE	*	*	*	*	*	
- WIDTH		*	*			
- PATTERN	*	*	*	*		
- SEPARATION		*				
PRESSURE - CONVERGENCE/ DIVERGENCE	*	*				
FREEZE-UP/BREAK-UP			*	*		
ICE ISLANDS - SIZE	*	*	*			
- LOCATION	*	*	*			
SNOW COVER	*	*				
FLOES - SIZE	*	*	*	*		
- MOVEMENT	*		*			

of the vessel, geographic location and the time of year. The large tankers which will be plying Canadian waters within the next decade have little to fear for the safety of their vessel through contact with the ice edge. This contrasts with smaller cargo ships and fishing vessels which have little or no ice capability. They may wish to know the location of the ice edge to avoid ice entirely.

Ice edge becomes important to a large tanker in the process of optimizing its route for economic reasons. The influence of the ice edge will be to change its mode of operation from open water to ice depending upon ice concentration. It is probable that operating horsepower will be increased to break the ice cover with resulting increases in fuel consumption. The forward speed of the ship also will likely be reduced. Therefore it may be desirable to steer a course such that the tanker maintains its route in open water for as long as it is practical to do so.

The ice edge is important to fishing boats for several reasons. Most have little or no ice breaking or resisting capability and so will want to avoid the ice as much as possible. At the same time, it has been shown that the fish stocks follow the ice so knowledge of the ice edge deterimines the probable best fishing areas.

Offshore drilling needs to know ice edge location for deploying its support vessels during the course of drilling operations. Presently the East Coast drilling is on a seasonal basis, so the location of the ice edge and its projected movement is needed in order to decide when the drillship can be sent to the site. In the Beaufort Sea, the position of the multi-year ice edge and its relation to the drilling sites is always of concern. The edge location affects the conduct of drilling operations in that differing distances of the edge from site call for differing levels of alert. Alert levels for Dome operations in the Beaufort Sea are based on the "T" time, or time to disconnect plus a number of hours determined by the estimated arrival time of significant ice. At each alert level certain procedures, such as close tactical reconnaissance or deployment of a supply vessel, are initiated while activities at the drillsite are altered or changed in accordance with the ice status. The declaration of an alert level is dependant upon the concentration of ice, its speed, as well as the nature of the ice itself (type, ridging, etc.).

Ice edge location for defence purposes defines the limit of normal operations since they presently have no ice-capable ships.

Ridges/Leads

Ridges and leads are of particular interest when there is a consolidated ice cover where such ice features can have a significant effect on a ship's progress. When transmitting a consolidated ice cover, the ship wishes to find the path of least resistance to speed up transit time to expend less fuel and to reduce wear and tear. Ridges are the single greatest ice impediment to a ship's forward progress.

Successful penetration is a function of the ship's horsepower and mass as well as the ridge geometry, type, degree of consolidation, surrounding ice thickness and the proximity of other ridges. Multi-year ridges are the worst case because of the stronger ice and full consolidation of the keel requiring a larger mass of ice to be broken. Should a ship become stuck in the ridge, it must back up in its own track and ram the ridge at nearly full power. This "ramming" cycle may have to be repeated several times before the ridge is penetrated. Significant fuel is spent during the ramming and there is greater potential for damage. The ship's net forward progress is slowed in penetrating ridges. When the ship backs up its track to enable it to build up proper speed before hitting the ridge, ice can be ingested into the propellers and/or hit the rudder. Therefore it is desirable to minimize the ship/ridge interactions as much as possible.

The significance of riding differs in relation to vessel capability. For smaller icebreakers and supply boats, considerable information on ridging may be required before deciding whether to attempt to penetrate the ridge or not, even for small ridges and rafts. It may be within the capability to pierce a 1 metre high ridge without undue wear and tear on the ship and within a reasonable period of time but not a 2 metre ridge. Knowing such information will permit the ship master to make the correct routing decision to limit the delays and fuel penalties.

Leads are paths of least resistance and wherever possible, ships will try to follow them. If the lead is properly oriented, the ship could use the opening to advantage in reaching its destination.

In geographic areas and times of year where the ice concentration is less than 10/10ths, the ridges and leads are of much less concern since there is considerable open water available. The exception to ridging would be where the ship encounters a large floe and a decision must be made whether to go through or around it. One of the criteria to use in the judgment would be the density of ridges and their geometry.

Ice Type/Thickness

Ice thickness presently cannot be ascertained through any remote-sensing method on an operational basis. Thickness is inferred by interpreting various ice types and relating these to a thickness range. Therefore the distinction of ice type leads to an estimation of ice thickness.

Thickness and ice type are fundamental parameters to know for all groups operating in ice-covered waters. The need to know ice thickness is again related to the vessel capability. Although detailed information on thinner ice types is of much less concern to large tankers, it does become important for less ice capable ships and boats. An ice reinforced fishing boat may be able to break several centimetres of ice but not tens of centimetres.

Differentiating first year from multi-year ice is a fundamental requirement of all operational user groups. Multi-year ice is thicker and stronger and poses a significant hazard to ships and platforms alike. The proposed large tankers may well be capable of breaking most occurences of multi-year ice but at increased cost in fuel, possible delays and increased repairs and maintenance. If the ice is sufficiently thick and strong, these tankers may well have to ram the ice to get through. Thus it is in their best interests to avoid multi-year ice as much as possible. For smaller icebreakers and vessels, multi-year ice presents a barrier impossible to pass through. Small pieces of multi-year ice embedded within a first year matrix also can be a significant hazard to small ships. Detection of these pieces is difficult and a collision with one could result in substantial damage to the vessel.

Offshore drilling platforms require a knowledge of first-year vs. multi-year ice floes, particularly since the latter are thicker and stronger and, if moving sufficiently fast, could displace the vessel off the site unless corrective action is taken.

Pressure - Convergence/Divergence

Converging and diverging areas occur for ice concentrations less than 10/10ths cover. This parameter is of greatest interest to ships. Areas of convergence, where the influx of floes results in a concentration increase are to be avoided for two reasons:

(1) more ice must be broken

(2) if the initial ice concentration was already high, the convergence of floes may be sufficient to pinch the ship and make icebreaking more difficult even in thinner ice.

Pressure is also very important for ships in consolidated ice covers. The ship's resulting track allows the pessured ice edges to close together which may adversely affect the ship if it has to ram a ridge, for example. In this case, the closed track will make it more difficult for the ship to back up a sufficient distance to initiate the ram. More horsepower is required with resulting fuel penalties and the risk of damage to propellers and rudders is greater. The pressure may be so great as to trap a moderately sized icebreaker for hours. The ship may simply have to wait until the pressure eases or fully subsides before proceeding.

Icebergs/Ice Islands

Both icebergs and ice islands are considered to be ice hazards, the importance of which depends on their size and the vessel or platform capability. As well, these features only occur in certain geographic areas. Ice islands are limited to the Beaufort Sea although fragments have been observed in the past in some of the channels in the Arctic Islands. Icebergs are a feature in the Eastern Arctic and adjacent southern latitudes.

Ice islands are to be avoided entirely by all ships and their incursion on a drilling platform, vessel and even artificial island could result in disaster.

Icebergs affect a wider range of activities because of their geographic origin and distribution. The iceberg size will determine what course of action is to be taken in relation to the operation and its capability. For example, a large tanker can withstand collisions with icebergs that would severely damage a smaller vessel. The known presence of icebergs in an area will undoubtedly cause a tanker master to slow down his vessel substantially. The above water profile of an iceberg is not necessarily sufficient to establish whether it is of concern. As well, the master wishes to minimize damage even though collision may not disable or stop the ship.

Present offshore drilling operations off Canada's East Coast, notably off the Labrador coast and at Hibernia, must always be aware of the location of icebergs. The size, movement and proximity of the icebergs relative to the site will decide the action to be taken. If the iceberg is small enough and projected to come dangerously close to the site, efforts will be initiated early to tow the iceberg away. If the threatening iceberg is sufficiently large to discourage towing efforts, the only option may be to move the drillship off the site.

Combination of Parameters

While any one parameter in itself may be of concern to a ship or boat operator or drillship master, more often it will be a combination of factors which ultimately will dictate the course of action to be taken. For example, alert level procedures for Dome's offshore drilling operations require knowledge of ice concentration and velocity along with a general description of the condition of the ice.

The declaration of an alert level is not only based on the available ice information, but also on the considered judgment of the master. It is in this context that the role of ice information must be assessed. Consider the decision making process of the master and the information sources he has at his disposal. Ice information provided by aircraft and satellite sensors is one source. They provide data which is remotely measured, giving some inferred information on the nature and sectional properties of the ice. While such information may be sufficient a large portion of the time, a closer look may be required in some instances. A supply vessel or ship-based helicopter may be needed as a probe. The information provided by such a probe, combined with remotely-sensed data and the considered judgment and experience of the master will all be given various weightings in deciding the appropriate course of action.

3.1.2 Ocean Parameters

Table 3.2 summarizes the ocean parameters cited by each user group. The need for ocean information is more limited than for ice in season and geographical extent, although in the context of present operating scenarios it is of greater concern than ice for many users.

A greater need for ocean information occurs only in areas and times of year when ice coverage is not a factor (with the noteable exception of icebergs). Further, the areas where wind and wave information

TABLE 3.2

OPERATIONAL USER GROUP VS. CITED STRATEGIC OCEAN PARAMETERS

PARAMETER	CCG	OIL & GAS	DRILLING	FISHERIES	METEOR-OLOGY	DEFENCE
WAVES - HEIGHT	*	*	*	*		*
- DIRECTION	*	*	*			
- PERIOD	*	*		*		*
SWELL - HEIGHT	*	*	*			
- PERIOD	*	*	*			
WIND - DIRECTION	*	*	*	*	*	*
- SPEED	*	*	*	*	*	*
SEA SURFACE TEMPERATURE			*	*	*	*
SURFACE CURRENTS			*	*		
ICE ACCRETION CONDITIONS	*	*	*	*		*
CHLOROPHYLL				*		
WATER COLOUR				*		
SALINITY				*		

become a concern are where there is sufficient fetch to build up waves such as in Baffin Bay, Davis Strait and the open waters off the East and West Coasts.

The preliminary statement of user requirements made reference to observational and forecast needs for ocean information parameters. Some time after issuing the report, a meeting was convened with users to further elaborate on their ocean information needs, particularly waves. All offshore and ship operators agreed that only forecast wave information was required, since the direct observations obtained via a satellite could never be turned around fast enough or be site specific enough to be of use. Offshore platforms will already have data collection systems in place near their immediate operating areas, so they will not need current information from outside sources. The exception to the need for observational wave data is DMETOC which require it for models to make the forecast predictions. The addition of gridded data on wind vectors would improve the initialization of the models and presumably improve the quality of the forecasts.

An additional required parameter which was strongly voiced by the user community through the RadarSat Information Standards Committee was a prediction of ice accretion or spindrift conditions. Icing on ships, boat and structures, if sufficiently severe, can have a significant effect on their performance and safety. The prediction of icing is dependant upon several ocean parameters besides waves including windspeed and direction, air and sea temperatures, salinity as well as the size and speed of the vessel.

Sea surface temperature (SST) was required by four user groups for differing reasons. Offshore drilling and production in the East Coast areas wanted SST information for predicting freezeup and breakup conditions. Meterology require SST as an input into regional and global climatic models. Defense needs SST data for use in anti-submarine warfare and for fog prediction. Anti-submarine warfare needs an analysis of the water column temperatures and boundaries known as an ocean frontal analysis to determine the success of acoustic methods for locating submarines. There is a correlation between SST and the distribution of fish species.

Surface currents provide indication of subsurface currents important for sediment transport studies related to offshore pipeline production installations and as an important for sediment transport studies related to offshore pipeline production installations and as an input into predictive models of iceberg movement.

3.2 Critical Ice Parameter Specifications

Parameter specifications for ice were obtained from the tables in Appendix C for CCG and general shipping, oil and gas shipping and offshore drilling production. Ice parameters are needed for all geographic regions except the West Coast on a year-round basis with the following exceptions:

1) Icebergs are a year-round feature in the Eastern Arctic and the Eastern seaboard. They are not present in the Beaufort Sea and in the Canadian Arctic Archipelago channels except for Jones Sound and eastern Lancaster Sound.

2) Ice Islands are limited to the Beaufort Sea and Arctic Ocean.

3) Deterioration and surface melt (strategic need only) is necessary to know during the melt season within areas of static ice. This is limited to the interior Arctic channels where ice tends to melt in-situ more than breaking up by movement like in Baffin Bay or the Beaufort Sea.

4) Certain parameters are dependent on the type of marine activity. Marine activities will dictate seasonal needs and parameter specification.

5) Multi-year ice is not present in the Gulf of St. Lawrence or the Great Lakes. Ice type will be limited to first year and thinner ice. While detailed information on thin ice types may not be important to large tankers, it will be important to the smaller boat operators such as fishing boats and cargo vessels.

6) The requirement for year round information was identified by oil and gas shipping and offshore production systems. Such of the activity will center in the Canadian Arctic Archipelago in channels where the ice does not move after freezing in. Once the distribution of ice and ridges is known, there may be no further need for information until the breakup period when the ice starts to move again.

7) The need for updates increases after the ice has broken up and during the period when it has the greatest potential for movement and change.

Strategic

Table 3.3 details the critical strategic parametric requirements. The table includes the number (maximum of 3) of user groups stating specifications. While some groups did not specify some parameters, this did not mean that such paramterss were not of interest. By not imposing any requirements, these groups either accept what is being done now, or see their needs would not impose any constraint. The minimum repetition of coverage was 6 hours with a 2 hour turnaround. The turnaround ranged from about 25 - 33% of the repetition time in order for the information to be useful.

The requirements stated in Table 3.3 were matched to the speciic user group which gave the critical specifications. Table 3.4 identifies the critical user group for each parameter specification. The table suggests that it is not always the same user group for

Table 3.3 CRITICAL STRATEGIC ICE INFORMATION REQUIREMENTS

PARAMETRIC REQUIREMENTS		SPECIFICATIONS				
PARAMETER	TYPE OF INFORMATION REQUIRED	ACCURACY	SPATIAL RESOLUTION	REPETITION OF COVERAGE	TURNAROUND OF INFORMATION	NUMBER OF GROUPS MAKING SPECIFICATIONS / CITING THE PARAMETERS
BOUNDARY/EDGE	location	100 m	100 m	6 hr	2 hr	3/6
	velocity	1 km/day	1 km	24 hr	6 hr	1/3
TYPE	% by area	5%	25 m	6 hr	2 hr	3/5
CONCENTRATION	% by area	5%	10 m	6 hr	2 hr	3/6
THICKNESS	m	0.2 m	0.2 m	24 hr	6 hr	3/4
LANDFAST ICE	location	<500 m	500 m	24 hr	6 hr	1/1
FLOES	size	10 m	20 m	12 hr	3 hr	3/4
	velocity	1 km/day	25 m	12 hr	6 hr	2/2
RIDGES	height	<1 m	1 m	6 hr	2 hr	3/3
	density	5%	20 m	6 hr	2 hr	2/3
	orientation	10°	-	6 hr	2 hr	1/1
	separation	<20 m	20 m	6 hr	2 hr	1/1
	type	FY/MY	-	6 hr	2 hr	1/3

Table 3.3 (cont'd)
CRITICAL STRATEGIC ICE INFORMATION REQUIREMENTS

PARAMETRIC REQUIREMENTS		SPECIFICATIONS				
PARAMETER	TYPE OF INFORMATION REQUIRED	ACCURACY	SPATIAL RESOLUTION	REPETITION OF COVERAGE	TURNAROUND OF INFORMATION	NUMBER OF GROUPS MAKING SPECIFICATIONS
LEADS	orientation	10°	25 m	6 hr	2 hr	2/4
	% area	2%	20 m	6 hr	2 hr	3/5
	width	25 m	25 m	12 hr	3 hr	2/2
	separation	<500 m	500 m	12 hr	3 hr	1/1
PRESSURE	convergence	positive sign	2 km	6 hr	2 hr	2/2
ICEBERGS, BERGY BITS' GROWLERS	size	5 m	10 m	6 hr	2 hr	3/4
	height	3 m	3 m	6 hr	2 hr	1/4
	location	20 m	100 m	12 hr	3 hr	2/5
ICE ISLAND FRAGMENTS	size	<20 m	20 m	12 hr	3 hr	3/3
	height	< 1 m	1 m	12 hr	3 hr	1/3
	location	20 m	100 m	24 hr	6 hr	2/3
SNOW COVER	thickness	0.2 m	-	12 hr	3 hr	2/2
DETERIORATION	% meltponds	5%	-	7 days	7 days	1/1
SURFACE CHARACTERISTICS		10 m	10 m^2	6 hr	2 hr	1/1

Table 3.4

Parameter Specification vs User Group

Strategic Ice Information

ICE	CRITICAL USER GROUP			
Parameter	Accuracy	Resolution	Repetition	Turnaround
Edge/Boundary				
- location	1	1	2	2
- movement	3	3	3	3
Type - % by area	1,3	1,3	2	2
Concentration				
- % by area	1,3	3	2	2
Thickness	2	2	1,2	1,3
Landfast ice				
- location	1	1	1	1
Ridges				
- height	2	2	2	2
- density	3	3	2	2
- orientation	2	2	2	2
- separation	2	2	2	2
- type	2	2	2	2
Leads				
- orientation	2	3	2	2
- % by area	3	2	2	2
- width	3	3	2	2
- separation	2	2	2	2
Pressure				
- convergence	1	2	2	2
Icebergs, bergy bits and growlers				
- size	2	3	2	2
- height	2	2	2	2
- location	1	1	3	1
Floes - size	3	1,3	2,3	2
- velocity	3	1	1,3	1

Parameter	Accuracy	Resolution	Repetition	Turnaround
Ice Islands	2	2	2	2
- size	2	2	2	2
- height	2	2	2	2
- location	1	1	1,3	1
Surface Characteristics	2	2	2	2
Snow Cover	1	1	2	2
Deterioration	1	1	1	1

Legend

1. CCG and general shipping
2. Oil and Gas Shipping
3. Offshore drilling/exploration
4. Fisheries
5. Meteorology
6. Defence
7. Research

all parameter specifications. For any given parameter, some users wanted the information more rapidly while others wanted better accuracy and spatial resolution. Shipping interests supplied most of the critical specifications for strategic support.

Tactical

The critical parameter specifications for tactical support are summarized in Table 3.5. Repetition and turnaround of information requirements are much more stringent than for strategic support. Continuous coverage and instantaneous turnaround are needed for many parameters. Accuracy and resolution/measurability of parameters does not change for many parameters.

Critical user groups for these parameter specifications are shown in Table 3.6. The offshore drilling and production group supplied the critical specification for ice movement parameters including ice edge floes and icebergs. Presumably this is due to their present capability for open water operations so that their tactical needs for ice movement and locations are of particular importance.

3.3 Critical Ocean Parameter Specifications

Contrary to ice covered waters, there is considerable experience in operations within the open water period for ships and sructures. Consequently, parameters for

Table 3.5

CRITICAL TACTICAL ICE INFORMATION REQUIREMENTS

PARAMETRIC REQUIREMENTS		SPECIFICATIONS				
PARAMETER	TYPE OF INFORMATION REQUIRED	ACCURACY	SPATIAL RESOLUTION	REPETITION OF COVERAGE	TURNAROUND OF INFORMATION	NUMBER OF GROUPS MAKING SPECIFICATION
TYPE	% of area	2%	25 m	continuous	instantaneous	3
CONCENTRATION	% of area	5%	10 m	continuous	instantaneous	3
THICKNESS	m	1 m	----	12 hr	2 hr	1
EDGE/ BOUNDARY	movement	1 km/day	1 km	continuous	instantaneous	1
	location	100 m	100 m	1 hr	instantaneous	1
LANDFAST ICE	location	50 m	500 m	12 hr	2 hr	1
RIDGES	height	0.25 m	1 m	continuous	instantaneous	3
	density	5%	20 m	12 hr	<12 hr (2)	1
	width	1 m	10 m	12 hr	<12 hr	1
	keel depth	1 m	1 m	24 hr	<24 hr	1
	type	FY/MY	10 m	continuous	instantaneous	2
	separation	<30 m	30 m (3)	continuous	instantaneous	1
FLOES	size	10 m^2	20 m	continuous	instantaneous	3
	magnitude	1 km/day	1 km	continuous	instantaneous	2
	direction	5°	5°	continuous	instantaneous	1

CRITICAL TACTICAL ICE INFORMATION REQUIREMENTS

PARAMETRIC REQUIREMENTS		SPECIFICATIONS				
PARAMETER	TYPE OF INFORMATION REQUIRED	ACCURACY	SPATIAL RESOLUTION	REPETITION OF COVERAGE	TURNAROUND OF INFORMATION	NUMBER OF GROUPS MAKING SPECIFICATION
LEADS	% of area	2%	20 m	3 hr	2 hr	2
	width	25 m	5 m	continuous	instantaneous	2
	pattern	25 m	25 m	3 hr	<3 hr	1
	separation	<500 m	500 m	continuous	instantaneous	1
PRESSURE	convergence	positive sign	10 km^2	3 hr	2 hr	1
ICEBERGS(4)	location	20 m	100 m	continuous	instantaneous	3
	movement direction	5°	5°	1 hr	<1 hr	1
	size	5 m	5 m	continuous	instantaneous	3
	height	<3 m	3 m	continuous	instantaneous	3
ICE ISLANDS(5)	size	<20 m	20 m	continuous	instantaneous	3
	height	<1 m	1 m	continuous	instantaneous	3
	location	20 m	100 m	12 hr	2 hr	2
SNOW COVER	yes/no thickness	0.2 m	10 m	continuous	instantaneous	2

Table 3.6

Parameter Specification vs. User Group

Tactical Ice Information

Parameter	Critical User Group			
	Accuracy	Resolution	Repetition	Turnaround
Type-% of area	3	1,3	2	2
Concentration -% of area	1,3	3	2	2
Thickness	1	1	1	1
Edge				
-location	3	3	3	3
- movement	3	3	3	3
Landfast ice -location	1	1	1	1
Ridges-height	3	2	2	2
-density	3	3	3	3
-width	3	3	3	3
-keel depth	3	3	3	3
-type	3	3	2	2
-separation	2	2	2	2
Floes-size	3	1,3	2	2
-magnitude	3	3	3	3
-margin	3	3	3	3
-direction	3	3	3	3
Leads-% of area	3	1	1,3	3
-width	3	3	2	2
-pattern	3	3	3	3
-separation	2	2	2	2
Pressure -convergence	1	1	2	2
Icebergs				
-location	1	1	2	2
-size	1,3	1,3	2	2
-height	2	2	2	2
-movement and direction	3	3	3	3

Table 3.6 (cont'd)

Parameter	Critical User Group			
	Accuracy	Resolution	Repetition	Turnaround
Ice Islands				
- size	2	2	2	2
- height	2	2	2	2
- location	1	1	1	1
Snow Cover	1	1	1	1

<u>Legend</u>

Group No.	Group Identification
1	CCG and general shipping
2	Oil and gas shipping
3	Offshore drilling/exploration
4	Fisheries
5	Meteorology
6	Defense
7	Research

ocean information are similar for most groups regardless of the mode of operation. Researchers would be the exception becuase of their physical oceanographic interests and their reasons for wanting ocean data.

Ocean information needs will also be mostly independent of geographic location except for the Canadian Arctic Archipelago where the continued presence of ice and the short fetches make ocean information much less important.

There is a seasonal variation in the need for ocean information related to operating procedures and the existence of ice. The exception is the Atlantic and Pacific Oceans, which for defence and trans-Atlantic shipping, the need is year round. For example, offshore drilling vessels currently operate only during the open water season (July to October) so their need for ocean information applies only to that time. The presence of ice will also reduce the need for ocean information because the former will be the greater concern. Ice in large quantities will tend to dampen the ocean patterns as well. An exception to this would be windspeed and direction which are needed for predicting ice movements.

Critical parameter specifications for ocean information area based on limited information sources from only two groups, CCG and general shipping and offshore drilling and production. Strategic ocean parameter specifications were obtained from a response to the user questionnaire by

Mobil Oil Ltd., of Calgary and the Cornwall minutes. Tactical ocean information was based on CCG small craft warnings on wave height and windspeed, as well as the Mobil submission and the Cornwall minutes.

Table 3.7 presents the critical ocean information requirements for both strategic and tactical support modes. Surface current specifications were supplied by Mobil Oil for their operations at Hibernia and Sable Island. Swell was needed by the CCG only. Windspeed and direction as well as wave height and period were needed by Mobil Oil as input into their own forecast models.

Table 3.8 shows the critical user group for each parameter specification. Offshore drilling and production has a great need for ocean data owing to their present operating season. These open water operations may actually need ocean date over ice data.

The critical ocean requirement that has been recognized by shipping and offshore drilling operations alike is the need for forecast wind and wave information. This was recognized as a fundamental requirement for the safe conduct of their operations.

While the observational data is not required directly by the end users, it is needed by the forecast modellers, be they D METOC or private consultants. These users require fast turnaround times in order that the resulting forecast products are available at an early stage in the forecast period.

Table 3.7

Critical Ocean Information Requirements

PARAMETRIC REQUIREMENTS		PARAMETER SPECIFICATIONS							
PARAMETER	TYPE OF INFORMATION REQUIRED	ACCURACY		SPATIAL RESOLUTION		REPETITION OF COVERAGE		TURNAROUND OF INFORMATION	
		S	T	S	T	S	T	S	T
SEA STATE	height	1 m	0.5 m	50 km^2	<1 m	6 hr	1 hr	<6 hr	instantaneous
	period	5 sec	0.5 sec	50 km^2	50 km^2	6 hr	1 hr	<6 hr	instantaneous
	direction	-	5°	-	-	-	6 hr	-	1 hr
SWELL	height	-	<1 m	-	<1 m	-	<3 hr		<<3 hr
	period	-	NS	-	NS		<3 hr		<<3 hr
WIND	velocity	1 m/s	0.5 m/s	100 km^2	-	6 hr	1 hr	<6 hr	instantaneous
	direction	20°	5°	-	-	6 hr	1 hr	<6 hr	instantaneous
SURFACE CURRENTS	velocity	-	0-0.25m/s ±5%	-	-	-	3 hr	-	1 hr
SEA SURFACE TEMPERATURE	°C	0.25°	0.25	100 km^2	-	6 hr	<3 hr	<6 hr	<<3 hr

NS - not specified

S - strategic

T - tactical

\- not stated

Table 3.8

Parameter Specification vs. User Group

Ocean Information

OCEAN PARAMETER	CRITICAL USER GROUP							
	ACCURACY		RESOLUTION		REPETITION		TURNAROUND	
	S	T	S	T	S	T	S	T
Seastate								
- height	3	3	3	1	3	3	3	3
- period	3	3	3	3	3	3	3	3
- direction	-	3	-	3	-	3	-	3
Swell								
- height	-	1	-	1	-	1	-	1
- period	-	1	-	1	-	1	-	1
WIND								
- velocity	3	1	3	-	3	3	3	3
- direction	3	1	3	-	3	3	3	3
Sea Surface Temperature	6	6	6	6	3	1	3	1
Surface Currents	-	3	-	-	-	1	-	1
Ocean Colour	7	-	7	-	7	-	7	-
Salinity	4	-	4	-	4	-	4	-
Chlorophyll	4	-	4	-	4	-	4	-

1. CCG and general shipping
2. Oil and gas shipping
3. Offshore drilling/production
4. Fisheries
5. Meteorology
6. Defense
7. Research

S: Strategic
T: Tactical
-: Not stated

3.4 General Observation

There is a considerable user need for ocean information in the form of forecasts for both the East and West Coast regions. Present East Coast offshore drilling operators have prioritized forecast ocean information over ice information. This strong requirement was also echoed by fisheries, meteorology, CCG and defence interests. With the disappearance of ocean station PAPA; there is a considerable need for wave and wind information for modelling purposes off the West Coast regions. Moreover this requirement extends outwards to cover the North Atlantic and Pacific Oceans. Satellite-based observations would have a higher density than what could be provided by a solely surfaced-based system.

The strong requirement for ocean information echoed by the user community points to the need for a scatterometer to be included on the RadarSat payload.

4. CONCLUSIONS AND RECOMMENDATIONS

This survey has attempted for the first time to gather opinions and needs for ice and ocean information from a wide community of users to be serviced by a single ice and ocean information system. The assembled package of requirements shows the widely diverse range of needs between the various classified groups. Not only were needs different between groups but they also varied considerably for organizations within the groups.

The user was asked for his ice and ocean needs regardless of the method of collection and recognizing there are many ways of obtaining the information be it from satellites, aircraft, buoys or ship based sensors. Some users responded in the intended way while others filtered their responses knowing the capabilities of present remote sensing systems in providing the information. Thus the stated requirements are to a certain extent a mixture of these answers. It was also observed that some users based their requirements on present operations and with regard to present ice and ocean information systems.

4.1 The Collective Information Need

The obvious conclusion from the survey is that many users desire to have the information collected and delivered in a frequent and timely way. Frequency and turnaround requirements however are strongly a function of the geographic location, time of year and the operational capabilities of the user. For example, the need for updates decreases in areas of consolidated ice because it changes little from hour to hour even day to day. After ice breakup the updates must be more frequent to account for changing conditions.

Resolution and accuracy requirements change little between strategic and tactical support.

It is also apparent that may of the specifications imposed on parameters cannot be fully met by any remote sensor nor can the frequency and turnaround needs be met by a public ice and ocean information system without tremendous effort and cost. Many tactical needs would and should be met by the individual operator or contractor. Any public system may meet tactical requirements, but not all the time. For example, the present arrangement between CCG and the Ice Branch provides for Electra aircraft to provide tactical support to icebreakers.

At the same time, the user would like to have an information system that will provide for the worst situations and will enable the selection of what is needed to meet the particular situation even if it is less than what the system can provide.

Therefore it is necessary to define an interface between what the user would like to have versus what can be realistically provided. The critical parameter specifications in Section 3 cannot be fully met all the time. Continuous repetition and instantaneous turnaround of information for a close tactical support is a requirement that is clearly the responsibility of the particular user.

It is therefore useful as an output from the survey to propose a compromise set of requirements for which a public ice and ocean information system could be designed with due consideration to the available platforms, sensors and cost. The final requirements list represents the overall collective need of the user community considering the practicality of design, development and implementation of the system as well as its cost. A further constraint to requirements is that the parameters must be presented in a suitable format as output information products.

The restatement of requirements is required as an input into two associated studies in the project, the aircraft/satellite tradeoff analysis and the RadarSat benefit study of the proposed second sensor. Each of these studies need to have a single table of user requirements to realistically conduct the respective studies.

In developing the collective requirements, the different ice and ocean parameters were matched to the number of citings (maximum of 6) by operational groups shown in Table 4.1.

Only ice concentration, ice edge location and windspeed and direction were unanimously wanted. Each parameter can then be placed in order by the number of user groups

TABLE 4.1

NUMBER OF OPERATIONAL GROUPS CITING PARAMETERS

(STRATEGIC SUPPORT)

ICE		OCEAN	
PARAMETER	NUMBER OF GROUPS	PARAMETER	NUMBER OF GROUPS
Distributed			
CONCENTRATION	ALL	WAVES - HEIGHT	5
ICE EDGE - LOCATION	ALL	- DIRECTION	3
- MOVEMENT	3	- PERIOD	4
LANDFAST ICE	1	SWELL - HEIGHT	1
FLOES - SIZE	4	- PERIOD	1
- MOVEMENT	2	WIND - DIRECTION	ALL
FREEZEUP/BREAKUP	2	- SPEED	ALL
		SEA SURFACE TEMPERATURE	4
Surface/Sectional		SURFACE CURRENTS	2
THICKNESS	4	ICE ACCRETION CONDITIONS	5
RIDGES - HEIGHT	3	CHLOROPHYLL	1
- WIDTH	1	WATER COLOUR	1
- SPACING	1	SALINITY	1
- PATTERN	3		
TYPE OF ICE	5		
LEADS - % COVERAGE	5		
- WIDTH	2		
- PATTERN	4		
- SEPARATION	1		
PRESSURE - CONVERGENCE	2		
SNOW COVER	2		
Hazards			
ICEBERGS - LOCATION	5		
- SIZE	4		
- MOVEMENT	1		
ICE ISLANDS - LOCATION	3		
- SIZE	3		

requiring it as shown in Table 4.2. The table gives equal priority to all six operational user groups. The list shows the order of cited parameters with associated measurements or information required about the parameter where applicable. For system design purposes, the list of parameters can be assumed to be in order of priority recognizing their importance will change from user to user, time of year, geographic location and the enviromental situation at the time. For example, parameters such as convergence apply only to periods following ice breakup.

The specifications on the parameters are also dependant on the season and geographic area. The frequency of coverage from a satellite radar will be daily at best in northern latitudes and daily for selected areas of importance in southern latitudes. Given this coverage restraint, the present and planned daily operation of aircraft reconnaissance systems and the daily strategic requirements of most users, the collection of information and the presentation of the parameters on a daily basis is reasonable. The turnaround for information for strategic support ranged from 25% - 33% of the update time so this equates to a turnaround of 6 hours for daily information. Accuracy and resolution requirements vary considerably between users but maximizing resolution will cover less stringent requirements. A resolution of 25 m would be sufficient and practical to implement with a remote radar system.

TABLE 4.2

ORDER OF PARAMETERS

ICE	OCEAN
ICE CONCENTRATION	WINDSPEED & DIRECTION
ICE EDGE LOCATION	WAVE HEIGHT
TYPE OF ICE	ICE ACCRETION
ICEBERG LOCATION	WAVE PERIOD
LEADS - % COVERAGE	SST
ICEBERG SIZE	WAVE DIRECTION
THICKNESS	SURFACE CURRENTS
FLOE SIZE	
LEADS - PATTERN	
ICE EDGE MOVEMENT	
RIDGES HEIGHT	
RIDGE PATTERN	
ICE ISLANDS - LOCATION	
- SIZE	
FLOE MOVEMENT	
PRESSURE - CONVERGENCE	
SNOW COVER	
LEADS - WIDTH	
FREEZEUP/BREAKUP	

For the systematic comparison of aircraft versus satellite platforms and sensors for ice information needs we have restated the requirements from this report into a coverage requirement by season and geographic area for the areas covering the proposed tanker routes. The coverage is the major additional requirement foreseen in ice and ocean information needs compared to the present and forecast levels of other activities. The chart is shown in this report as Table 4.3 which accounts for the user requirements as well as the typical ice conditions to be encountered in each area on a monthly basis.

The collective ice information need must also be viewed from the output side of the ice information system. The ice information must be presented in a suitable format, primarily charts which are and will be the responsibility of the Ice Branch of the Atmospheric Environment Service. Although they were grouped into the CCG and general shipping group, their needs to produce the chart and narrative products desired by the user community were never articulated in the initial phases of the survey. Accordingly Ice Central was interviewed to determine their needs in order to provide the service wanted by the CCG and others. Since Ice Central is to become the Ice Information Centre (IIC) for the public ice information system, their requirements best provide an indication of what is collectively wanted by the users they serve.

In the context of present operations, the provision of daily coverage of all ice covered areas would be a major advance in preparing the present and future products outlined in the separate information products report

TABLE 4.3

SEASONAL ICE RECONNAISSANCE REQUIREMENT

SECTION	1 BEAUFORT	2 AMUND-SEN	3 PRINCE OF WALES STRAIT	4 VISCOUNT MELVILLE SOUND	5 BARROW STRAIT	6 LANCASTER SOUND	7 BAFFIN BAY (≥70°N)	8 DAVIS STRAIT (≥60°N)	9 LABRADOR SEA (≤60°N)	10 NFLD/ BELLE ISLE	11 GULF	12 HUDSON BAY/ FOXE BASIN	13 EUREKA/ NORWEGIAN BAY	14 RESEARCH
AREA (km^2)	33,000	23,000		20,000	6,000	6,000	137,500	175,000	70,000			ad hoc	ad hoc	ad hoc
A/C HRS ON SITE (1)	0.72	0.7	0.5	1.2 (550km)	1	25	3 + .5 (6)	3.8 + .5 (6)	2 + .5 (6)			7½ hrs/ flt.	8 hrs./ flt.	8 hrs.
JANUARY	9/10 cover (4) 0-9/10 MY D	9/10-10/10 cover 0-2/10 MY D		10/10 cover 5/10-8/10 MY shorefast 3/wk	10/10 cover 1/10-6/10 MY shorefast 3/wk	9/10 cover trace MY bergs, 3/wk	9/10 cover bergs 2/10 MY D	0-9/10 cover trace MY bergs D						
FEBRUARY									(6)		40 hrs./wk (5)			Two 8 Hr. flts/ mo.
MARCH										40 hrs/ wk (5)				
APRIL		10/10 cover 0-2/10 MY 3/week									clear			
MAY	9/10-10/10 (3) cover 0-9/10 MY D	9/10-10/10 cover trace MY D				9/10 cover 1/10 MY bergs D	9/10 cover 2/10 MY bergs, leads D	0-9/10 cover trace MY bergs D		bergs				Two 8 Hr. flts/ mo.
JUNE	0-10/10 cover (4) 0-9/10 MY D	5/10-10/10 cover 0-2/10 MY D (reduced area)				0-6/10 cover icebergs 1/10 MY D	5/10-9/10 cover 0-2/10 MY (1) bergs, D							
JULY	0-9/10 (4) cover 0-9/10 MY D			10/10 shorefast D	6/10-9/10 cover 0-3/10 MY D	trace FY trace MY icebergs D	0-9/10 cover 0-2/10 MY bergs D			10 hrs per wk		9 flt/ mo.		
AUGUST	0-9/10 cover 0-9/10 MY (4) Edge Cleaner D	clear 0 MY ø		8/10-10/10 cover 2/10-5/10 MY D	0-5/10 cover 0-1/10 MY D		0-7/10 centre 0-2/10 MY bergs D	0-5/10 cover trace MY bergs D				12 flt/ mo.	2 flt/mo	
SEPTEMBER	reduced area			2/10-9/10 cover 2/10-5/10 MY D	0-5/10 cover Traces MY D reduced area		clear bergs D	clear bergs D	bergs 20 hrs/wk				4 flt/mo	
OCTOBER	0-9/10 cover 0-9/10 MY (4) Edge Clean NY from shore D	0-5/10 cover 0-2/10 MY D		9/10-10/10 cover 5/10-8/10 MY D	7/10-9/10 cover D	5/10-9/10 cover trace MY icebergs, D	0-5/10 cover bergs D	trace MY bergs D						Two 8 Hr. flts/ mo.
NOVEMBER	9/10 cover 0-9/10 MY (4) D	9/10-10/10 cover 0-2/10 MY D		10/10 cover 5/10-8/10 MY 3/wk	9/10 cover 1/10-6/10 MY D	9/10 cover trace MY icebergs D 3/wk	9/10 cover bergs 2/10 MY D	0-9/10 cover trace MY bergs D						
DECEMBER					10/10 fast 1/10-6/10 MY 3/wk					ø				

SEASONAL ICE RECONNAISSANCE REQUIREMENT

REMARKS

D = Daily

(1) where corridor width is less than 100 km aircraft time is derived from length of track.

(2) ice edge is well defined; daily reconnaissance needed re. ice edge.

(3) distinct pack edge to 9/10 MY; pack edge varies continuously.

(4) ice island fragments year round.

(5) from W. Markham.

(6) additional hours are for end-of-lane turns in pattern flying.

(7) aircraft speed 250 knots (460 km/hr), 100 km swath.

(8) area of interest moves.

shows very little has been changed or altered. We must accept this lack of responses as tacit approval of the stated requirements.

Another useful input into the survey was the discussions of the RadarSat Information Standards Committee which focussed on the presentation of these parameters as delivered products to the user. Any discussion of products required examination of the parameters and with members representing oil and gas shipping, CCG, drilling meteorology and defense on the committee their deliberations and the resulting activity/information product matrix were valuable inputs into the survey.

Concluding, it is our view that the best method for a survey of this type is to conduct personal interviews with qualified individuals and operators. Not only does one obtain the numerical information but also insights into the activities and attitudes of the user.

The questionnaire was much less successful and its further use should be discouraged except in developing the questions and issues to be raised with users during the interviews.

The discussion of user requirements is an interative process that should continue throughout the development and operations of the ice and oceans information system. Therefore, a parallel activity to interview should be the creation of a standing committee similar to the Information Standards Committee which would meet on an annual basis and on an as needed basis to further the iteration.

4.3 Conclusions

1. User requirements for ice and ocean information are a function of the following:

   - season
   - geographic location
   - technological limitations of the user in his operations and in receiving and manipulating data
   - user objectives
   - user attitude towards the information
   - how the information is to be used
   - user activity
   - environmental circumstances
   - presentation of the information.

The user wishes to have a system which provides for the maximum possible requirements and permits flexibility in choosing parameters of interest.

2. Forecast windspeed and direction as well as forecast wave height are the highest priority ocean parameters. Nowcast or observational data on winds and waves is not useful except as input into forecast models.

3. Judgement must be made on the extent for which requirements can be met by a public ice and ocean information system. The public system should be responsible for global and regional coverage while site specific needs are the responsibility of the user. However, the collection of data for public system may be sufficient to meet many tactical site specific needs a large portion of the time.

4. Users require the fastest possible turnaround of observation and forecast information-in the range of hours.

5. User requirements, particularly for year round tanker shipping may be overstated because of the lack of operating experience. The first few years of shipping will be learning experience which will confirm the importance of some parameters while eliminating or reducing the importance of others. As well, increasing ship traffic will become a major source of information as the ships confer with each other on ice conditions and the difficulties in routing through an area.

4.4 Recommendations

1. The RadarSat Project should maintain a continuing liaison with the user community through the design and operational stages of RadarSat. The liaison should continue the dialogue and discussion of user requirements as well as to keep users informed on the directions of the project. The best method to achieve these goals would be to convene a committee of users on an annual and as needed basis. A parallel activity more to update user requirements would be interviews with individual users to allow them to state their specific needs.

2. Canadian Coast Guard captains should be interviewed for their views on ice information needs and their role in decisions affecting the operations of icebreakers. Approval to conduct this activity from CCG came too late in the study to be implemented. These captains have the largest accumulated experience in operating in ice covered waters and such interviews could provide further insight into the uses for ice and ocean information.

* * *

APPENDIX A

LIST OF CONTACTS

Date	People Contacted	Organization
Feb. 18	Mr. D. Smith Dr. R. Ramseier	Atmospheric Environment Service
March 10	Mr. G. Spedding	Esso Resources Ltd.
	Mr. R. Dick Mr. B. Dixit	Melville Shipping Ltd. " " "
	Mr. B. Jonassen Mr. J. Miller	Petro-Canada Exploration Ltd. " " "
March 11	Dr. H. Kivisild Dr. A. Paro Dr. B. Morad	Fenco Consultants Ltd. " " " " " "
	Dr. B. Mercer	Dome Petroleum Ltd.
	Mr. G. Hood Mr. M. Van Ieperen	Panarctic Oils Ltd. " " "
	Mr. M. Comyn	Esso Resources Ltd.
March 12	Dr. F.G. Bercha	F.G. Bercha and Associates Ltd.
	Mr. D. North	Mobil Oil Canada Ltd.
March 9	Dr. A. Collin	Energy, Mines and Resources

APPENDIX A (cont)

LIST OF CONTACTS

Date	People Contacted	Organization
April 10	Mr. J. Bruce	Atmospheric Environment Service
	Dr. O. Loken Dr. J. Keys	Indian and Northern Affairs " " "
April 22	Captain M. Johnson Captain M. Frampton	Newfoundland Ship Owners Assoc. " " "
	Mr. P. Outerbridge	Harvey Offshore Services
	Mr. S. Roche	National Sea Products Ltd
	Mr. B. Winsor	C-Core
April 23	Captain I. Green Captain P. Whitehead	Canadian Coast Guard " " "
	Dr. Needler Dr. C. Mason	Bedford Inst. of Oceanography " " "
	Mr. B. Chapman	Atlantic Fishing Vessels Association
April 24	Mr. J. Benoit	MacLaren Plansearch Ltd
	Mr. C. Ross	Mobil Oil Ltd
	Mr. J. Merrick	Metoc Center
May 4	Dr. J. Gower	Inst. of Oceanography

APPENDIX A (cont)

LIST OF CONTACTS

Date	People Contacted	Organization
May 4	Dr. J. Garrett	Inst. of Oceanography
May 5	Dr. Calvert	U.B.C. Oceanography Dept.
	Dr. P. Leblond	" " "
	Dr. L. Mysak	" " "
	Mr. Williams	A.E.S. West Coast Office
	Mr. Harring	" " "
	Mr. T. Mulligan	Federal Fisheries Management
May 8	Dr. S. Peteherych	A.E.S.
May 19/20	Mr. B. Wright	Gulf Canada
	Mr. H. Brusset	Mobil Oil
	Mr. D. Pearson	Petro Canada
	Mr. Y. Lussenberg	Gulf Canada
	Dr. B. Mercer	Dome Petroleum
	Dr. H. Cheung	Melville Shipping
	Mr. V. Wetzel	Suncor Inc.
	Mr. H. Westergard	Aquitane
	Mr. M. Comyn	Esso Resources
	Mr. J. Miller	Petro Canada
	Dr. A. Molozzi	DOC
	Joint APOA/EPOA Remote Sensing Committee	
May 20	Dr. G. Glazier - Chairman	Petro Canada
	Mr. G. Jones - secretary	APOA - EPOA
	(APOA/EPOA Executive Meeting)	

APPENDIX A (cont)

LIST OF CONTACTS

Date	People Contacted	Organization
May 22	Mr. B. Borodchak Mr. J. Woodbury	Canadian Coast Guard " " "
June 5	Mr. T. Mullane	A.E.S. Ice Branch
June 9	Dr. R. Asselin Mr. D. Nowell	A.E.S./DND A.E.S./DND
July 14	Captain K. Mueller	Arctic Pilot Project
July 15	Mr. G. Veldekamp	Volker-Stevin Dredging
July 16	Mr. M. Luce	CanArctic Shipping Ltd.
	Mr. D. Brown Mr. A. Evans	Federal Commerce and Navigation Ltd.
July 28	Mr. A. Simpson	Arctic Transportation Ltd.
	Mr. J. Steen	Dome Petroleum Ltd.
Sept. 25	Dr. P. Merilees	Canadian Climate Center
Sept. 29	Captain C. Kirkland	Northern Transportation Company Ltd.

APPENDIX A (cont)

LIST OF CONTACTS

Nov. 2	Mr. W. Emberley	McElhaney Offshore Surveys Ltd.
	Dr. S. Parashar	Remotec Applications Ltd.
	Dr. G.R. Peters	Faculty of Engineering and Applied Science - Memorial University of Newfoundland

APPENDIX B

QUESTIONNAIRE RESPONDENTS

Draft Questionnaire

Mr. N. McIntyre	Mobil Oil Canada
Mr. J. Davies	Petro Canada Exploration Ltd.
Mr. J. Miller	" " " "

Fishing Industry Questionnaire

Mr. M. Comeau	Comeau's Sea Food Ltd.
Mr. E. Bourgeois	Madelipeche Inc.
Mr. J. Lawrence	Lawrence Enterprises Ltd.
Mr. R. Nathan	C.W. McLeod Fisheries Ltd.

DRAFT QUESTIONNAIRE

This questionnaire is intended to determine user needs for ice and ocean information related to the types of activities that take place within your organization. Part 1 of this questionnaire addresses those needs which should be specified without regard for the methods, probable, actual or otherwise of collecting the data required to define that parameter.

Part 1: Parameter Identification, Needs and Justification for Specified Ice and Ocean Activities

1. Identify present on-going marine operations and/or planned activities listing the type of operation, location and project timetables and milestones which require ice and/or ocean information. If possible, state activities in terms of the present, 1985, 1990 and 2000 time frames.

2. Under each activity listed in question 1, state required ice and ocean information categories necessary

   (1) to plan and design the operational system
   (2) for strategic planning and deployment
   (3) for operational support
   (4) for site-specific or near tactical support

   Consider differences in required parameters between geographic areas and the changes in needs with time as well as the differences between design and operation phases. Justify the selection of each parameter with respect to the particular activity and state how it is used and its importance to the activity.

3. For each parameter identified in question 2 in each geographic area and each activity, list specific aspects or parameters that need to be defined and quantified. Outline the reasons why each parameter is needed and explain its role and importance to the stage of the operation (design/planning/operation support). Note any seasonal dependance on the types of parameters required.

4. For each parameter identified in question 3 and keeping geographical and seasonal differences in mind, state requirements as related to your planned operations and activities

   (1) spatial requirements
   (2) geometric requirements if applicable. Specify measurables
   (3) timeliness (turnaround) of information
   (4) frequency of information

   State your requirements in terms of desired and minimum specifications and state the rationale behind the stated numbers.

5. List the top five ice and/or ocean parameters you feel would yield the greatest benefit to your planned or on-going operation stating reasons for your selection.

Part 2: Present Methods of Data Collection

For each subparameter listed in part 1 of this questionnaire, it is desired to know the present methods used in collecting data to define each subparameter and to assess the degree of success in meeting stated needs. The next set of questions relate to each subparameter identified in part 1.

1. Is data now being collected to define the subparameter or is historical information used or is a value assumed based on past experience?

2. Specify methods and technology presently used in data collection for each subparameter. Identify information sources used.

3. Specify achievable spatial, geometric, timeliness and frequency specifications using your present data collection systems and methods of analysis. Assess the degree of success in meeting your present needs.

4. Identify major data gaps not fulfilled by your present data and information gathering system.

5. Outline problem areas which hamper the general data collection systems you are now using and in defining each subparameter to your proper specifications.

6. What forms are the data assimilated to define a parameter for use in operation/planning/design decision making?

TABLE 1.1

Type of operation/ planned activity	Geographic Location	Project Timetable/ Milestones

TABLE 1.2

Type of Operation/ Planned Activity	Geographic Area	Time Frame	Project Stages			
			Plan/Design	Strategic/ Deployment	Operational Support	Site specific close tactical support

TABLE 1.4

Ice/Ocean Parameter	Spatial		Geometric		Timeliness		Frequency	
	Desired	Min	Desired	Min	Desired	Min	Desired	Min

APPENDIX: Example List of Parameters

Distributed

1. Ice thickness
2. Ice boundary - ice edge - position
   - marginal zone
   - pack ice edge
3. Concentration - ice in water
   - ice fractions by type
4. Albedo
5. Ice motion - concentration movement - rotation
   - pack - direction
   - floe - magnitude
   - margin - position
6. Ice type identification - multi-year - % concentration
   - first year - seasonal variation
   - thin ice - geographic distribution
   - open water and variation
7. Ice melt - stage - % surface water
   - areal extent
   - meltponds
   - thaw holes
8. Ice floes - type - floe size distribution
   - size/area
   - position
   - shape
9. Surface temperature
10. Snow Cover

Linear

1. Ridges - detection
   - density/frequency
   - orientation
   - height/width of sail
   - type (consolidated/unconsolidated)
   - depth of keel
2. Leads - fractional area
   - orientation
   - width
   - frozen/open
   - detection
   - position

Point

1. Icebergs (Growlers) - detection
   - geometry/size
   - location
   - movement
   - distribution

2. Ice islands - location
   - movement
   - detection of fragments

Considerations in Defining Parameters

1. Geographic differences
2. Seasonal variations
3. Type of activity
4. Project timetables/milestones
5. Particular Ice Feature
6. Desired and Minimum Specifications
7. Spatial, geometric, turnaround for information and frequency of information

List of Ocean Parameters

1. Wave Height
2. Wave Period
3. Sea Surface Period
4. Tides
5. Ocean Currents
6. Wind Direction and Speed

QUESTIONNAIRE - FISHING INDUSTRY

1. STATE FULL NAME; LAST NAME FIRST:

2. COMPANY/AFFILIATION, if any:

3. TOTAL NUMBER OF BOATS OPERATED BY YOURSELF AND JOINTLY WITH OTHERS:

4. LIST NUMBERS OF BOATS BY TYPE:

5. For each boat you operate, please fill out table 1 as it appears in this questionnaire. Use additional pages if necessary to complete the table.

6. Does your boat have a facsimile receiver to receive charts on weather or ocean information? Check (✓) the appropriate box.
   yes ☐ no ☐

7. Do you operate and/or fish in

   a. ice-covered waters yes ☐ no ☐

   b. ice-infested waters (icebergs + water) yes ☐ no ☐

   c. open water only yes ☐ no ☐

TABLE 1

CHARACTERISTICS OF OPERATING BOATS

TYPE OF BOAT	LENGTH	TONNAGE	HORSE-POWER	ICE CAPABLE? YES OR NO	COMMUNICATIONS EQUIPMENT	NAVIGATIONAL AIDS	EMERGENCY EQUIPMENT	OTHER EQUIPMENT

8. For each fishing zone specified by the Department of Fisheries and Oceans, state the number of sea days spent in the area and the type of fish you were catching in 1980.

FISHING ZONE	TOTAL NUMBER OF SEADAYS	TYPE(S) OF FISH CAUGHT

9. Is your boat(s) ice strengthened or ice reinforced. If you operate more than one boat, list the number of boats of the total number that are ice strenghtened or ice-reinforced. Check (✓) the appropriate box.

ice strengthened ☐ number of ice strengthened boats ____
ice-reinforced ☐ number of ice-reinforced boats ____

10. Does your boat sustain ice damage? Describe the damage and in general how it occurs.

yes ☐ description of damage: ______________________________
no ☐ ______________________________
____
____
____

situation: ______________________________
____
____
____
____

TABLE 2

SOURCES OF INFORMATION VS. TIME OF YEAR AND LOCATION

OPERATING AREA	TIME OF YEAR	ICE INFORMATION SOURCES		SEA INFORMATION SOURCES		WEATHER INFORMATION SOURCES	
		SOURCE	RATING	SOURCE	RATING	SOURCE	RATING

11. Has your boat(s) ever been unable to proceed due to pack ice or icebergs?

yes no

If yes, state why: ______________________________

____

____

12. The next questions relate to the present information sources for weather, sea and ice information. We would like to find out what sources you use and problems with these sources such as not timely enough, not accurate etc.

A. Sources of information - please fill out table 2 which indentifies the information sources you consult which assists you in your operation. Possible information sources include:

1. weather radio
2. boat to boat communication
3. own experience
4. ice charts supplied by A.E.S. (weekly or daily), tax transportation or by mail.
5. weather charts
6. wave charts
7. other sources
8. government regulations

Also state how frequently you consult these sources and the circumstances.

B. Under each source of information consulted, rate the quality and accuracy of the information on a scale of 1 to 5 with 1 being the best.

13. The next questions relate to those characteristics of ice, sea and weather which are important to your operations.

13A. For each parameter listed below please circle the number you feel properly rates the importance of having that information for your operation. For those parameters you identify as being more important please state how they are important to your operation and and reasons why they are most important.

ICE COVERAGE	Very Important				Least Important
Thickness	1	2	3	4	5
Distribution	1	2	3	4	5
Location of ice edge	1	2	3	4	5
Ice movements	1	2	3	4	5
Type of ice	1	2	3	4	5
Location of leads	1	2	3	4	5
Size of leads	1	2	3	4	5
Direction of leads	1	2	3	4	5
Percent overall ice coverage now	1	2	3	4	5
Percent overall ice coverage forecast	1	2	3	4	5
Snow on ice	1	2	3	4	5
Other (please specify)					
______________________	1	2	3	4	5
______________________	1	2	3	4	5
______________________	1	2	3	4	5

ICEBERGS					
Location	1	2	3	4	5
Numbers within an area concentration	1	2	3	4	5
Size	1	2	3	4	5
Shape	1	2	3	4	5
Speed and direction of movement now	1	2	3	4	5
forecast	1	2	3	4	5
Location of growlers	1	2	3	4	5
Other (please specify)					
______________________	1	2	3	4	5
______________________	1	2	3	4	5
______________________	1	2	3	4	5

OCEAN AND WEATHER INFORMATION

	Very Important				Least Important
Sea State	1	2	3	4	5
Wave Height	1	2	3	4	5
Wave direction	1	2	3	4	5
Swell direction	1	2	3	4	5
Sea Surface temperature	1	2	3	4	5
Windspeed and direction	1	2	3	4	5
Other (please specify)					
______________________	1	2	3	4	5
______________________	1	2	3	4	5
______________________	1	2	3	4	5

13B. For each of the important parameters you have identified above, how frequently would you desire the information (e.g. 1/day, every 3 hours etc.)

Parameter	Frequency

APPENDIX C

PARAMETRIC SPECIFICATIONS BY USER GROUP

This appendix contains the summary tables for ice and ocean information developed for each user group. Each table presents the critical specifications which are drawn from individual organizations, persons or documents. Tables are presented for both strategic and tactical needs where sufficient information was available. Not all groups defined specifications for their parameters, nor have all planning, strategic and tactical support levels been filled.

Specifications include accuracy, spatial resolution, repetition of coverage and turnaround of information. Accuracy is estimated as the difference in a measured size or location of a feature in relation to its actual size. Spatial resolution has different meanings to different user groups. It can be defined either as the minimum detectable size for an object or its minimum measurable size. Repetition of coverage relates to the frequency of observations. Turnaround of information defines the time period between date acquisition to the delivery of the final product, in whatever form to the user.

The tables contained herein were derived principally from the first three user groups: CCG and general shipping, oil and gas shipping and offshore drilling/production. Their information needs were the most well defined.

The tables presented for each user group represent a compilation of the most stringent requirements from all contributing information sources. All parameters that were stated by at least one or more user or sources of information are included. In compiling these tables, some assumptions were made in setting out the specifications:

1) Accuracy requirements must be at least the equivalent of spatial resolution or measurability in magnitude or better.

2) Turnaround of information must be much less than the frequency of coverage in order that the information is still useful.

The tables for each user group follow the list of parameters shown in the main body of the report. These parameters are not listed in any order of priority.

C.1 ICE PARAMETER TABLES - PLANNING

OFFSHORE DRILLING/PRODUCTION GROUP

Table C-1

PLANNING ICE INFORMATION REQUIREMENTS

PARAMETRIC REQUIREMENTS		SPECIFICATIONS			
PARAMETER	TYPE OF INFORMATION REQUIRED	ACCURACY	SPATIAL RESOLUTION	REPETITION OF COVERAGE	TURNAROUND OF INFORMATION
ICE TYPE	AREA % (1)	5%	100 m	1 day	2 months
FLOES	SIZE	10 m	10 m	1 day	2 months
	TYPE	FY/MY	10 m	1 day	2 months
	THICKNESS	0.5 m	10 m	1 day	2 months
RIDGES	DENSITY (2)	10%	1 km	1 day	2 months
	HEIGHT	0.5 m	5 km	1 day	2 months
	WIDTH	5 m	10 m	1 day	2 months
	LENGTH	10 m	10 m	1 day	2 months
	KEEL DEPTH (3)	0.5 m	10 m	1 day	2 months
MOTION	MAGNITUDE	1 km/day	100 m	6 hrs	2 months
LEADS	% AREA (4)	10%	10 km	6 hrs	2 months
	PATTERN (5)	10 m	10 km	6 hrs	2 months
ICE SURFACE (6) TEMPERATURE	°C	1°	1 km	1 day	2 months
LOCAL DEFORMATION PATTERN (7)	m	10 m	10 m	6 hrs	2 months

OFFSHORE DRILLING/PRODUCTION GROUP

PLANNING ICE INFORMATION REQUIREMENTS

PARAMETRIC REQUIREMENTS		SPECIFICATIONS			
PARAMETER	TYPE OF INFORMATION REQUIRED	ACCURACY	SPATIAL RESOLUTION	REPETITION OF COVERAGE	TURNAROUND OF INFORMATION
HEIGHT OF DEFORMATION	m	0.5 m	5 m	6 hrs	2 months
BLOCK SIZE	m	0.5 m	0.5 m	6 hrs	2 months
LARGE SCALE[8] DEFORMATION PATTERN	m	100 m	100 m	6 hrs	2 months
PRESSURE BUILDUP PRIOR TO DEFORMATION	CONVERGENCE/[9] DIVERGENCE	10 m	10 m	6 hrs	2 months
THICKNESS	m	1 m	1 km	1 day	2 months

PLANNING ICE INFORMATION REQUIREMENTS

OFFSHORE DRILLING/PRODUCTION GROUP

Footnotes

1. Percent of total area covered by specific ice types.

2. Percent of total ice cover that is ridged.

3. This represents the depth of consolidation within the ridge.

4. Percent of total area that is leads.

5. The definition of lead patterns provides an indication of ice stress areas.

6. Temperature profile is preferred. However the determination of surface temperature with an extrapolation will meet the need for ice temperature.

7. Local deformation refers to the pattern of circumferential cracks around a structure.

8. Large-scale deformation relates to the formation of ridges and rubble piles around a structure particularly through shearing action.

9. Pressure buildup differs with varying ice concentrations which will have varying effects on the ice cover and the structure. For concentrations up to 9/10, pressure will be indicated by concentration increases. For concentrations greater than 9/10, the deformation will be in the form of ridges or pileups.

C.2. ICE PARAMETER TABLES - STRATEGIC

CANADIAN COAST GUARD AND GENERAL SHIPPING

Table C-2

ICE INFORMATION REQUIREMENTS - STRATEGIC OBSERVATION

PARAMETRIC REQUIREMENTS		SPECIFICATIONS			
PARAMETER	TYPE OF INFORMATION REQUIRED	ACCURACY	SPATIAL RESOLUTION(1)	REPETITION OF COVERAGE	TURNAROUND OF INFORMATION
TYPE	% of area	5%	25 m	12 hrs	6 hrs
CONCENTRATION	% by area	5%	500 m	1 day	6 hrs
THICKNESS	m	1 m	--	1 day	6 hrs
EDGE	location	100 m	100 m	12 hrs	6 hrs
LANDFAST ICE	location	<500 m	500 m	1 day	6 hrs
MOTION	velocity	0.1 m/s	25 m	12 hrs	6 hrs
ICEBERGS, BERGY BITS, GROWLERS	size(2)	20 m	100 m	1 day	6 hrs
	location	20 m	100 m	1 day	6 hrs
RIDGES	height	2 m	25 m	1 day	6 hrs
FLOES	size	20 m	20 m	1 day	6 hrs
LEADS	size	10 m	20 m	1 day	6 hrs

CANADIAN COAST GUARD AND GENERAL SHIPPING

ICE INFORMATION REQUIREMENTS - STRATEGIC OBSERVATION

PARAMETRIC REQUIREMENTS		SPECIFICATIONS			
PARAMETER	TYPE OF INFORMATION REQUIRED	ACCUARACY	SPATIAL RESOLUTION	REPETITION OF COVERAGE	TURNAROUND OF INFORMATION
PRESSURE	convergence	positive sign	10 km^2	12 hr	6 hrs
ICE ISLANDS (3)	size	20 m	100 m	1 day	6 hrs
	location	20 m	100 m	1 day	6 hrs
SNOW COVER	thickness	0.2 m	-	1 day	6 hrs
DETERIORATION	% meltponds	5 %	-	7 days	7 days

Footnotes

1. Spatial resolution refers to the limit of detectability of an object.

2. Size refers to horizontal plane dimensions.

3. Beaufort Sea requirement only.

OIL AND GAS SHIPPING

Table C-3

STRATEGIC ICE INFORMATION REQUIREMENTS[8]

PARAMETRIC REQUIREMENTS		SPECIFICATIONS			
PARAMETER	TYPE OF INFORMATION REQUIRED	ACCURACY (±)	SPATIAL RESOLUTION[1]	REPETITION OF COVERAGE[2]	TURNAROUND OF INFORMATION[3]
RIDGES	HEIGHT	<1 m	1 m	6 hr	2 hr
	DENSITY	10%	-	6 hr	2 hr
	ORIENTATION	10°	-	6 hr	2 hr
	SEPARATION	<20 m[4]	20 m	6 hr	2 hr
	TYPE	FY/MY	-	6 hr	2 hr
THICKNESS	m	0.2 m	0.2 m	24 hr	8 hr
PRESSURE	CONVERGENCE[5]	10%	2 km	6 hr	2 hr
CONCENTRATION	% BY AREA	10%	2 km	6 hr	2 hr
TYPE	% BY AREA	FY,MY, thin ice, open water	2 km	6 hr	2 hr
LEADS	ORIENTATION	10°	2 km	6 hr	2 hr
	% AREA	10%	2 km	6 hr	2 hr
	WIDTH	<50 m	50 m	12 hr	3 hr
	SEPARATION	<500 m	500 m	12 hr	3 hr

C-12

OIL AND GAS SHIPPING

STRATEGIC ICE INFORMATION REQUIREMENTS

PARAMETRIC REQUIREMENTS		SPECIFICATIONS			
PARAMETER	TYPE OF INFORMATION REQUIRED	ACCURACY (±)	SPATIAL RESOLUTION	REPETITION OF COVERAGE	TURNAROUND OF INFORMATION
SURFACE CHARACTERISTICS		10 m	10 m^2	6 hr	2 hr
ICEBERGS	SIZE	5 m	20 m	6 hr	2 hr
	HEIGHT	<3 m	3 m	6 hr	2 hr
EDGE	LOCATION	2 km	2 km	6 hr	2 hr
FLOES	SIZE	<100 m	100 m	12 hr	3 hr
ICE ISLAND(7) FRAGMENTS	SIZE	<20 m	20 m	12 hr	3 hr
	HEIGHT	<1 m	1 m	12 hr	3 hr
SNOW COVER		yes/no	-	12 hr	3 hr

Footnotes

1. Spatial resolution refers to the minimum measurability of the parameter, not minimum pixel size. The relationship between the measurability of an object and the resolution of the satellite system, that is, the number of pixels required to reliably identify and measure an object is not yet known.

2. Repetition of coverage requirements for strategic needs was subdivided into two areas by the APP. Area 1 matches the Canadian Arctic and East Coast north of 65^0 which has the critical system requirements. Area 2 is in southern regions and has less stringent needs.

3. Turnaround of information as specified by the APP was 33% of the coverage repetition. The turnaround requirement for information will be highly dependent on prevailing ice conditions and visibility. Turnaround times as low as 5 minutes may be necessary in certain situations.

4. Accuracy specifications with a less than sign indicate the desired accuracy must be less than the minimum detectability.

5. Ice pressure cannot be measured directly. Pressure can be characterized by estimating areas of convergence of ice floes, or, in the presence of a solid ice cover, the existence of leads will indicate no pressure. APP stated a minimum of detecting positive pressure for determining whether the magnitude is sufficient to create ridges or leads.

6. Surface characteristics refer primarily to the identification of rubble fields and multi-year hummock fields.

7. Required for navigation in the Beaufort Sea only.

8. Repetition of coverage and information turnaround requirements are primarily Melville specifications. Dome Petroleum's submission was in the form of its remote sensing needs which is likely a subset of its total ice and ocean parametric requirements.

OFFSHORE DRILLING/PRODUCTION GROUP

Table C-4

STRATEGIC ICE INFORMATION REQUIREMENTS

PARAMETRIC REQUIREMENTS		SPECIFICATIONS			
PARAMETER	TYPE OF INFORMATION REQUIRED	ACCURACY (±)	SPATIAL RESOLUTION	REPETITION OF COVERAGE	TURNAROUND OF INFORMATION (2)
BOUNDARY/EDGE (1)	LOCATION	2% concentration or 5 km	2% concentration or 1 km	6 hr	<6 hr
CONCENTRATION	% (3)	5%	10 m	12 hr	<12 hr
ICE TYPE	AREA % (4)	5%	25 m	7 days	12 hr
	GEOGRAPHIC DISTRIBUTION	5 km	5 km	30 days	<30 days
FLOES	SIZE/AREA	10 m	20 m	7 days	12 hr
RIDGES	DENSITY	5%	20 m	12 hr	<12 hr
	HEIGHT	2 m	10 m	7 days	<12 hr
ICE MOTION	MARGIN	1 km/day	1 km	1 day	12 hr
	MAGNITUDE	1 km/day	1 km	1 day	12 hr
LEADS	WIDTH	25 m	25 m	12 hr	<12 hr
	% AREA (6)	2%	25 m	12 hr	<12 hr
	PATTERN	25 m	25 m	12 hr	<12 hr

OFFSHORE DRILLING/PRODUCTION GROUP

STRATEGIC ICE INFORMATION REQUIREMENTS

PARAMETRIC REQUIREMENTS		SPECIFICATIONS			
PARAMETER	TYPE OF INFORMATION REQUIRED	ACCURACY (±)	SPATIAL RESOLUTION	REPETITION OF COVERAGE	TURAROUND OF INFORMATION
ICEBERGS	LOCATION	200 m	200 m	12 hr	<12 hr
	GEOMETRY (8)	200 m	10 m	12 hr	<12 hr
ICE ISLANDS (9)	SIZE	25 m	25 m	1 day	< 1 day
	LOCATION	1 km	1 km	1 day	< 1 day
THICKNESS	m	1 m	20 m	7 days	6 hr

STRATEGIC ICE INFORMATION REQUIREMENTS

OFFSHORE DRILLING/PRODUCTION GROUP

Footnotes

1. Ice edge/boundary has been defined in two ways. The first method is define a minimum concentration of ice which is considered the ice boundary. However ice boundary in the WMO ice nomenclature is defined as the demarcation between open water and sea ice of any kind. Thus ice edge definition requires the detection of ice in minimal concentrations as well as to define a boundary between ice/no ice to be marked with the positional accuracy stated in the table.

2. Several users defined turnaround of information requirements on the same time scale as repitition of coverage or frequency. However, in order to make the information of use it must be delivered to the user in a time period less than the frequency. Thus for the critical specifications the turnaround time must be less than the frequency. The precise turnaround time cannot be specified in these cases until further clarification is received.

3. Percent concentration is the ratio of ice to no ice.

4. Area percent is the percent coverage of a given area by a specific ice type.

5. Density of ridging is the percentage of ice cover that is ridged.

6. Area percent of the total ice cover.

7. Not required for Beaufort Sea and interior Arctic Island channels.

8. Refers to above surface height and dimensions.

9. Required for Beaufort Sea operations only.

C.3. ICE PARAMETER TABLES - TACTICAL

CANADIAN COAST GUARD AND GENERAL SHIPPING

Table C-5

ICE INFORMATION REQUIREMENTS - TACTICAL OBSERVATION

PARAMETRIC REQUIREMENTS		SPECIFICATIONS			
PARAMETER	TYPE OF INFORMATION REQUIRED	ACCURACY	SPATIAL RESOLUTION	REPETITION OF COVERAGE	TURNAROUND OF INFORMATION
TYPE	% of area	5 %	25 m	6 hr	2 hr
CONCENTRATION	% of area	5 %	50 m	3 hr	2 hr
THICKNESS	m	1 m	-	12 hr	2 hr
LANDFAST ICE	location	50 m	500 m	12 hr	2 hr
MOTION	velocity	0.1 m/s	25 m	3 hr	2 hr
ICEBERGS, BERGY BITS, GROWLERS	size	5 m	5 m	3 hr	2 hr
	location	20 m	100 m	3 hr	2 hr
RIDGES	height	2 m	25 m	6 hr	2 hr
FLOES	size	20 m	20 m	12 hr	2 hr
LEADS	size	10 m	20 m	3 hr	2 hr
PRESSURE	convergence	positive sign	10 km^2	3 hr	2 hr

CANADIAN COAST GUARD AND GENERAL SHIPPING

ICE INFORMATION REQUIREMENTS - TACTICAL OBSERVATION

PARAMETRIC REQUIREMENTS		SPECIFICATIONS			
PARAMETER	TYPE OF INFORMATION REQUIRED	ACCURACY	SPATIAL RESOLUTION	REPETITION OF COVERAGE	TURNAROUND OF INFORMATION
ICE ISLANDS	size	20 m	100 m	12 hr	2 hr
	location	20 m	100 m	12 hr	2 hr
SNOW COVER	thickness	0.2 m	-	3 hr	2 hr

OIL AND GAS SHIPPING

Table C-6

TACTICAL ICE INFORMATION REQUIREMENTS

PARAMETRIC REQUIREMENTS		SPECIFICATIONS			
PARAMETER	TYPE OF INFORMATION REQUIRED	ACCURACY	SPATIAL RESOLUTION (1)	REPETITION OF COVERAGE (2)	TURNAROUND OF INFORMATION (2)
RIDGES	height	<1 m	1 m	continuous	instantaneous
	separation	<30 m	30 m	continuous	instantaneous
LEADS	width	<50 m	50 m	continuous	instantaneous
	separation	<500 m	500 m	continuous	instantaneous
	orientation	10^o	-	continuous	instantaneous
ICEBERGS	size	5 m	20 m	continuous	instantaneous
	height	<3 m	3 m	continuous	instantaneous
PRESSURE	convergence/ divergence	positive sign	*	continuous	instantaneous
FLOE	size	<100 m	100 m	continuous	instantaneous
TYPE AND CONCENTRATION	% by area	MY, FY, thin ice, open water	NS	continuous	instantaneous

NS: not stated

*: within vessels immediate operating area of a few kilometres

Footnotes

1. Spatial resolution for this group refers to the minumum measurable extent of an object.

2. Repetition of coverage and turnaround of information is based on Dome's close tactical surveillance requirement.

OFFSHORE DRILLING/PRODUCTION GROUP

Table C-7

TACTICAL ICE INFORMATION REQUIREMENTS

PARAMETRIC REQUIREMENTS		SPECIFICATIONS			
PARAMETER	TYPE OF INFORMATION REQUIRED	ACCURACY (±)	SPATIAL RESOLUTION	REPETITION OF COVERAGE	TURNAROUND OF INFORMATION (1)
BOUNDARY/ EDGE	LOCATION	2% concentration or 100 m	2% concentration or 100 m	1 hr (2)	instantaneous (2)
CONCENTRATION	% (3)	5%	10 m	3 hr	<3 hr
ICE TYPE	AREA % (4)	2%	25 m	3 hr	<3 hr
	GEOGRAPHIC DISTRIBUTION	5 km	5 km	30 days	<30 days
FLOES	SIZE/AREA	10 m^2	20 m	1 day	<1 day
	TYPE	FY/MY	20 m	1 day	<1 day
RIDGES (5)	DENSITY (6)	5%	20 m	12 hr	<12 hr
	HEIGHT	0.25 m	1 m	12 hr	<12 hr
	WIDTH	1 m	10 m	12 hr	<12 hr
	KEEL DEPTH	1 m	1 m	1 day	<1 day
	TYPE	FY/MY	10 m	1 day	<1 day

OFFSHORE DRILLING/PRODUCTION GROUP

TACTICAL ICE INFORMATION REQUIREMENTS

PARAMETRIC REQUIREMENTS		SPECIFICATIONS			
PARAMETER	TYPE OF INFORMATION REQUIRED	ACCURACY (±)	SPATIAL RESOLUTION	REPETITION OF COVERAGE	TURNAROUND OF INFORMATION
MOTION	MARGIN	1 km/day	1 km	instantaneous (7)	instantaneous (7)
	DIRECTION	5°	5°	1 day	<1 day
	MAGNITUDE	1 km/day	1 km	instantaneous (7)	instantaneous (7)
LEADS	WIDTH	25 m	5 m	3 hr	<3 hr
	% AREA	2%	25 m	3 hr	<3 hr
	PATTERN	25 m	25 m	3 hr	<3 hr
ICEBERGS (8)	DETECTION	1 km	1 km	1 hr	<1 hr
	LOCATION	200 m	200 m	1 hr (7)	<1 hr (7)
	MOVEMENT DIRECTION	5°	5°	1 hr	<1 hr
	GEOMETRY	5 m	5 m	1 hr	<1 hr
ICE ISLANDS (9)	SIZE	25 m	25 m	1 day	<1 day
	LOCATION	1 km	1 km	1 day	<1 day

OFFSHORE DRILLING/PRODUCTION GROUP

TACTICAL ICE INFORMATION REQUIREMENTS

Footnotes

1. Most critical specifications matched repetition of coverage requirements. The time to receive information received must be less than the frequency at which information is collected. The magnitude of information turnaround or timeliness has not been specified for the listed parameters, but it will likely close to an instantaneous or real time requirement.

2. Instantaneous information on ice edge location is of primary concern to open water drilling or production platforms. Considerably less stringent requirements would be needed for ice-capable operations.

3. Percentage of total area covered with ice.

4. Percentage of total area covered by particular ice types.

5. Ridges are of greater concern in the Canadian Arctic and Labrador Sea. On the East Coast at Hibernia the mobility of the ice cover rarely permits ridges of any significance to form.

6. Percentage of total ice cover that is ridged.

7. Ice movements will require constant monitoring particularly when it is determined an operation is imperiled by presence of ice nearby. When such a scenario exists, it may be necessary to shut down the operation at any time and with enough time to move off site before the ice arrives. This need will be considerably less stringent when ice or icebergs are far enough away to be of less concern.

8. Icebergs are a concern in all areas but the Beaufort Sea and interior Arctic Island channels with the exception of Lancaster Sound.

9. Knowledge of ice islands is needed for primarily the Beaufort Sea.

C.4. OCEAN PARAMETER TABLES - STRATEGIC

OFFSHORE DRILLING/PRODUCTION GROUP

Table C-8

STRATEGIC OCEAN INFORMATION REQUIREMENTS

PARAMETRIC REQUIREMENTS		SPECIFICATIONS			
PARAMETER	TYPE OF INFORMATION REQUIRED	ACCURACY (±)	SPATIAL RESOLUTION	REPETITION OF COVERAGE	TURNAROUND OF INFORMATION
SEA STATE[(1)]	HEIGHT	1 m	50 km^2	6 hr	<6 hr
	PERIOD	5 sec	50 km^2	6 hr	<6 hr
WIND[(1),(2)]	VELOCITY	1 m/s	100 km^2	6 hr	<6 hr
	DIRECTION	20°	-	6 hr	<6 hr
SEA SURFACE TEMPERATURE	°C	z°	100 km^2	6 hr	<6 hr

OFFSHORE DRILLING/PRODUCTION GROUP

STRATEGIC OCEAN INFORMATION REQUIREMENTS

Footnotes

1. It is desirable to obtain forecasts of sea state and wind as opposed to actual observations for strategic purposes. However observational data is required as inputs into models to produce the forecasts. To meet a 6 hour requirement a forecast would be necessary to be generated in a considerably less time period in order for it to be useful by the time it is received.

2. Although wind is specifically a meteorological parameter, it is felt the importance of wind to ice and ocean circulation merits its inclusion as a fundamental user need. Such information is required for both strategic and tactical support.

C.5 OCEAN PARAMETER TABLES - TACTICAL

CANADIAN COAST GUARD AND GENERAL SHIPPING

Table C-9

TACTICAL OCEAN INFORMATION REQUIREMENTS [1]

PARAMETRIC REQUIREMENTS		SPECIFICATIONS			
PARAMETER	TYPE OF INFORMATION REQUIRED	ACCURACY	SPATIAL RESOLUTION	REPETITION OF COVERAGE [3]	TURNAROUND OF INFORMATION [4]
SEA STATE	HEIGHT	< 1 m [2]	< 1 m [2]	< 3 hr	<< 3 hr
	PERIOD	NS	NS	< 3 hr	<< 3 hr
SWELL	HEIGHT	< 1 m [2]	< 1 m [2]	< 3 hr	<< 3 hr
	PERIOD	NS	NS	< 3 hr	<< 3 hr
WIND	VELOCITY	1 knot	< 1 knot	< 3 hr	<< 3 hr
	DIRECTION	5°	< 5°	< 3 hr	<< 3 hr
SEA SURFACE TEMPERATURE	°C	NS	NS	< 3 hr	<< 3 hr
SURFACE CURRENTS	VELOCITY	NS	NS	< 3 hr	<< 3 hr

NS: not stated

Footnotes

1. Tactical ocean information requirements have been specified by the CCG only. CCG considers tactical ocean information necessary for marine environmental emergencies such as oil spills. Both observations and special spot forecasts are required.

2. Wave and swell height accuracy requirements are based on CCG warning criteria for small craft. The requirement to issue a small craft warning is 1 m wave height. Therefore it will be necessary to have an accuracy and a resolution substancially less than 1 m.

3. The on-scene commander for the cleanup of a spill requires "constant and immediate consultation on all aspects of the weather information" with emphasis on the next three hours. Such consultation will be necessary for ocean information as well. Therefore repetition of information and spot forecasts will have to be less than three hours.

4. With a repetition in information of less than three hours, the turnaround to produce the observations and/or the forecast will have to be much less than three hours.

   Exact values for repetition and information/forecast turnaround are not known at this time.

OFFSHORE DRILLING/PRODUCTION GROUP

Table C-10

TACTICAL OCEAN INFORMATION REQUIREMENTS

PARAMETRIC REQUIREMENTS		SPECIFICATIONS			
PARAMETER	TYPE OF INFORMATION REQUIRED	ACCURACY (±)	SPATIAL RESOLUTION	REPETITION OF COVERAGE	TURNAROUND OF INFORMATION
SEA STATE	HEIGHT	0.5 m	50 km^2	1 hr	instantaneous
	DIRECTION	5°	-	6 hr	1 hr
	PERIOD	0.5 sec	50 km^2	1 hr	instantaneous
SEA STATE (1) SPECTRA	% ENERGY	5%	-	3 hr	1 hr
	DIRECTION	10°	-	3 hr	1 hr
WIND	VELOCITY	0.5 m/s	100 km^2	1 hr	instantaneous
	DIRECTION	10°	-	1 hr	instantaneous
SURFACE CURRENT (2)	VELOCITY	0 - 0.25 m/s ± 5%	-	3 hr	1 hr

OFFSHORE DRILLING/PRODUCTION GROUP

TACTICAL OCEAN INFORMATION REQUIREMENT

Footnotes

1. Specified by Mobil Oil for Hibernia and Scotia Shelf drillsites.

2. Surface currents would provide an indication of possible iceberg movement magnitudes.

Table C-11 Ice Sheet, Ice Shelf, and Iceberg Observation Requirements

PARAMETER	CATEGORY: BASIC	CATEGORY: CLIMATE	CATEGORY: OPN/COMM	TYPE OF OBSERVATION	OBSERVATION REQUIREMENT: ACCURACY DESIRED	ACCURACY MIN.	RESOLUTION SPACE DESIRED	SPACE MIN.	RESOLUTION TIME DESIRED	TIME MIN.
ICE SHEETS, ICE SHELVES, AND ICEBERGS										
Elevation of Surface	IV			Line Profile	1 m	10 m	5 km	50 km	NA	NA
Elevation Change	III	III		Change in Line Profile	10 cm	50 cm	5 km	5 km	90 days	10 years
Boundary	III	III		Line Position	100 m	100 m	100 m	100 m	1 year	10 years
Thickness	IV			Line Profile	10 m	50 m	5 km	50 km	NA	NA
Ice Accumulation Rate	III	III		Area Average	10%	50%	10 km	100 km	1 year	10 years
Surface Temperature (Annual Mean)	III	III		Area Average	$0.2^{o}K$	$1^{o}K$	10 km	100 km	1 year	10 years
Surface Horizontal Velocity	III	III		Point Value	10 cm/yr	1 m/yr	Select Points	NA	5 years	10 years
	III	III		Point Value	50 m/yr	100 m/yr	Select Points	NA	5 years	10 years
Strain Rate	III	III		Relative Point Displacement	10^{-6}/yr	10^{-5}/yr	Select Lines	NA	5 years	10 years
Surface Melting	II	II		Area Average	10 cm/yr	Yes/No	10 km	100 km	1 day	3 days
Surface Roughness	II			Area Average	10 cm	1 m	10 km	100 km	90 days	

Table C-11

Ice Sheet, Ice Shelf, and Iceberg Observation Requirements (cont.)

PARAMETER	CATEGORY: BASIC	CATEGORY: CLIMATE	CATEGORY: OPN/COMM	TYPE OF OBSERVATION	OBSERVATION REQUIREMENT: ACCURACY: DESIRED	ACCURACY: MIN.	RESOLUTION: SPACE: DESIRED	SPACE: MIN.	TIME: DESIRED	TIME: MIN.
Iceberg Volume Discharge	III	III	III	Regional Average	5%	20%	NA	NA	90 d	10 years
Iceberg Detection			II	Point Location	5 m	100 m	5 m	100 m	6 hours	2 days
Internal Properties and Bottom Conditions	III			Point Values, Vertical Profiles, Area Averages						

Sampling Key

I - Continuous
II - Frequent
III - Occasional
IV - Infrequent

Table C-12 Mission requirements for oceanographic applications

	Frequency	Polarization	Inc. Angle	Swath Width	Time between repeat coverage	Spatial resolution	Latitude range	Earth location accuracy	Processing time	Calibration		Best sensor in order	
Surface Winds:													
Global	10-14GHz	VV, HH or VH (Scatterometer for direction	20° -60°	1500km-2000km	~6hrs. preferred	50km	global	≤ 2km	< 1hr	1-2dB	abs. & rel.	1, 4, 2, 3	
Regional	"	"	20° -60°	~ 100km-200km	≤6hrs.	10km fine scale (≤1km)	coastal	≤ meters	~ hrs.	"	"	1, 2, 3, 6	
Waves:													
Spectra	"	"	Intermediate	"	~6hrs.	50-100km ~ km's	global coastal	~ 1km ~ 30-100m	~ hrs. ?	"	"	2, 6 about even	
Internal	"	"	"	"	days ?	20-50m		10-20m	~ 1 day	"	"	2	
Fronts	"	"	"	"	~day	20-50m	coastal	10-20m	~ 1 day	"	"	2, 5, 4, 3, 6	5 probably best for thermal gradient cloud free 2 probably best for all weather
Eddies	"	"	"	"	days	5-10km	open ocean coastal	1km	week (ocean) day (coastal)	"	"	3, 2, 5	
Refraction	"	"	"	"	<day	20-50m	coastal	10-20m	< day	"	"	2	
Swell	"	"	"	"	<day	20-50m	coastal	1km	< day	"	"	3, 6, 2	
Currents:													
Surface	"	"	"	"	~day	20-50m	global coastal	≈ 1km	< day	"	"	2	

Source: S. Peteherych, AES.

Scatterometer	(1)
SAR	(2)
Altimeter	(3)
Microwave Radiometer	(4)
IR Radiometer	(5)
Radar Spectrometer	(6) as flown on aircraft CS
CZCS	

APPENDIX D

REFERENCES AND INFORMATION SOURCES

1. Lapp, P.A. and D. Lapp, "Preliminary Statement of User Requirements for Ice and Ocean Information" RadarSat Project Report 81-3, July, 1981.

2. J.D. Taylor, "A Conceptual Design Study for Future Operational Remote Sensing Satellite Systems," Canadian Astronautics Ltd., March 28, 1980.

3. RadarSat Project Office, "Final Mission Requirement Document", RadarSat Project Report 82-7, March, 1982.

4. "Bilateral SAR Satellite Mission Requiraement Study Program Implementation Plan Approval." NASA; DEMR, Nov. 26, 1980.

5. Lapp, P.A., "Information Products Required for Ice and Ocean Operations Interim Report", RadarSat Project Report 82-9, April, 1982.

6. Barry, J. "Aircraft/Satellite Trade Off Study Interim Report", RadarSat Project Report 82-5, April, 1982.

7. Pound, C.P., "RadarSat Benefit Analysis Interim Report", RadarSat Project Report 82-6, May, 1982.

8. "Arctic Marine Service Policy," Transport Canada, January 29, 1981.

9. "Ice Information Requirements, Canadian Marine Transportation," MOU between AES and Canadian Coast Guard.

REFERENCES AND INFORMATION SOURCES (Cont'd)

10. "Arctic Shipping Pollution Prevention Regulations" Transport Canada; Marine Legislation, Oct. 10, 1972.

11. D.J. Lapp and K.E. Laidlaw, "Minutes of the first Canada - U.S. Ice Study Team Workshop for Ice Mission Requirements," Feb. 11-13, 1981.

12. F. Carsay, R.O. Ramseier and W.F. Weeks, "RadarSat Mission Requirement Review - ICE", June 5, 1981.

13. "Report of the Environmental Assessment Panel," Arctic Pilot Project, Federal Environmental Assessment Review Office, Oct. 1980.

14. "LNG Carrier Stategic Routing Study: Final Report," Viatec Resources System Inc., Leigh Instruments Ltd., April 20, 1981.

15. B.M. Johansson, A.J. Keinonen and B. Mercer, "Technical Development of an Environmentally Safe Arctic Tanker," June 17-19, 1981.

16. "Development of Beaufort Sea Hydrocarbons an Opportunity for Canadian Industry," Dome Petroleum Ltd., April - May 1, 1981.

17. Dome Petroleum, Esso Resources Canada Ltd., Gulf Canada Resources Incorporated, "Hydrocarbon Development in the Beaufort Sea, Mackenzie Delta Region", June, 1981.

APPENDIX D

REFERENCES AND INFORMATION SOURCES (Cont'd)

18. "Atlantic Fishery Regulations," Chapter 807 pp. 5029 - 5050, 1978.

19. "An Evaluation of the Utility of Seasat Data to Ocean Industry." Volume I and II Jet Propulsion Laboratory, Oct. 31, 1980.

20. S. Peterherych, "Weather and Ocean Experiments", Sursat Project Draft Report, Fall, 1981.

21. "Report of the CCP Climate Research WorkshoP" Atmospheric Environment Service, Downsview, Ontario, March 10-11, 1981.

22. F.D. Carsey, R.O. Ramseier and W.F. Weeks, "Sea Ice Mission Requirements for the U.S. Firex and Canada RadarSat Programs", January, 1982.

23. "An Evaluation of the Utility of Seasat Data to Ocea Industry." Volume I and II Jet Propulsion Laboratory Oct. 31, 1980.

24. J.F. Gower, "RadarSat Planning Letter to Clive Mason" April 29, 1981.

APPENDIX D

REFERENCES AND INFORMATION SOURCES (Cont'd)

25. "Arctic Marine Transportation forecast of ship Movement: 1985, 1990, 1995," Transport Canada, Oct. 1979.

26. "A.E.S Marine Meteorological Services Base Year 1980 Annex III, April 13, 1981.

27. "Forecasts of Marine Shipments of Arctic Oil and Gas," Transport Canada, Sept. 7, 1979.

28. "Meteorological and Sea Conditions Requirements" Canadian Marine Transportation, Annex I.

29. R. Boubonnais and T. Mullane, "Survey of Canadian Coast Guard Icebreaker Captains," Report of Survey of Laurentian Region - Internal Report, June 12-13, 1980

30. "W.M.O. Sea Ice Nomenclature" English Terminology, WMO No 259.

31. W.W. Denner, Chairman, "Labrador Ice Dynamics Experiment, LIDEX - Workshop Report", Newfoundland Institute for Cold Ocean Science, Memorial University of Newfoundland, March 6-8, 1980.

32. Goddard Space Flight Center, "Ice and Climate Experiment Report of Science and Applications Working Group", National Aeronautics and Space Administration, December, 1979.

Table 3.3 CRITICAL STRATEGIC ICE INFORMATION REQUIREMENTS

PARAMETRIC REQUIREMENTS		SPECIFICATIONS				
PARAMETER	TYPE OF INFORMATION REQUIRED	ACCURACY	SPATIAL RESOLUTION	REPETITION OF COVERAGE	TURNAROUND OF INFORMATION	NUMBER OF GROUPS MAKING SPECIFICATIONS / CITING THE PARAMETERS
BOUNDARY/EDGE	location	100 m	100 m	6 hr	2 hr	3/6
	velocity	1 km/day	1 km	24 hr	6 hr	1/3
TYPE	% by area	5%	25 m	6 hr	2 hr	3/5
CONCENTRATION	% by area	5%	10 m	6 hr	2 hr	3/6
THICKNESS	m	0.2 m	0.2 m	24 hr	6 hr	3/4
LANDFAST ICE	location	<500 m	500 m	24 hr	6 hr	1/1
FLOES	size	10 m	20 m	12 hr	3 hr	3/4
	velocity	1 km/day	25 m	12 hr	6 hr	2/2
RIDGES	height	<1 m	1 m	6 hr	2 hr	3/3
	density	5%	20 m	6 hr	2 hr	2/3
	orientation	10°	-	6 hr	2 hr	1/1
	separation	<20 m	20 m	6 hr	2 hr	1/1
	type	FY/MY	-	6 hr	2 hr	1/3

6) The requirement for year round information was identified by oil and gas shipping and offshore production systems. Such of the activity will center in the Canadian Arctic Archipelago in channels where the ice does not move after freezing in. Once the distribution of ice and ridges is known, there may be no further need for information until the breakup period when the ice starts to move again.

7) The need for updates increases after the ice has broken up and during the period when it has the greatest potential for movement and change.

Strategic

Table 3.3 details the critical strategic parametric requirements. The table includes the number (maximum of 3) of user groups stating specifications. While some groups did not specify some parameters, this did not mean that such paramterss were not of interest. By not imposing any requirements, these groups either accept what is being done now, or see their needs would not impose any constraint. The minimum repetition of coverage was 6 hours with a 2 hour turnaround. The turnaround ranged from about 25 - 33% of the repetition time in order for the information to be useful.

The requirements stated in Table 3.3 were matched to the speciic user group which gave the critical specifications. Table 3.4 identifies the critical user group for each parameter specification. The table suggests that it is not always the same user group for

CANADIAN COAST GUARD AND GENERAL SHIPPING

Table C-5

ICE INFORMATION REQUIREMENTS - TACTICAL OBSERVATION

PARAMETRIC REQUIREMENTS		SPECIFICATIONS			
PARAMETER	TYPE OF INFORMATION REQUIRED	ACCURACY	SPATIAL RESOLUTION	REPETITION OF COVERAGE	TURNAROUND OF INFORMATION
TYPE	% of area	5 %	25 m	6 hr	2 hr
CONCENTRATION	% of area	5 %	50 m	3 hr	2 hr
THICKNESS	m	1 m	-	12 hr	2 hr
LANDFAST ICE	location	50 m	500 m	12 hr	2 hr
MOTION	velocity	0.1 m/s	25 m	3 hr	2 hr
ICEBERGS, BERGY BITS, GROWLERS	size	5 m	5 m	3 hr	2 hr
	location	20 m	100 m	3 hr	2 hr
RIDGES	height	2 m	25 m	6 hr	2 hr
FLOES	size	20 m	20 m	12 hr	2 hr
LEADS	size	10 m	20 m	3 hr	2 hr
PRESSURE	convergence	positive sign	10 km^2	3 hr	2 hr

C.3. ICE PARAMETER TABLES - TACTICAL

CANADIAN COAST GUARD AND GENERAL SHIPPING

ICE INFORMATION REQUIREMENTS - TACTICAL OBSERVATION

PARAMETRIC REQUIREMENTS		SPECIFICATIONS			
PARAMETER	TYPE OF INFORMATION REQUIRED	ACCURACY	SPATIAL RESOLUTION	REPETITION OF COVERAGE	TURNAROUND OF INFORMATION
ICE ISLANDS	size	20 m	100 m	12 hr	2 hr
	location	20 m	100 m	12 hr	2 hr
SNOW COVER	thickness	0.2 m	-	3 hr	2 hr

Table C-6

TACTICAL ICE INFORMATION REQUIREMENTS

PARAMETRIC REQUIREMENTS		SPECIFICATIONS			
PARAMETER	TYPE OF INFORMATION REQUIRED	ACCURACY	SPATIAL RESOLUTION (1)	REPETITION OF COVERAGE (2)	TURNAROUND OF INFORMATION (2)
RIDGES	height	<1 m	1 m	continuous	instantaneous
	separation	<30 m	30 m	continuous	instantaneous
LEADS	width	<50 m	50 m	continuous	instantaneous
	separation	<500 m	500 m	continuous	instantaneous
	orientation	10^{o}	-	continuous	instantaneous
ICEBERGS	size	5 m	20 m	continuous	instantaneous
	height	<3 m	3 m	continuous	instantaneous
PRESSURE	convergence/ divergence	positive sign	*	continuous	instantaneous
FLOE	size	<100 m	100 m	continuous	instantaneous
TYPE AND CONCENTRATION	% by area	MY, FY, thin ice, open water	NS	continuous	instantaneous

NS: not stated

*: within vessels immediate operating area of a few kilometres