20/81

RADARSAT PROJECT REPORT 81-3

PRELIMINARY STATEMENT OF USER REQUIREMENTS FOR ICE AND OCEAN INFORMATION

PHILIP A. LAPP LTD.

JULY, 1981

DSS CONTRACT NO.
OSR 80-00068

PHILIP A. LAPP
DAVID J. LAPP

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont.)

LIST OF TABLES

LIST OF TABLES (Cont.)

RADARSAT PROJECT

PRELIMINARY STATEMENT OF USER REQUIREMENTS FOR ICE AND OCEAN INFORMATION

1. INTRODUCTION

1.1 Background

This report is a first formal attempt to define the requirements of users that need and make use of environmental information concerning ice and the oceans. It is part of a larger project known as Radarsat (Radar Satellite), a polar orbitting satellite to be launched in 1988 that will carry as its principal payload a synthetic aperture radar (SAR).* Radarsat is an outgrowth 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[(1)]. The system described therein is used as the baseline design for Radarsat.

Radarsat is the subject of a bilateral study established through a Program Implementation Plan signed by the

---

* A serious contender for the secondary and complementary payload is a scatterometer similar to the one deployed on the U.S. SEASAT satellite.

Department of Energy, Mines and Resources (DEMR) and the National Aeronautics and Space Administration (NASA), dated November 26, 1980[2]. 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 Requirement 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.

This report addresses the first term of reference, and is a milestone document marking the end of the first four months of work on the study. The intention is to circulate this preliminary statement broadly among users to obtain feedback before a more complete statement is made. Other milestone reports will be issued, but the final report which will contain further iterations of user requirements will be issued by March 31, 1982.

1.2 Method 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. Meteorology
6. Defence
7. Research

Oil and gas shipping was separated from general shipping because it is planned to operate 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 subdivions 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 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 questionnaire was geared particularly to shipping activities where there has been some considerable thought put into future planning. It was followed up buy a series of field visits and interviews with users across Canada. A total of 31 user agencies were visited, and 65 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 compling the preliminary set of user requirements. These references appear in Appendix D.

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 - are not as quantitative as the first three. However, it is expected that further contact with these groups will yield numerical information at a later stage in the study.

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. Critical user requirements are summarized in Section 3 which identifies the most stringent requirement for each element of the parameter specification, and the user group responsible. Requirements also are summarized regionally and seasonally.

1.4 Limitations of Study

The writers wish to emphasize that this is a preliminary report which will be circulated widely among user groups to obtain feedback and comment for incorporation into a final document. It is hoped that more quantitative requirements can be generated by some user groups, and that through this iterative process, a realistic set of user requirements will emerge.

The output of the user requirements definition will be used to formulate suitable data presentation products to meet user needs. These products will form the basis of overall systems design including the satellite, its earth stations and the 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 marine 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 has responsibility for the management of marine spill cleanups and other marine disasters. 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

(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 encompose all types of shipping other than oil and gas. 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. Since 1978, they have operated two ice reconnaissance aircraft, one equipped with side-looking airborne radar (SLAR) which 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 predict 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 Maritime Administration within CCG "shall be responsible for the identification of ice reconnaissance and information services and requirements for the satisfactory performance of marine operators in the Arctic[3]."

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 Maritime 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 Program Objectives versus Level of Information Required

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 Canadian Coast Guard and AES[(4)]. 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 extent required for tactical information is the distance covered by the vessel within one day.

Ocean

There is a requirement for ocean information for planning marine activities. As stated by Coast Guard such information is needed to plan:

(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. Forecasts in particular are needed.

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 and frequent special spot 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)(5). 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 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.

According to forecasts made within the Canadian Maritime Transporation Administration, 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. 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 oil and mineral exploration activities is carried in fluctuating levels.

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.

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 are within these specifications.

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.

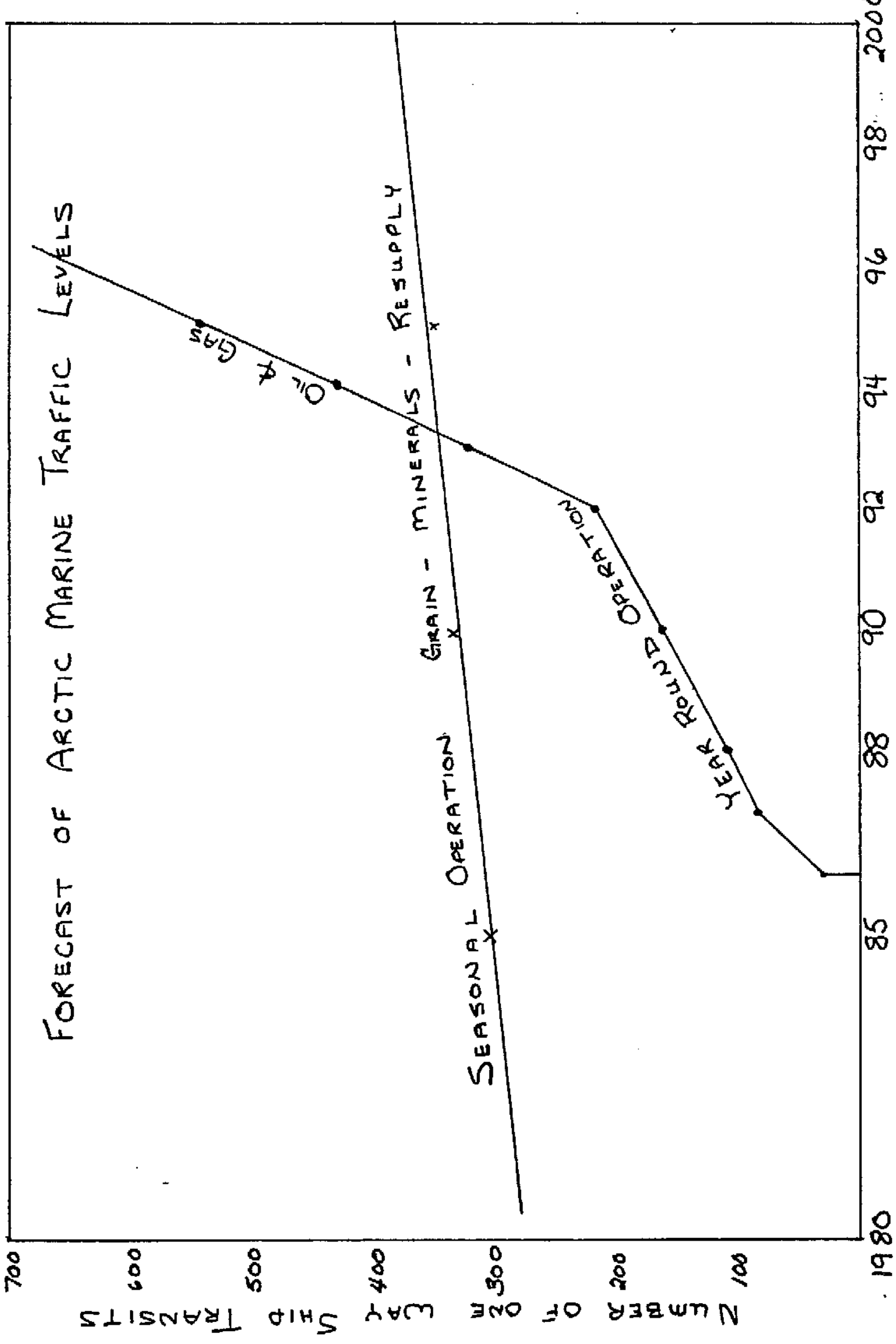

Forecast of Arctic Marine Traffic Levels
Oil & Gas
Year Round Operation
Seasonal Operation
Grain - Minerals - Resupply
Number of One Way Ship Transits
700
600
500
400
300
200
100
1980
85
88
90
92
94
96
98
2000

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 Sea	mid June - mid November
Hudson Bay and Approaches Labrador Sea north of 55°	early June - early December
East Coast south of 55° Gulf of St. Lawrence	mid December - mid May
Great Lakes	December - end of April
West Coast	no requirement

2. OCEAN INFORMATION

Area	
Canadian Arctic East Coast north of 55°	mid June - mid November
Hudson Bay and Approaches	early June - early December
East Coast south of 55° Gulf of St. Lawrence, West Coast	year - round

Some of the parameter specification tables could not be completed at this point in time. 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[14] and from the presentation given on ice by Ramseier and Weeks at the U.S. - Canada RadarSat review meeting on June 5, 1981[6].

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 operations 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.

2.1.4 Summary of Parametric Requirements

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 not detailed as yet; however, because CCG services general shipping, it is felt forecast parameter requirements would be similar.

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 summer "open water" navigation season, there is always the possibility for such a ship to 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, 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 will be similar to the CCG and general shipping needs. 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. 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 may not be necessary for all 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 no further need for information, although of course its thickness will grow. 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.

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[9].

(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[10].

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 using remote sensing.

Neither organization has submitted a list of ocean parameter requirements to this date. However, the writers have assumed the need for ocean information for oil and gas shipping would be similar to general shipping and the CCG.

Both organizations stated the need for forecast information, although a specific list of forecast requirements for ice and ocean parameters has not yet been submitted.

2.2.4 Summary of Parametric Requirements

Table 2.3 lists the parametric requirements stated by Dome and the APP. No ice parameters were explicitly stated for planning support.

The APP ranked its ice parameters in a descending order, recognizing all the parameters and associated specifications could not be met at all times:

(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. Their list of ice parameters included:

Table 2.3

OIL AND GAS SHIPPING

Summary of Parametric Requirements

1. Ice

Planning	Strategic Observation	Strategic Forecast (1)	Tactical (5)
not specified	Ridges-height -density -orientation -separation -type Thickness Pressure -convergence Concentration -% by area Leads -orientation -% by area -width -separation Surface (3) characteristics Icebergs -size -height Edge -location Floes -size Ice Island (4) fragments -area -height Snow Cover	Ridges-height -separation Leads -width -separation Icebergs -size -height (2) -location Floe-size Type -% by area Concentration -% by area	Ridges-height -separation Leads-width -separation Icebergs-size -height -location Floes-size Type-% by area Concentration -% by area

2. Ocean

Planning	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

This list was used to generate the parameter list for the strategic forecast mode for which Dome stated a need.

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.

2.2.5 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 certain parameters is as high as once every 6 hours while the turnaround time ranges down to 2 hours.

Tactical

Tactical ice information requirements are listed in Table C-6 in Appendix C. Dome Petroleum has 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 defind 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. Repetition of coverage for tactical 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.

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 Program Objectives Versus Level of Information Required

The essential objective within an offshore hydrocarbon program is to explore for and produce hydrocarbons 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. This is particularly true for fixed structures within an ice cover with the exception of 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

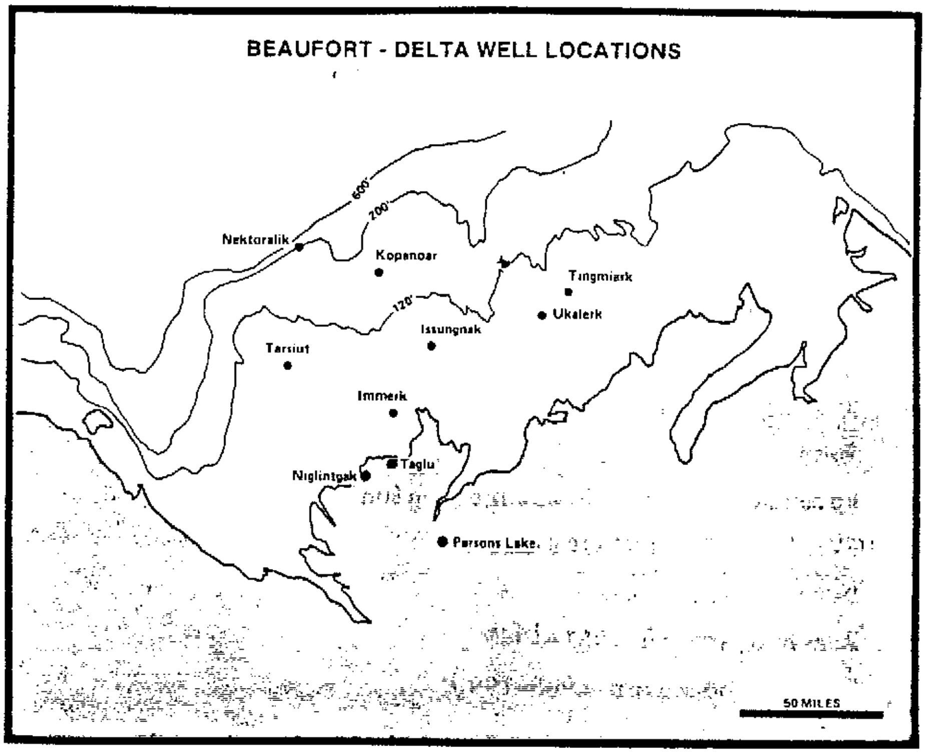
Offshore drilling and exploration has been conducted in both Arctic and sub-Arctic waters within Canadian jurisdiction. In particular, the following offshore areas have been presently determined to be important for hydrocarbon development:

(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 principle operators are active in the region: Dome Petroleum, Imperial Oil (now Esso Resources) and Gulf Canada Ltd. These companies have been charged with preparing an environmental impact statement (EIS) for Beaufort Sea/Mackenzie Delta[24]. 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: (25)

Dome, Esso and Gulf have presented a number of development scenarios for oil development [25]. 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 artifically-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 through the Arctic Pilot Project. This past winter 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 or as the ice permits. Aquitaine, Esso and others have undertaken drilling in Davis Strait while Petro Canada has become the major 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. Even then, it will likely be a seasonal operation (July-October) with perhaps some seasonal extension into 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 likely within the next five years; however, this is dependent 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 will not be producing until the 1990's; 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 requiring 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 seasonal for the East Coast and Eastern Arctic until the end of the decade at least. This requirement will apply for the open water season. Therefore ocean information is more urgently needed in these areas with the exception of icebergs are year round. 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) Because of the continuing presence of ice and the short fetches on most marine channels, needs for ocean information in the Canadian Arctic areas as defined in this study are minimal.

5) Plans for year round production and exploration systems are most advanced in the Beaufort Sea area. Dome's shipping plans for tanker navigation by 1988 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.

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 also be a need for timely forecasts of ice and ocean parameters required to make operational decisions.

9) The relative importance of parameters varies considerably with geographic area. For example, leads and ridges become less significant in more southerly areas because of continuous ice motion. Icebergs are an East Coast concern, while ice islands and ice islands fragments are found almost exclusively in the Beaufort Sea.

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

2.3.4 Summary of Parametric Requirements

Table 2.4 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.

Needs for forecast information have not been specified by any members of this group so far except to say forecasting is a requirement. Some members said the observational information would be input into their own forecast models.

2.3.5 Parameter Specifications

Planning

For offshore drilling and production, planning requirements relate to design only. To date, only ice information requirements have been submitted. These are shown in Table C-1 in Appendix C.

Planning/design requirements need accurate, relatively frequent gathering of information, but with a relaxed turnaround time.

Table 2.4

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	-geometry	-magnitude
Height of detormation	Ice Islands-size	Leads-width
Block size	-location	- % area
Large scale deformation	Thickness	-pattern
Pressure buildup		Icebergs-location
Thickness		-movement
		-geometry
		Ice Islands-size
		-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

Strategic

Tables C-4 and C-8 of Appendix C detail the ice and ocean requirements. No differentiation of requirements between the observations and forecasts have yet been received from this group.

Tactical

Tables C-7 and C-8 in Appendix C show the requirements for ice and ocean information.

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.

2.4 Fisheries

Fisheries encompass the execution of two main activities: fishing operations and fisheries research to support 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 within the fishing group in this report.

Fishery operators on the East Coast can be classified 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 primarily composed of three companies operating larger vessels. The three companies include Fisheries Products, National Sea Products and the 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 Reglations [11] 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 International Commission for Northwest Atlantic Region. Twenty different subregions are defined within an area bordered by 39-61^{0}N by 42^{0}W - 71^{0} 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. 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 the Hamilton Bank. Located off the Labrador coast around 54^{0}N

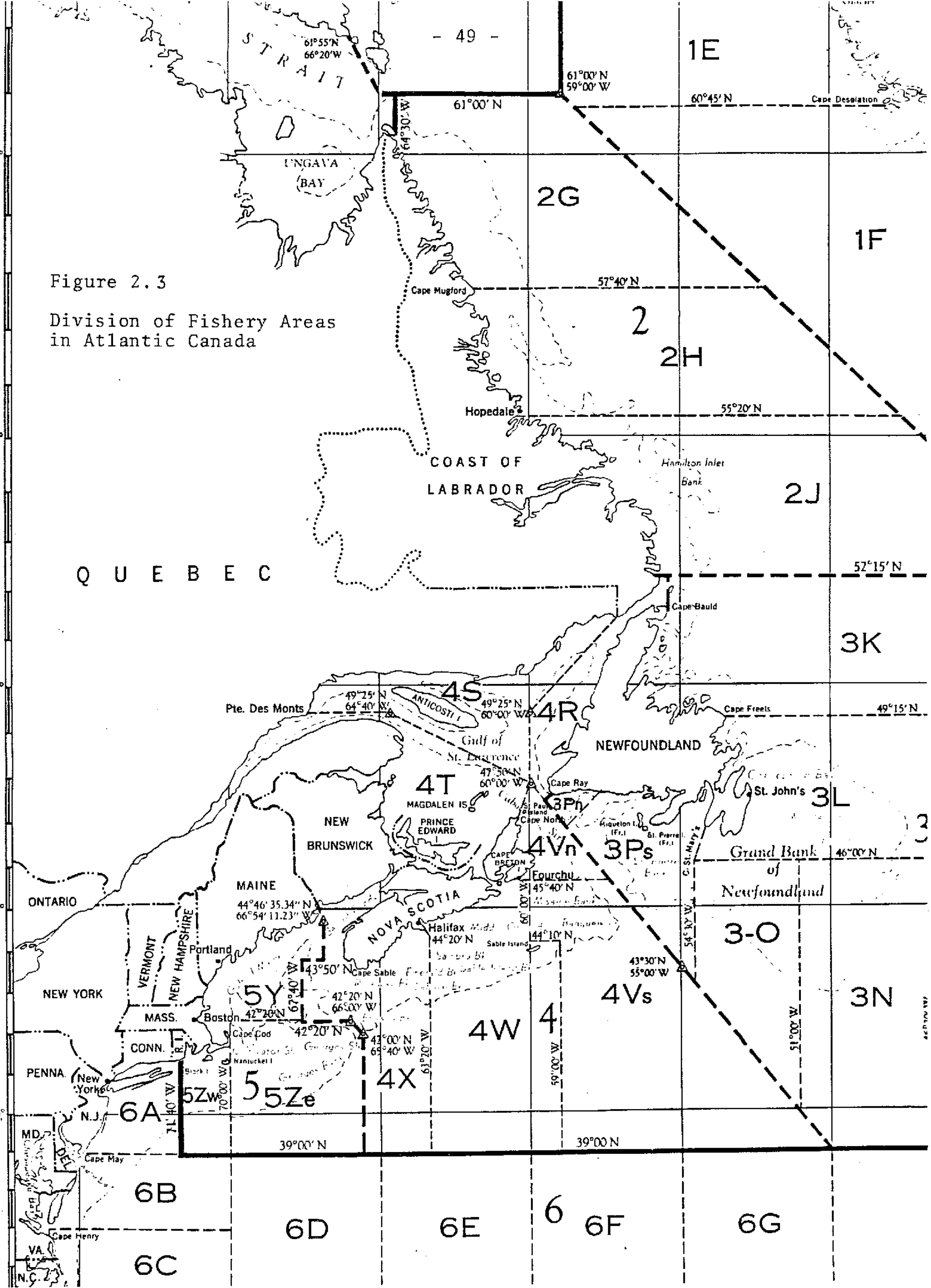


Figure 2.3

Division of Fishery Areas in Atlantic Canada latitude, its area has become increasingly important to the deep sea fishing fleet both in summer and winter months. The area was stated by several people to be one of increasing 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 last year 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.

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 environment 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.

The writers had insufficient information to classify fishery operator needs into the more formalized structure of planning, strategic and tactical support partly because of the variation of activity within fishery operations themselves.

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, distribution 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.

2.4.3 Parametric Requirements

A list of parametric requirements for both fishery operators and researchers is given in Table 2.5. 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, it is likely these parameters would be needed for both levels depending upon prevailing conditions. Fishery operators stated a preference for forecasts of these parameters rather than observations.

Specifications for ice parameters were not available. 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.

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

Table 2.5

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	

B. Fishery Researchers

Ice	Ocean
N/A	Sea surface temperature
	Chlorophyll
	Surface currents
	Water colour
	Salinity
	Fishing vessel locations

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 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.

Meteorological applications of SAR would appear to be in the provision of information on mesoscale variability (at scales of 1-10 km), according to the U.S. Radarsat Ocean SAR Study Team which met Apr. 27-28, 1981. Such information is not readily obtainable in other ways. SAR also is capable of providing precise location of atmospheric fronts which may be useful in conditions where a general cloud cover is present.

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 recommedations on the Canadian input to the programme. A document entitled "Report of the CCP Climate Workshop[24] was drafted which listed 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 cover 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 on RadarSat would make a significant contribution to such a goal particularly since it is a proven sensor system.

The report addresses 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.

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 in the Arctic, and none of their fighting vessels are ice-strengthened. 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.

METOC wave forecasts (12, 24 and 36 hr.) are considered to be a good product. It has just been evaluated through a user questionnaire, and a report "CF METOC Wave

Program Evaluation " by B.D. Brotill and D.J. Russell, Apr. 10, 1981, had just been completed in draft form. 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 thought to be a good product, they do lack the detail needed for some DND activities. The basic data comes 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 periodicity and could improve the detail in the present charts.

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 forecast weather and waves, but research only now is trying to prove the efficacy of satellite sensors for measuring such parameters.

Sea surface temperatures (SST's) are useful for ASW work; however, the accuracy from a passive microwave radiometer ($\pm 1.5^{0}C$) is not sufficient for DND's needs which are $\pm 0.5^{0}C$. Moreover, temperature profiles throughout the water column are needed which are not possible to measure from a satellite. The weekly SST contour charts put out by METOC, which might be improved using 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 becomes classified and would need to be encrypted before it is communicated. 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 Radarsat wind and wave data 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

The principle source of information on the requirements for ice research is the minutes of the first Canada - U.S. Ice Study Team Workshop for Ice Mission Requirements held at Cornwall, Ontario, in February, 1981[14]. 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, ice-bergs 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

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

Icebergs

Snow Pack

- percent cover
- water content

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 Antartic 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[26]. 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.

The above mission requirements for the ice research community are very preliminary and represent the results of only one workshop session. Further interactions should result in the definition of more specific needs.

The 24 hour, year-round operation of RadarSat will result in more faithful periodic coverage of any geographical region than has been possible with Landsat. For research purposes, such time series observations will be most useful in phenological and climate studies. For this reason, an important requirement is to archive data retained by Radarsat, and provision should be made in the initial design of the satellite system for archiving capacity.

2.7.2 Oceans Research

There are no operational oceanography programs of any significance in Canada at the present time. However, there is a need for improvement in the provision of information about our offshore areas including better marine weather information, site-specific information on waves and wave directional spectra, improved charts of sea surface temperature and oceanographic fronts, long-term measurements of surface and subsurface water velocities, etc. Synthetic apeture radar and other remotely-sensed data must play a significant role if these operations information needs are to be met.

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. While the team will not hold its first formal meeting until late in August, 1981, a preliminary report was filed with the RadarSat Project Office dated May 29, 1981[15]. 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 recommended 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 waves (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 $\pm 20^{0}$.

Ocean colour monitors have ben developed for coastal sedimentaion and biological studies.* Sea surface temperature can be measured to within 0.5^{0}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 oceangraphic applications to include sensors other than 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[22], 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 would strongly endorse this view and urge the RadarSat Oceanographic Study Team to address this broader issue at its meeting in late August, 1981.

3. SUMMARY OF CRITICAL USER REQUIREMENTS

From the information received so far in the study, it is evident that the first three groups, 1) CCG and general shipping, 2) oil and gas shipping and 3) offshore drilling and production are the most comprehensive 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.

The summary tables in this section are a compilation of the most stringent specifications for each parameter for accuracy, spatial resolution, repetition of coverage and turnaround of information taken form the various tables in Appendix C of this report. Included in the summary tables are the number of user groups setting specifications. There are several parameters which were required by only one user group.

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.

The study is unable to produce a summary list of parameters and specifications for each geographic region because of a lack of information. Beyond lists of parameters applied to geographic regions as the Canadian Coast Guard has done, no geographical differences in specifications were available. It is recognized specifications may change from location to location. The Arctic Pilot Project in its strategic routing study subdivided the route into two areas, each with its own specifications for the same parameters. These differences however relate only to frequency of observation and turnaround of information.

3.1 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 rather 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. Much 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.

Strategic

Table 3.1 details the critical parametric requirements for the strategic support mode. The table includes the number (maximum of 3) of user groups stating specifications. 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.

Table 3.1 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
BOUNDARY/EDGE	location	100 m	100 m	6 hr	2 hr	3
TYPE	% by area	5%	25 m	6 hr	2 hr	3
CONCENTRATION	% by area	5%	10 m	6 hr	2 hr	3
THICKNESS	m	0.2 m	0.2 m	24 hr	6 hr	3
LANDFAST ICE	location	1.5 km	500 m	24 hr	6 hr	1
MOTION	margin	1 km/day	1 km	24 hr	6 hr	1
	magnitude	1 km/day	25 m	12 hr	6 hr	2
RIDGES	height	<1 m	1 m	6 hr	2 hr	3
	density	5%	20 m	6 hr	2 hr	2
	orientation	10°	-	6 hr	2 hr	1
	separation	<20 m	20 m	6 hr	2 hr	1
	type	FY/MY	-	12 hr	<3 hr	1

Table 3.1 (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
	% area	2%	20 m	6 hr	2 hr	3
	width	25 m	25 m	12 hr	3 hr	2
	separation	500 m	500 m	12 hr	3 hr	1
PRESSURE	convergence	positive sign	2 km	6 hr	2 hr	2
ICEBERGS, BERGY BITS' GROWLERS	size	5 m	10 m	6 hr	2 hr	3
	height	3 m	3 m	6 hr	2 hr	1
	location	20 m	100 m	12 hr	6 hr	2
FLOES	size	10 m	20 m	12 hr	3 hr	3
ICE ISLAND FRAGMENTS	size	20 m	20 m	12 hr	3 hr	3
	height	1 m	1 m	12 hr	3 hr	1
	location	20 m	100 m	24 hr	6 hr	2
SNOW COVER	thickness	0.2 m	10 m	12 hr	3 hr	2
DETERIORATION	% meltponds	5%	10 m	7 days	7 days	
SURFACE CHARACTERISTICS		10 m	10 m^2	6 hr	2 hr	1

The requirements stated in Table 3.1 were matched to the specific user group which gave the critical specifications. Table 3.2 identifies the critical user group for each parameter specification. The table suggests that it is not always the same user group for 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 3.3 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 3.4. The offshore drilling and production group supplied the critical specification for ice motion parameters in particular for ice edge, floes and icebergs. Presumably this is due to their present mode of open water operations so that their tactical needs for ice movement and locations are of particular importance.

Table 3.2

Parameter Specification vs User Group

Strategic Ice Information

ICE Parameter	CRITICAL USER GROUP Accuracy	Resolution	Repetition	Turnaround
Edge/Boundary - location	1	1	2	2
Type - % by area	1,2	1,2	2	2
Concentration - % by area	2,3	3	2	2
Thickness	2	2	1,2	1,3
Landfast ice - location	1	1	1	1
Motion - margin	3	3	3	3
- magnitude	3	1	1,3	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

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

Table 3.3

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	20 m	12 hr	2 hr	1
EDGE/ BOUNDARY	location	100 m	100 m	1 hr	instantaneous	1
LANDFAST ICE	location	50 m	500 m	12 hr	2 hr	1
FLOES	size	10 m^2	20 m	continuous	instantaneous	3
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
MOTION	magnitude	1 km/day	1 km	continuous	instantaneous	2
	margin	1 km/day	1 km	continuous	instantaneous	1
	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)	detection	1 km	1 km	1 hr	<1 hr	1
	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 3.4

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
Landfast ice -location	1	1	1	1
Floes-size	3	1,3	2	2
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
Motion				
-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	1	1
Icebergs				
-detection	3	3	3	3
-location	1	1	2	2
-size	1,3	1,3	2	2
-height	2	2	2	2
-movement direction	3	3	3	3

Table (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

Legend

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

3.2 Critical Ocean Parameter Specifications

Contrary to ice covered waters, there is considerable experience in operations within the open water period for ships and structures. Consequently, parameters for ocean information are similar for most groups regardless of the mode of operation. Researchers would be the exception because 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. 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 are 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 questionnarie 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 3.5 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 3.6 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 data over ice data.

3.3 General Observation

There is a considerable user need for ocean information, both in the East and West Coast regions. Present East Coast offshore drilling operators have prioritized ocean information over ice information. The strong requirement for ocean information 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 off the West Coast regions. Satellite-based observations would have a higher density than what could be provided by a solely surface-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.

Table 3.5

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	2°	NS	100 km^2	-	6 hr	<3 hr	<6 hr	<<3 hr

NS - not specified

S - strategic

T - tactical

\- not stated

Table 3.6

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	3	1	3	-	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

APPENDIX A

LIST OF CONTACTS

Date	People Contacted	Organization
Feb. 18	Mr. D. Smith Dr. R. Ramseier	Atmospheric Environment Service
March 10	Dr. 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.
	Dr. 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	Indian and Northern Affairs
	Dr. J. Keys	" " "
April 22	Captain M. Johnson	Newfoundland Ship Owners Assoc.
	Captain M. Frampton	" " "
	Mr. P. Outerbridge	Harvey Offshore Services
	Mr. S. Roche	National Sea Products Ltd
	Mr. B. Winsor	C-Core
April 23	Captain I. Green	Canadian Coast Guard
	Captain P. Whitehead	" " "
	Dr. Needler	Bedford Inst. of Oceanography
	Dr. C. Mason	" " "
	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. Melozzi	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)

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

TA[illegible] 1.[illegible]

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: ________________________________

____

____

____

____

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	1	2	3	4	5
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

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.

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	20 m	1 day	6 hrs
EDGE	location	100 m	100 m	12 hrs	6 hrs
LANDFAST ICE	location	1.5 km	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	% of area	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	10 m	1 day	6 hrs
DETERIORATION	% meltponds	5 %	10 m	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	-	12 hr	<3 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 km	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 known at present.

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 with less stringent needs than Area 1 specified.

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 and visibility. Turnaround times as low as 5 minutes may be necessary.

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. Information was supplied by Melville Shipping and Dome Petroleum. 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	6 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	1 km	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	<6 hr
CONCENTRATION	% of area	5 %	50 m	3 hr	2 hr
THICKNESS	m	1 m	20 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	% of area	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	10 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
ICEBERGS	size	<20 m	20 m	continuous	instantaneous
	height	<3 m	3 m	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

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	2°	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

Table C-9

CANADIAN COAST GUARD AND GENERAL SHIPPING

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			TYPE OF OBSERVATION	OBSERVATION REQUIREMENT					
					ACCURACY		RESOLUTION			
							SPACE		TIME	
	BASIC	CLIMATE	OPN/COMM		DESIRED	MIN.	DESIRED	MIN.	DESIRED	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°K	1°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			TYPE OF OBSERVATION	OBSERVATION REQUIREMENT					
					ACCURACY		RESOLUTION			
							SPACE		TIME	
	BASIC	CLIMATE	OPN/COMM		DESIRED	MIN.	DESIRED	MIN.	DESIRED	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	obs. & 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 GSFC
CZCS

APPENDIX D

REFERENCES AND INFORMATION SOURCES

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

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

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

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

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

6. F. Carsey, R.O. Rammseier and W.F. Weeks, "RadarSat Mission Requirement Review - ICE", June 5, 1981.

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

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

9. "LNG Carrier Strategic Routing Study: Final Report," Viatec Resources Systems Inc., Leigh Instruments Ltd., April 20, 1981.

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

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

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

13. S. Peterherych, Atmospheric Environment Service.

14. 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.

15. C. Mason, "Oceanographic Study Team Report - Radar Sat" Bedford Institute of Oceanography, May 29, 1981.

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

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

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

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

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

21. "W.M.O. Sea Ice Nomenclature" English Terminology, KMO No 259.

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

23. 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.

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

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

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