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ANALYSIS OF CURRENT OPERATIONS OF THE INTERNATIONAL ICE PATROL

Annex A of Cost and Operational Effectiveness Analysis for Selected International Ice Patrol Mission Alternatives

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FINAL REPORT

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16. Abstract

This report presents the results of a cost and operational effectiveness analysis (COEA) of selected mission alternatives for the International This report is Interim Report Volume 1 for the Cost and Operational Effectiveness Analysis for Ice Patrol Mission Analysis Study. The report characterizes the various processes used in International Ice Patrol (IIP) operations, including the types of information used by the IIP, the data requirements and processes necessary to develop that information, and how the information is provided to the mariner. Included are descriptions of the existing authority, organization, and management of the IIP as well as initial characterizations of the operating cost of the IIP. The purpose of the report is to provide a broad, accurate description of the IIP as it currently operates.

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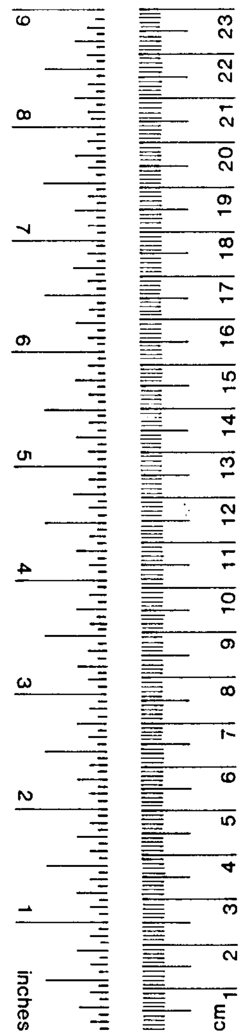
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

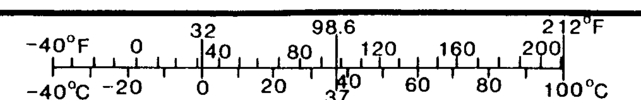
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (WEIGHT)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (EXACT)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly).



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (WEIGHT)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (EXACT)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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ANALYSIS OF CURRENT OPERATIONS OF THE INTERNATIONAL ICE PATROL

Executive Summary

This report characterizes the various processes used in International Ice Patrol (IIP) operations, including the types of information used by the IIP, the data requirements and processes necessary to develop that information, and how the information is provided to the mariner. Included are descriptions of the existing authority, organization, and management of the IIP as well as initial characterizations of the operating cost of the IIP. The purpose of the report is to provide a broad, accurate description of the IIP as it currently operates.

The basic mission of the International Ice Patrol is unchanged since the inception of the ice patrol service. The IIP operationalizes the mission as ***determining the Limits of All Known Ice along the southeastern, southern, and southwestern edge of the ice region and publishing that information to mariners in a timely fashion***. This mission involves data and information acquisition, processing, and distribution--finding out where the ice danger is for trans-Atlantic shipping and telling the mariner so as to prevent ship-iceberg collisions.

The IIP effectively captures available data on iceberg and radar target sightings from other organizations. Because of the importance of high quality information along the Limits of All Known Ice, the IIP deploys an Ice Reconnaissance Detachment to provide information on icebergs and radar targets in that area. The primary surveillance device is the AN/APS-135 SLAR augmented with the AN/APS-137 FLAR mounted on an HC-130H aircraft. The present assignment of aircraft effectively limits searches of particular geographic regions to once every two weeks. Limitations and possible methods for performance improvement have been identified for both radars in this initial analysis. The detection this past year of a very large tabular iceberg significantly outside of the LAKI clearly indicates that some icebergs are undetected. A probability analysis incorporating the actual search effectiveness for SLAR searches and revisit frequency should be conducted.

A major argument for the reduced frequency of visit is the use of iceberg drift and iceberg deterioration models. While the models appear to be conceptually sound, they depend heavily on environmental data and iceberg characteristics that may have significant estimation errors. Before any significant expense is incurred to identify/acquire higher quality environmental data, a sensitivity analysis of the models should be conducted along with an examination of the model interaction, including the effects of resights.

The IIP operation is well managed. Fairly detailed procedures are established and documented. Personnel are well-trained and knowledgeable. The new (2 years) computer system greatly facilitates the processing of data. The electronic file interchange procedures in use permit effective quality assurance checks of input data. The major equipment deficiency is the processor speed on the main computer system. Personnel levels recently have been reduced to allowance levels. This appears to be adequate for continued operation, although there is little room for personnel vacancies. Costs are driven primarily by the ICERECDET which accounts for nearly 85% of the total cost of the IIP that is billed to the contributing governments.

The critical factor which is well known, confirmed by this detailed review of present IIP operations, is the role of detection. Much of the effort in the IIP has been to compensate for the deficiency in detection. Primary emphasis in this analysis will be on identifying alternative means of detecting, identifying, and classifying icebergs. Unless that can be done on a continuous basis, some prediction capability will be required. Although a key assumption at the kick-off meeting was that the Coast Guard will continue to actively manage and conduct the Ice Patrol, we will explore other possible arrangements as management alternatives.

Part of the analysis will further review the proposed program performance measures of effectiveness. A further evaluation of the present operations in Phase 1 will provide a basis for developing alternative approaches, procedures, facilities, and equipment for the conduct of the IIP. That evaluation will be conducted in mid-October. With the Program Manager's concurrence, the characterization of the IIP in this Interim Report will form the basis for detailed cost and operational effectiveness analysis in Phase 2 of the study.

ANALYSIS OF CURRENT OPERATIONS OF THE INTERNATIONAL ICE PATROL

1.0 Objective and Purpose of the Report.

This report satisfies the requirement of Task 3.3.6 of the contract. The report characterizes the various processes used in International Ice Patrol (IIP) operations, including the types of information used by the IIP, the data requirements and processes necessary to develop that information, and how the information is provided to the mariner. Included are descriptions of the existing authority, organization, and management of the IIP as well as initial characterizations of the operating cost of the IIP. The purpose of the report is to provide a broad, accurate description of the IIP as it currently operates. With the Program Manager's concurrence, this characterization will form the basis for detailed cost and operational effectiveness analysis in Phase 2 of the study. A further evaluation of the present operations in Phase 1 will provide a basis for developing alternative approaches, procedures, facilities, and equipment for the conduct of the IIP. This revision of the interim report incorporates the comments and suggestions of the IIP staff that correct and clarify various items in the original version.

2.0 Overview of the International Ice Patrol.

2.1 Background and Authority.

Following the sinking of RMS *Titanic* in 1912, the International Ice Patrol (IIP) was formed to track icebergs and provide warnings to vessels using the trans-Atlantic shipping lanes over the Grand Banks of Newfoundland. Under the provisions of the International Convention for the Safety of Life at Sea (SOLAS), 1974, Chapter V, Regulations 5 through 8, and the provisions of U.S. Code, Title 46, Sections 738, 738a through 738d, the U.S. Coast Guard has been tasked with the management and operation of the IIP. The primary mission of the IIP has not changed over the years. Specifically, the mission of the IIP is to provide a service of observing and disseminating information on ice conditions in the Grand Banks region of the Northwest Atlantic ocean. During the ice season, the southeastern, southern, and southwestern limits of the regions of icebergs in the vicinity of the Grand Banks of Newfoundland are guarded for the purpose of informing passing ships of the extent of this dangerous region. The IIP also studies ice conditions in general, with emphasis on the formation, drift and deterioration of icebergs and assists ships and personnel requiring aid within the limits of operation of the IIP forces.

Large numbers (over 10,000) of icebergs are calved from glaciers on the west coast of Greenland each year. Many are carried south by the Labrador current to the

Grand Banks where periods of dense fog occur nearly half of the year. Within its area of responsibility from 40°N to 52°N latitude and 39°W to 57°W longitude, the IIP actively tracks icebergs that cross 48°N and may be carried into the shipping lanes. Icebergs, fog, and heavy shipping present the ingredients for maritime disaster during the iceberg season extending from March through August. Figure 1 illustrates the IIP area of operation and the bathymetry on the Grand Banks of Newfoundland along with the major branches of the Labrador current.

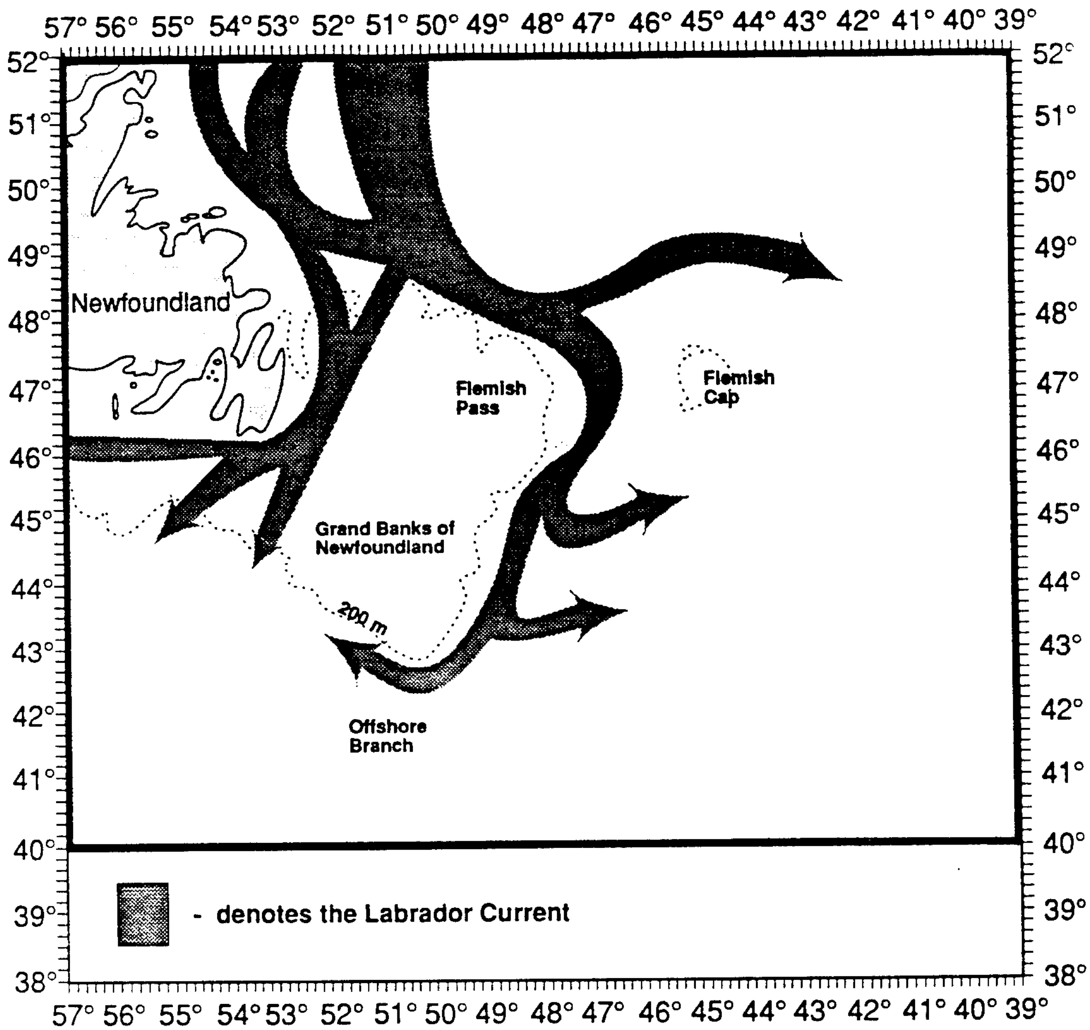

Figure 1. International Ice Patrol Area of Operation
(Source: IIP Bulletin No. 78, CG-188-47, 1992)

Commander, International Ice Patrol (CIIP) is under the operational control of Commander, Coast Guard Atlantic Area. The Program Director for IIP is Chief, Office of Navigation Safety and Waterway Services (G-N) in Coast Guard Headquarters with direct management responsibility delegated to Chief, Ice Operations Division (G-NIO) as the Program Manager. Commander, International Ice Patrol directs the IIP from its

Operations Center located with the USCG Research and Development Center in Groton, Connecticut. IIP obtains and analyzes iceberg and environmental data, prepares daily ice bulletins and facsimile charts, and responds to requests for ice information. IIP uses aerial ice reconnaissance detachments, observations from other agencies, and, when necessary, surface patrol cutters to survey the southeastern, southern, and southwestern regions of the Grand Banks of Newfoundland for icebergs. IIP's Operation Center uses iceberg drift and deterioration computer models to produce radio broadcasts and facsimile charts to warn mariners of the Limits of All Known Ice based on predicted positions of icebergs.

2.2 Operating Environment.

The IIP ice season usually commences in February or March of each year when icebergs begin to exit the sea ice south of 48°N latitude and pose a threat to trans-Atlantic shipping. IIP usually conducts one or two aerial reconnaissance flights in January and February to ascertain the sea ice and iceberg conditions to 52°N. These flights help to determine season threat and commencement of the ice season. The ice season usually runs to about July or August when CIIP determines that the iceberg threat has receded and the "Limits of All Known Ice" including icebergs has generally retreated north of the trans-Atlantic shipping lanes.

One measure of the severity of the ice season is the number of icebergs that pass south of 48°N latitude. The IIP defines those years with less than 300 icebergs crossing 48°N as light ice years; those with 300-600 crossing 48°N as average; those with 600 to 900 crossing 48°N as heavy ice years; and those with over 900 crossing 48°N as extreme. The annual counts of icebergs crossing 48°N for the period from 1912-1993 for the IIP iceberg year from October-September is shown in Figure 2 (Anderson, 1993). These data should be used with caution due to the very different ways the data were collected and recorded over the years. In addition to the severity of the season, changes in operating procedures, technological changes, levels of surveillance effort, changes in reconnaissance techniques, and personnel factors contribute to variability in the estimates.

Over the years, IIP has developed innovative ways to improve its mission effectiveness. Increased international cooperation, improved communications, new technology for detection, and models for predicting iceberg drift and deterioration have been used to improve the quality of information delivered to mariners and reduce the risk of disaster while reducing the cost of operations.

2.3 Iceberg Detection and Identification.

The key element in IIP operations is obtaining information on the location of icebergs. Initially, icebergs were identified visually from ship sightings. Following World War II, aerial visual surveillance was used to increase the coverage and amount of iceberg information. In 1983, the IIP began using Side Looking Airborne Radar (SLAR) which resulted in increased levels of performance.

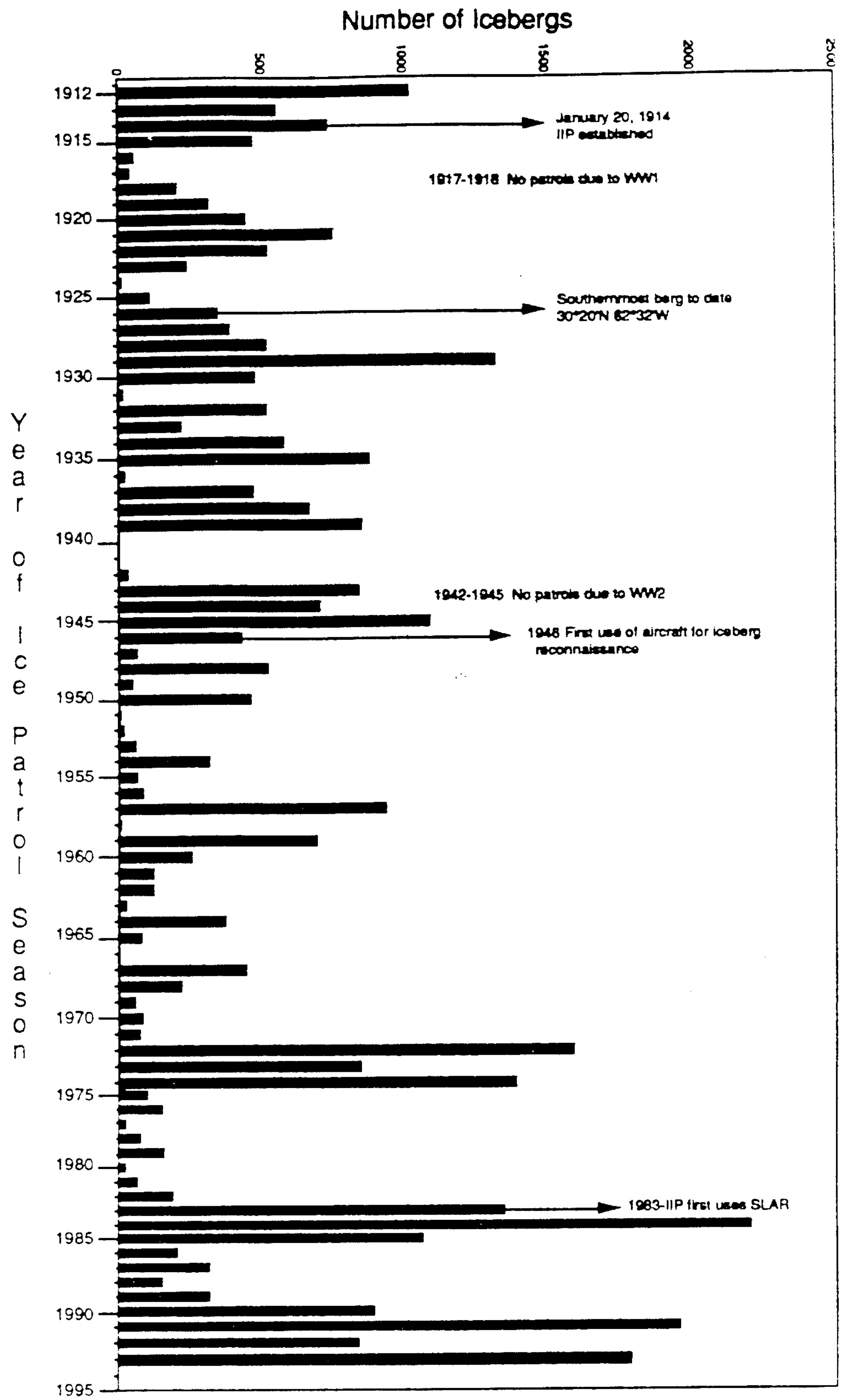

Figure 2. Counts of Icebergs Crossing 48°N Latitude (1912-1993).
(Source: Anderson, 1993)

The IIP receives reports of icebergs and radar targets that may be icebergs from numerous sources. Present sources of iceberg and/or radar targets include: IIP's aerial reconnaissance by its Ice Reconnaissance Detachment (ICERECDET); the Canadian Atmospheric Environmental Service (AES) aerial reconnaissance provided through Ice Centre Environment Canada (ICEC); the Canadian Department of Fisheries and Oceans (DFO) aerial reconnaissance provided by the contracted Atlantic Airways; the NOAA/U.S. Navy Joint Ice Center (from a variety of DOD sources); ships passing through the ice area, and other sources such as the hydrocarbon industry. ICEC provides IIP with predicted positions of icebergs that have been sighted north of 52°N, when they drift south of 52°N using their data management system identified as BAPS (iceBerg Analysis and Prediction System). A total of 11 sighting category source codes are used by the IIP.

The IIP ICERECDET presently uses HC-130H aircraft equipped with an AN/APS-135 Side Looking Airborne Radar (SLAR) and an AN/APS-137 Forward Looking Airborne Radar (FLAR) from Air Station Elizabeth City and HU-25B aircraft equipped with an AN/APS-131 SLAR from Air Station Cape Cod. Although the HU-25B aircraft is less expensive to operate, the IIP has found the HC-130H aircraft to be significantly superior operationally because it has much more endurance and effective on scene search time and is a more stable platform. In the 1970s, Inertial Navigation Systems provided increased initial detection position accuracy of 10 nm. This is expected to be further improved in the near future with installation of GPS navigation systems. (Initial position errors are critical as they are compounded when the berg is exposed to different oceanographic and environmental factors.)

In recent years, using the aircraft sensor suite, the ICERECDET has deployed to St. John's, Newfoundland for approximately one week approximately every other week. Average reconnaissance revisit to an area is 12 to 14 days. Since the closing of the U. S. Naval Air Station in Argentia, Newfoundland in the early 1970s, the ICERECDET has deployed from Canadian Forces Base Prince Edward Island, St. John's Newfoundland, Gander Newfoundland, and recently from St. John's, Newfoundland. The continental United States is too distant for staging IIP reconnaissance flights, and it now appears that St. John's, Newfoundland is the best site for staging the ICERECDET.

Iceberg detection systems and other iceberg location information sources are discussed in detail in section 5.0.

2.4 Environmental Data and Iceberg Location Prediction.

In order to predict the future positions of icebergs, the IIP uses two computer models to estimate the drift and deterioration of the icebergs. In addition to the initial position and estimated size of the icebergs, these models depend heavily on various meteorological and oceanographic data such as wind and current velocities, wave heights and periods, and sea surface temperatures obtained from a number of sources such as surface observations by vessels, satellite imagery, and deployed buoys. The majority of these data are provided/processed by other agencies.

Sea surface temperature (SST), wave height, and wave period data and average wind data are received daily from the U.S. Navy Fleet Numerical Meteorology and Oceanography Center (FNMOC) Monterey via Internet to be used in the iceberg deterioration and drift models. The Sea Ice Edge (1/10 coverage) is received daily from ICEC as their FICN2 product and is included on facsimile charts.

The ICERECDETs strategically deploy 8 to 15 satellite tracked ocean drifting buoys each year. These World Ocean Circulation Experiment (WOCE) drifters have surface temperature sensors and a drogue at 50 meters. They cost approximately $3,000.00 and have a life expectancy of 4 to 6 months. The information acquisition costs is $4,000 per buoy year through Service ARGOS. Drifter track current and SST data is received and processed daily. IIP uses the current data to update the historical current data file once per week. IIP believes that this reliable current information helps to justify the 12 to 14 day reconnaissance interval. IIP plans to permanently modify the historical current data file with the data provided by approximately 175 drifters. Drifter data is shared with other interested activities.

Air-deployable eXpendable BathyThermographs (AXBTs), provided by the Canadian Maritime Command/Meteorological and Oceanographic Center (METOC), are deployed by the ICERECDET. The data received from the ICERECDET is forwarded to the Canadian (METOC), the U.S. Naval Atlantic Meteorology and Oceanography Center (NLMOC), and FNMOC for use in their ocean temperature models which support IIP. Sea Surface Temperature reports are also received from transiting ships and Coast Guard patrol/ research vessels and forwarded to FNMOC.

2.5 Ice Bulletins and Other Products.

The initial iceberg positional data and the environmental data are used in two iceberg drift and iceberg deterioration models to predict the positions of icebergs. These models and the environmental data are discussed in detail in section 6.0. A system of desktop microcomputers and a modified VAX computer-based system developed by INTERGRAPH are used to process the data and execute the models. The critical information for preparing the Ice Bulletin and Facsimile Chart is the estimated position of known icebergs. Using the present model, the predicted position of each iceberg has a defined error circle depending on the duration of the prediction (up to 30 nm maximum error). New sightings are used to update estimated positions (termed resighting) and reduce the error in estimation. Generally, limit setting icebergs are removed from active status when they have achieved 150% melt, while non limit setting icebergs are removed from the active file after 125% melt. The IIP uses the predicted position of icebergs with associated error circles to determine the "Limits of All Known Ice." Particular emphasis is given to the southeastern, southern, and southwestern edges of the IIP area of operation. Within the Limits of All Known Ice, the IIP identifies an "area of many icebergs." At no point does the IIP attempt to provide a comprehensive identification of all icebergs within the region nor does it provide any iceberg density estimates to the maritime community.

The primary products of the IIP are the 0000Z and 1200Z Ice Bulletins and the 1200Z Facsimile Chart broadcast at 1600Z and 1810Z. U.S. Coast Guard Communications Station Boston, MA, NMF/NIK, and Canadian Coast Guard Radio Station St. John's, Newfoundland, VON, are the primary radio stations that disseminate the 0000Z and 1200Z Bulletins. Other Bulletin transmitting stations include: METOC Halifax, Nova Scotia/CFH; Canadian Coast Guard Radio Station Halifax/VCS; Radio Station Bracknel, UK/GFE; U.S. Navy LCMP Broadcast Stations Norfolk/NAM and Key West; and the INMARSAT-C Safety Net AOR-W satellite. Fifty-two additional commands and organizations are listed in the Ice Bulletin Address Indicator Group (AIG 8916).

The 1600Z and 1810Z Facsimile Chart depicting the Limits of All Known Ice is broadcast daily by U. S. Coast Guard Communications Station Boston NMF/NIK. It is also distributed to DMAHTCNAVWARN, NLMOC, and Naval Ice Center (NAVICECEN) for further dissemination.

IIP originates Safety Broadcasts of icebergs and stationary radar contacts reported outside the Limits of All Known Ice, if more than one hour before the next scheduled broadcast. These Safety Broadcast Notice to Mariners are broadcast by Communications Station Boston NMF/NIK, Radio Station St. John's/VON, DMAHTCNAVWARN Washington, and INMARSAT SAFETYNET. IIP also responds to routinely received requests for ice information. IIP also originates the NAVTEX broadcast message with the 0000Z and 1200Z Limits of All Known Ice for broadcast by Communications Station Boston NMK/NIK.

2.6 Costs and Other Services.

The direct cost of operating the IIP is approximately $3.3 million. There is a potential to recover a significant portion of this amount from countries who agree to be billed in proportion to their shipping tonnage through the area during the ice season. Over the past few years, 17-19 countries have agreed to support the cost of operating the IIP. Reimbursement is obtained through the Department of State. However, the degree of actual cost recovery is unknown at this time.

The IIP conducts significant scientific endeavors from time to time to support its operations. The results of those experiments along with complete descriptions of the conduct of the IIP are regularly published in an annual report in the CG-188-NR series. IIP also operates as a mini oceanographic unit providing limited marine science support to other missions such as: quality control of the FNMOC regional Gulf Stream current product that is entered into the Coast Guard Computer Assisted Search Planning (CASP) program; serving as a point of contact for Self Locating Data Marker Buoy (SLDMB) data in support of Coast Guard Search and Rescue.

Over its history, the IIP has been very effective in accomplishing its primary mission. While there have been occasional losses due to collisions between vessels and icebergs/ growlers within the published Limits of All Known Ice, there are no reported collisions outside of those limits in the North Atlantic shipping lanes. There have been occasional sightings of icebergs outside of the Limits of All Known Ice which obviously are a cause for concern and deserve investigation.

3.0 Authority and Organizational Structure.

3.1 Establishment of the International Ice Patrol.

Following the sinking of the RMS *Titanic* on April 15, 1912 after a collision with an iceberg, the U.S. government sent two Navy cruisers, *Chester* and *Birmingham*, to the area to locate icebergs and broadcast their positions to trans-Atlantic shipping. They remained on patrol for the remainder of the 1912 ice season. In 1913, the Navy declined to assign ships to such a patrol and the U.S. shipping industry asked that the United States Revenue-Cutter Service be assigned responsibility for such a patrol. The Secretary of the Treasury issued instructions to the commanding officers of Revenue Cutters on ice patrol to determine the southerly, easterly, and westerly limits of the icefields and icebergs and send out daily radio messages giving the whereabouts of the ice to trans-Atlantic shipping. The Cutters *Seneca* and *Miami* conducted the first patrol and at the end of the season published a report of their activities as *R.-C.S. Ice Patrol Bulletin No. 1*.

Before the 1914 season could begin, the value of the patrol was recognized internationally with the signing of the International Convention for the Safety of Life at Sea on January 20, 1914 that provided for the establishment of an International Service of Ice Observation and Ice Patrol. This service was to be directed by the United States, but supported financially by the family of maritime nations concerned. On February 7, 1914, the President directed the Revenue-Cutter Service to be responsible for this service. *Seneca* sailed on February 19, 1914 from New York to make preliminary ice observations and was joined by *Miami* when the southward drifting icebergs began to threaten the shipping lanes. This responsibility for the IIP was transferred to the Coast Guard when it assumed the duties of the Revenue-Cutter Service. [Adapted from Evans (1949), pp. 194-197.]

3.2 International Convention for the Safety of Life at Sea (SOLAS).

As indicated above, the signing of the International Convention for the Safety of Life at Sea in 1914 officially established the International Service of Ice Observation and Ice Patrol. The present authority for this service is the International Convention for the Safety of Life at Sea, 1974 (SOLAS 74). Specifically, Chapter V, Regulation provides the present authority as follows:

Regulation 5

Ice patrol service

(a) The Contracting Governments undertake to continue an ice patrol and a service for study and observation of ice conditions in the North Atlantic. During the whole of the ice season the south-eastern, southern and south-western limits of the regions of icebergs in the vicinity of the Grand Banks of Newfoundland shall be guarded for the purpose of informing passing ships of the extent of this dangerous region; for the study of ice conditions in general; and for the purpose of affording assistance to ships and crews requiring aid within the limits of operation of the patrol ships. During the rest of the year the study and observation of ice conditions shall be maintained as advisable.

(b) Ships and aircraft used for the ice patrol service and the study and observation of ice conditions may be assigned other duties by the managing Government, provided that such other duties do not interfere with their primary purpose or increase the cost of this service.

SOLAS 74 also provides for distributing the cost among those countries which benefit from the ice patrol service. Regulation 6 of Chapter V provides the authority for the United States to manage the ice patrol service and obtain reimbursement for operating costs.

Regulation 6

Ice patrol — management and cost

(a) The Government of the United States of America agrees to continue the management of the ice patrol service and the study and observation of ice conditions, including the dissemination of information received therefrom. The Contracting Governments specially interested in these services undertake to contribute to the expense of maintaining and operating these services; each contribution to be based upon the total gross tonnage of the vessels of each contributing government passing through the regions of icebergs guarded by the ice patrol; in particular, each Contracting Government specially interested undertakes to contribute annually to the expense of maintaining and operating these services a sum determined by the ratio which the total gross tonnage of that Contracting Government's vessels passing during the ice season through the regions of icebergs guarded by the Ice Patrol bears to the combined gross tonnage of the vessels of all contributing Governments passing through the regions of icebergs guarded by the Ice Patrol. Non-contracting Governments specially interested may contribute to the expense of maintaining and operating these services on the same basis. The managing Government will furnish annually to each contributing Government a statement of the total cost of maintaining and operating the Ice Patrol and of the proportionate share of each contributing Government.

Paragraphs (b) - (e) of Regulation 6 include provisions for terminating participation or altering the provisions of Regulations 5 and 6 by the contributing governments. Paragraph (e) requires a review of the arrangements relating to contributions to the cost of the services at intervals not exceeding three years, and requires the managing Government (here the United States) to initiate that review. Regulation 7 addresses speed near ice and Regulation 8 addresses routeing, which in paragraph (e), requires Contracting Governments to induce ships to avoid, as far as practicable, the fishing banks of Newfoundland north of latitude 43°N and to pass outside of regions known or believed to be endangered by ice.

The specific cost allocation regime from paragraph (a) of Regulation 5 above is also included in the multilateral agreement regarding financial support of the ice patrol titled "Safety of Life at Sea: Financial Support of the North Atlantic Ice Patrol" which entered into force on July 5, 1956. This agreement identifies the routes passing through the regions of icebergs. For calculating the tonnage in the cost allocation formula, the ice season is considered to be the period from February 15 through July 1 of each year. There is no specification on the period of time for which ice patrol costs are collected. Article 6 simply states that the "Government of the United States of America will furnish annually . . . a statement of the cost of operating the Ice Patrol."

3.3 Authority Provided by 46 USC 738, 738a to 738d.

Section 738 of Title 46 United States Code provides the basic authority for the President to conclude international agreements for the conduct of an ice patrol and related issues. It authorizes the President to include in such agreements a provision for payment by countries concerned of their proportionate share of the expense of the service, or for the United States to contribute its proportionate share should it be agreed that another country maintains the patrol.

The specific responsibility for the ice patrol is provided in 46 USC 738a as follows:

> (a) Unless the agreements made in accordance with section 738 of this title provide otherwise, an ice patrol shall be maintained during the whole of the ice season in guarding the southeastern, southern, and southwestern limits of the region of icebergs in the vicinity of the Grand Banks of Newfoundland, and the patrol shall inform trans-Atlantic and other passing vessels by radio and such other means as are available of the ice conditions and the extent of the dangerous region. A service of study of ice and current conditions, a service of affording assistance to vessels and crews requiring aid, and a service of removing and destroying derelicts shall be maintained during the ice season and any or all such services may be maintained during the remainder of the year as may be advisable.
>
> (b) The ice patrol vessels shall warn vessels known to be approaching a dangerous area and recommend safe routes.
>
> (c) The ice patrol vessels shall record the name, together with all the facts of the case, of any ship which is observed or known to be on other than a regular recognized or advertised route crossing the North Atlantic Ocean, or to have crossed the fishing banks of Newfoundland north of latitude forty-three degrees north during the fishing season, or, when proceeding to and from ports in North America to have passed through regions known or believed to be endangered by ice. The name of any such ship and all pertinent information relating to the incident shall be reported to the government of the country to which the ship belongs, if the government of that country so requests.

(d) The Commandant of the Coast Guard, under the direction of the Secretary of Transportation, shall administer the services provided for in this section and shall assign thereto such vessels, material, and personnel of the Coast Guard as may be necessary. Any executive department or agency may upon the request of the Secretary of Transportation detail personnel, loan or contribute material or equipment, or otherwise assist in the carrying out of the services named.

(e) The Commandant of the Coast Guard shall publish each year a report of the activities of the services provided for in this section, a copy of which shall be furnished to each interested foreign government and to each agency assisting in the work.

Note that the statute requires the Commandant of the Coast Guard to maintain the ice patrol service unless the international agreements provide otherwise.

3.4 International Ice Patrol, the Ice Operations Program, and Program Management.

Responsibility for provision of ice patrol and related services falls under the Ice Operations Program under the Marine Science section. The function which provides the actual ice patrol services and related functions is termed the *International Ice Patrol*. The specific responsibilities for the International Ice Patrol are identified in Objective #3 of the Ice Operations Program:

> Provide mariners in the Northwest Atlantic Ocean with information on the limits of known icebergs to facilitate safe navigation.

In order to support this objective, the International Ice Patrol performs/coordinates the following:

> Conduct reconnaissance flights to locate and track icebergs that may become a hazard to navigation and to identify the limits of known icebergs.
>
> Obtain environmental data on iceberg drift and deterioration to predict future iceberg positions.
>
> Disseminate information on the location and drift of icebergs to mariners crossing the Northwest Atlantic.

The present Program Standard is "to ensure that vessels transiting the Northwest Atlantic Ocean have the most current and accurate information available on icebergs."

The present measure of effectiveness for the IIP is the casualty rate defined as follows:

$$\text{Casualty Rate} = 100\% - \frac{\#\,vessels\ damaged}{\#\,vessel\ transits} * 100$$

The Chief, Office of Navigation Safety and Waterway Services (G-N) is the Program Director for IIP. Management responsibility has been assigned to Chief, Ice Operations Division (G-NIO) as the Program Manager and further assigned to Chief, Science Branch (G-NIO-3) for managing the IIP. The Program Manager is responsible for the overall conduct of the IIP.

The Program Manager's primary functions are to establish the general purposes and goals of the IIP, develop a suitable strategic plan for accomplishing IIP objectives, develop necessary budgeting materials and identifying equipment needs to support the program, and monitor the actual conduct of the program. The Program Manager is the key liaison with the Department of State and other agencies/governments with regard to ice patrol policy.

3.5 Atlantic Area Operations.

The Commandant of the Coast Guard has assigned responsibility for the conduct of the International Ice Patrol to Commander, Atlantic Area. The direction is provided in Commandant (G-NIO) letter serial 3145 dated October 11, 1988 which specifies that Commander, Atlantic Area use ships, aircraft, and command and control facilities to meet the requirements of ice patrol service as specified in 46 USC 738, 738a through 738d and SOLAS (1974). This letter authorizes direct liaison between IIP and other Coast Guard commands, between IIP and various U.S. government and military agencies, and between the IIP and various Canadian agencies for conducting the ice patrol service.

Supervisory responsibility for the conduct of the International Ice Patrol is with the Chief of the Atlantic Area Operations Division (Commander, Atlantic Area (Ao)). Specific requirements for the conduct of the International Ice Patrol are delineated in the Atlantic Area Operation Plan.

3.6 Commander, International Ice Patrol.

3.6.1 *IIP mission.* The mission objectives of the IIP as presented in the *Standing Orders for IIP Operations Center Duty Personnel* (CIIPINST M3120B dated 18 December 1992 (CH-2)) are:

a. To observe icebergs in the northwestern Atlantic Ocean in the vicinity of the Grand Banks of Newfoundland.
b. To identify the southeastern, southern, and southwestern limits of the iceberg region.
c. To inform mariners of the extent of the danger area based on all known iceberg and sea ice information.

The recent Measures of Effectiveness workshop conducted on March 14-15, 1994 stated the mission of the IIP as follows:

1) Provide International Ice Patrol service to the mariner.
2) Provide marine science activity support to other Coast Guard programs.

This workshop identified three Goals that support this mission:

1) Warn mariners of the limits of iceberg danger in the vicinity of the Grand Banks.
2) Determine the limits of the iceberg danger throughout the ice season.
3) Provide value added marine science activity support to operational commanders.

At the kick-off conference for this contract on July 21, 1994, it was repeatedly stressed that the primary mission of the IIP is ***to determine the Limits of All Known Ice along the southeastern, southern, and southwestern edges of the ice region and publish that information to the mariners in a timely fashion***. Knowledge of icebergs in the interior of that region is an objective only to the extent that it provides information for determining the Limits of All Known Ice. This mission statement is considered to be controlling for purposes of the present analysis.

3.6.2 *IIP operations*. As indicated above, the International Ice Patrol is an Atlantic Area unit. Commander, International Ice Patrol is under the operational control of Commander, Coast Guard Atlantic Area and reports directly to Commander, Atlantic Area (Ao). For management purposes, IIP operations are divided into three categories: ice season operations, pre- and post-season operations, and off-season operations.

The IIP maintains a continuous Duty Watch Officer (DWO) and Watchstander (WS) in the IIP Operations Center during the day and on call at night throughout the year. During the ice season, usually from late winter to mid-summer, the IIP DWO is responsible for executing the mission of the IIP by receiving iceberg and radar target reports; analyzing this information; receiving environmental information; running the computer drift and deterioration prediction models (known as the iceberg Data Management and Prediction System -- DMPS); and producing the IIP products to serve the mariner. The DWO and WS follow the instructions in the CIIP *Standing Orders for IIP Operations Center Duty Personnel* and the CIIP *Computer Documentation Manual*.

Staffing the ICERECDET is another major function of the IIP during the ice season. ICERECDETs are normally deployed for a period of nine days (two days enroute, five days of patrols, one day crew rest, and one day aircraft maintenance). IIP staffing includes one Senior Ice Observer and three Ice Observers. Eleven or twelve air crew members complete the ICERECDET.

During the pre- and post-season and the off-season periods, the IIP Duty Watch Officer, Watchstander, and staff perform their duties in accordance with the instructions and schedules in the CIIP *Standing Orders for IIP Operations Center Duty Personnel*. During the pre- and post-season period, duties include preparing for the on coming season and wrap up of the just completed season. The DMPS is maintained and operated during this period. This routine is normally for a two month period before the season starts and for one month after the end of the season. Projects that improve IIP processes and procedures are undertaken during the off-season. During the off-season, the DWO, WS, and staff perform other assignments such as research, preparation of the annual bulletin and reports, and marine science activity support functions. In addition to ice patrol functions, IIP also serves as the communications center for three commands.

4.0 Information Acquisition, Processing and Distribution.

4.1 Overview.

The IIP accomplishes its mission by acquiring data and information about the location and extent of ice and most recent environmental conditions in its area of operation , processing those inputs to develop relevant information regarding the threat of ice to the trans-Atlantic shipping lanes, and distributing that information to interested mariners. A key element in this process is the use of an iceberg Data Management and Prediction System (DMPS) that is capable of managing these data within the IIP area of operation from 40°N to 52°N latitude and 39°W to 57°W longitude. The primary products generated by IIP include ice bulletins, INMARSAT, and NAVTEX messages that contain the 0000Z and 1200Z Limits of All Known Ice, a facsimile chart with the 1200Z ice limits that is transmitted at 1600Z and 1810Z, and safety messages to warn shipping of icebergs sighted outside of the published ice limits. The various elements of this information process are described in some detail in the following subsections. The purpose of this discussion is to identify the major elements affecting data/information acquisition and the required processing. Estimates of processing workload are also developed. The overall information context is illustrated in Figure 3.

In processing iceberg data, the IIP conducts *analysis* runs and *prognosis* runs. The analysis runs use the latest environmental data. In an analysis run, both the drift model and the deterioration model are applied to each iceberg and radar target on plot. The resulting analysis run is the basis for the deletion of icebergs from the plot. The closest analysis run to the time of sightings is the basis for the resight analysis where reported sightings are identified with predicted positions of icebergs and radar targets and new sightings that can not be identified with an existing iceberg or radar target are added to the plot. The resulting set of icebergs and radar targets is the basis for the prognosis run. A prognosis run is used to develop the 0000Z and 1200Z products. Note that the prognosis run only applies the drift model and does not include any iceberg deterioration beyond the time of the last analysis run.

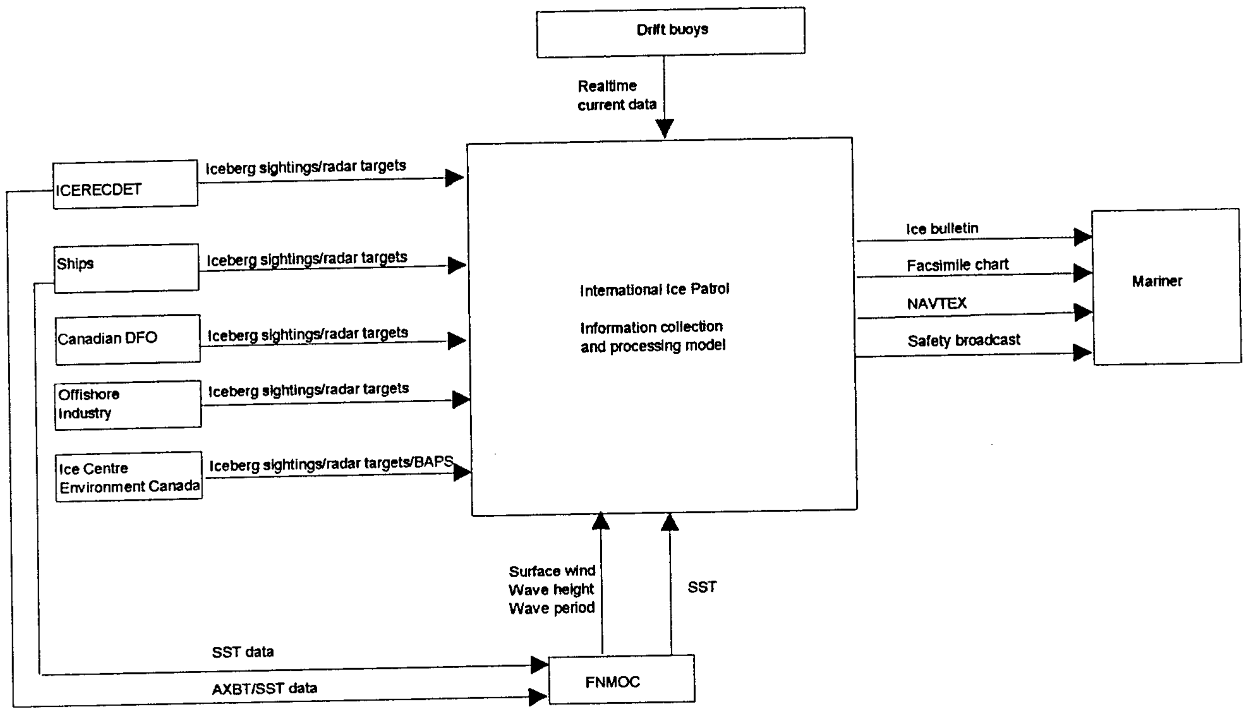

Figure 3. IIP Information Processing Context Diagram.

4.2 Iceberg Sightings/Radar Targets.

4.2.1 *Sources and classification.* The Iceberg Sighting Database contains 11 different sources of iceberg sightings (some are to distinguish between radar/SLAR sightings and visual sightings). Essentially, there are five major sources: the ICERECDET patrols, Canadian AES patrols, ships operating in the area, the offshore industry consisting primarily of air reconnaissance flights by Atlantic Airways which is chartered by the Canadian Department of Fisheries and Oceans, and ICEC consisting primarily of BAPS icebergs that have drifted south of 52°N and ship reports that have been transmitted directly to ICEC.

A standard Iceberg Reconnaissance Message format is used by IIP and ICEC. (See Appendix K in the *Standing Orders for IIP Operations Center Duty Personnel* for a complete description.) The ICERECDET messages, AES messages, Atlantic Airways messages, and BAPS messages arrive in this format. In addition, ICEC uses this format (usually coded by CCG at St. John's) to report the iceberg sightings reported by ships before sending the reports to IIP. All of these messages are received via internet. Sightings by ships that are sent directly to IIP must be converted to this format before they can be processed. Sightings on the Iceberg Reconnaissance Messages will include visual sightings, radar sightings with visual confirmation, and radar only sightings. Generally, only visual sightings/confirmations and IIP ICERECDET SLAR sightings are considered icebergs. The remaining reported sightings (radar only) are considered as radar targets. The radar targets are treated as medium non-tabular icebergs in the drift and deterioration models.

4.2.2 *Preprocessing and quality assurance*. Ship sightings received by IIP are reviewed for accuracy/reasonableness before preparing the standard format file for entry into the computer. A key purpose of this review is to provide early recognition of an iceberg that is sighted outside of the Limits of All Known Ice. If such a sighting has occurred, a Safety Broadcast is issued unless an Ice Bulletin containing the new information will be transmitted within the next hour.

The incoming Iceberg Reconnaissance Messages are received by internet. Before they are transferred to the VAX system for possible entry into the iceberg Data Management and Prediction System (DMPS), each message is reviewed to identify obvious field errors or garbled text. If the message passes the test, it is transferred to the VAX where the reported sightings (icebergs and radar targets) are evaluated for entry into the model.

4.2.3 *Addition/resighting analysis*. Iceberg Reconnaissance Messages and iceberg sighting reports may be received at any time during the day. The sightings may be considered for addition to the DMPS twice daily when the DWO conducts the morning (AM) analysis or the afternoon (PM) analysis. At the time of the AM analysis, the DWO has on hand the 0000Z and 1200Z prognosis runs showing the predicted positions and predicted deterioration (as of the last analysis run) of icebergs and radar targets at those times. These prognosis runs were developed as part of the previous PM analysis. The AM analysis is typically conducted in the 1200-1400Z time frame. At the time of the PM analysis, the DWO has on hand the 1200Z (today) and 0000Z (tomorrow) prognosis runs showing the predicted positions of icebergs and radar targets at those times and predicted deterioration as of the time of the last analysis run. These prognosis runs were developed as part of the previous AM analysis. The PM analysis is typically conducted in the 1900-2100Z time frame.

The reported sightings may be new (previously undetected) icebergs or sightings of previously reported icebergs (resights). If a sighting is determined to not be a resighting, then it is added to the DMPS as a new iceberg/radar target. The *Standing Orders for IIP Operations Center Duty Personnel* directs the DWO to use the closest available analysis run file to the sighting time. It further directs that sighting messages be entered in chronological order and notes that multiple reports may resight the same iceberg. There is no indication as to how multiple sightings of the same iceberg shall be identified. In addition, the resighting analysis is typically accomplished using one analysis file. There is no indication as to how to handle sightings that are more than 6 hours divergent in time (making the time of each such sighting closer to different analysis files.)

Resighting criteria are prescribed in Chapter 4, Section F of the *Standing Orders for IIP Operations Center Duty Personnel*. The primary criteria for considering as resights are those sightings which (a) overlap, within twice the system error (maximum 60 nm), of icebergs or radar targets already being modeled, and (b) agree, within system error (1 size category), with deterioration information. If a sighted iceberg is designated as a resight of a radar target, the modeled entity is regarded as an iceberg with the reported properties; if a radar target is designated as a resight of an iceberg, the modeled entity continues as an iceberg with only the location information changed by the resight. The guidance in Section O of Chapter 4 indicates that a 5 nm error circle is to be used for all sightings. This would imply that the maximum separation distance for a resighting would be 65 nm (5 nm sighting error plus 60 nm--twice the system error.)

The INTERGRAPH computer system and DMPS provide a graphical display which facilitates the resight analysis by the DWO. Specifically, the DMPS displays the icebergs on plot with their reported size, error circle, melt state, and drift track, and simultaneously displays the new sightings. Using an analysis run closest in time to the reported sighting, the DWO compares the existing icebergs and radar targets with the new sightings using the resight criteria to determine whether a particular sighting is a resight or a new iceberg or radar target. There is a significant amount of "art" involved in this process. Numerous other factors such as bathymetry and areas of highly variable currents may impact the resight decision. Additionally, extra attention is given to those icebergs and sightings near the Limits of All Known Ice. In several areas, icebergs will ground and eventually melt. In addition, there are numerous sightings along particular enroute flight paths that do not contribute significant new information. In these situations, a number of sightings may not be entered in the data base. Additionally, when there a large number of sightings, the press of time may delay entering sightings, particularly those removed from the Limits of All Known Ice. After completing the resight analysis, the new positions of icebergs/radar targets have been merged into the DMPS. For icebergs and radar targets outside of the IIP area of operation, particularly below 40°N, special manual procedures are specified.

The DMPS was placed into service for the 1993 ice season. Prior to that time, resights were conducted manually. Viekman (1993) analyzed the effectiveness of the use of DMPS. While the system experienced a significant increase in sightings and targets merged into the system (due partly to the nature of the ice year), There was an increase of nearly 50% in the "probability" that an iceberg would be resighted. The implications for this type of analysis on iceberg counts is addressed both by Viekman (1993) and Anderson (1993).

4.3 Environmental Data.

4.3.1 *Categories and sources.* The key environmental data include the sea surface temperature (SST), 12 hourly averaged winds, wave height/period, and current data. The wave height and wave period data and the average wind data are received twice daily from the U.S. Navy Fleet Numerical Meteorology and Oceanography Center (FNMOC) Monterey via Internet. Both products are available for use in the AM and PM analysis. SST data is updated and provided once a day and entered for the PM analysis. The same SST data are used in the AM analysis run.

Realtime position data from the WOCE drifters is captured from Service ARGOS daily and transferred to the DMPS. The position data is used to plot buoy trajectories weekly and the current file is updated from the computed local currents. The updated current file is then used in subsequent analysis runs until it is modified in the following week.

The Sea Ice Edge (1/10 coverage) is received daily from ICEC. This is used directly on the facsimile chart. In addition, SST, wind, and wave data are received from METOC. These may be used as necessary if comparable products are not received from FNMOC.

4.3.2 *Quality assurance.* The FNMOC products are received as Internet files. They are initially reviewed on the PC to check for transmission errors and other possible discrepancies. The files are transferred to the VAX and the coarse grid values of the SST, wind vectors, and wave heights and periods are interpolated to the IIP grid. The resulting estimates are displayed graphically and reviewed by the DWO for reasonableness. Following that review, the data are added to the DMPS data base. Similarly, the drifter buoy data is reviewed before it is added to the DMPS file.

4.4 Analysis Runs and Products.

4.4.1 *Iceberg/radar target deletion.* An analysis run is conducted to incorporate the latest sighting and environmental data. This provides a graphical display of the estimated positions of icebergs and radar targets at the designated run time along with the previous Limits of All Known Ice. Using this display, the DWO can delete icebergs and radar targets that satisfy the deletion criteria in Chapter 4, Section E of the *Standing Orders for IIP Operations Center Duty Personnel.* Two factors apply to deletion: modeled deterioration, and ICERECDET reconnaissance. Radar targets outside of the LAKI and limit setting bergs within 60 nm of the LAKI may be deleted when modeled deterioration exceeds 150%; icebergs and radar targets more than 60 nm inside the LAKI, may be deleted when modeled deterioration exceeds 125%. Radar targets outside of the LAKI and limit setting bergs within 60 nm of the LAKI may be deleted when visual search or 200% SLAR coverage with wave heights less than 6 feet finds nothing; icebergs and radar targets more than 60 nm inside the LAKI, may be deleted when visual search or 100% SLAR coverage with wave heights less than 6 feet finds nothing. When deletion of an iceberg results in a significant change in the LAKI, CIIP must review and approve the deletion.

4.4.2 *Ice bulletins and facsimile chart.* The Ice Patrol Bulletins are prepared in accordance with the format in Chapter 4, Section J of the *Standing Orders for IIP Operations Center Duty Personnel.* The ice bulletins are transmitted at 0000Z and 1200Z daily. They contain the following information: the estimated Limits of All Known Ice, the estimated limit of sea ice (based on latest information from ICEC), positions of southern and eastern most bergs, positions of growlers, positions of radar targets, and the area of many icebergs. The Bulletins are based on conducting a prognosis run (drift only) from the latest analysis run. The predicted positions of the icebergs are used to estimate the Limits of All Known Ice.

The 0000Z and 1200Z Ice Bulletins are both prepared using prognosis runs (predicting future positions of icebergs/radar targets drifted from the latest analysis run) during the PM analysis (conducted approximately 1900-2100Z). The analysis run on which they are based should have the benefit of the latest environmental data, including the most recent SST data (provided once each day). The positions in the prognosis runs are used to determine the Limits of All Known Ice. The AM analysis conducted the following morning during the 1200-1400Z time frame has the primary objective of preparing the facsimile chart. The AM analysis, using the latest wind and wave data and the previous SST data, prepares another analysis run from which the 1200Z prognosis (and a 0000Z prognosis) run is prepared. It is possible that the 1200Z Limits of All Known Ice from the AM analysis which will appear on the facsimile chart will be different than those already published in the 1200Z ice bulletin (based on the previous PM analysis.) In that case, a revised ice bulletin is sent if it can be accomplished before broadcast time. Otherwise, sightings outside of the limits are disseminated by safety broadcast An explanatory note is placed on the facsimile chart if the limits thereon differ significantly from the 1200Z ice bulletin limits. The INMARSAT and NAVTEX messages are prepared at the same time as the ice bulletins using the estimated Limits of All Known Ice.

4.4.3 *Estimating the Limits of All Known Ice*. CIIP provides detailed guidance on estimating the Limits of All Known Ice in Chapter 4, Section H of the *Standing Orders for IIP Operations Center Duty Personnel*. The icebergs that remain after the deletion analysis are used to set the new Limits of All Known Ice for each prognosis run. The general guidelines are that the LAKI should be constructed so that a convex polygon defined by no more than seven points encloses all icebergs and their error circles. Normally, the polygon is tangent to the error circles of the limit setting icebergs. A general guideline is that the LAKI enclose an area no larger than is necessary. Note that radar targets may not be used to set the limits. Those radar targets outside of the LAKI and those between the boundary of the LAKI and the Area of Many Icebergs are included in the ice bulletin and shown on the facsimile chart. Additional criteria require the use of easily plotted points.

The Area of Many Icebergs is defined by a specified latitude as the southern limit and a longitude as the eastern limit, normally rounded to the nearest 30 minutes. The criteria (Section I in Chapter 4 of the *Standing Orders for IIP Operations Center Duty Personnel*) specify that no limit setting icebergs may be in the Area of Many Icebergs and that generally, no more than 16 icebergs will be in the area between the LAKI and the Area of Many Icebergs.

4.4.4 *Delivery*. The above analyses generate all of the information needed for the ice bulletins and facsimile chart. A copy of the 1200Z ice bulletin for 21 July 1994 is included in Figure 4. The facsimile chart for the same time is included in Figure 5. The ice bulletin and facsimile chart are delivered as summarized in section 2.5. Chapter 3 of the *Standing Orders for IIP Operations Center Duty Personnel* contains detailed instructions on external communications and the use of the various communications devices available. Backup and emergency communications procedures are provided.

NC DE U9
O 202250Z JUL 94
FM COMINTICEPAT GROTON CT
TO AIG EIGHT NINE ONE SIX
CANADIAN COASTAL RADIO STATION ST JOHNS NFLD
MV PAUL BUCK
COMSAT SAFETYNET
950 L ENFANT PLAZA
WASHINGTON DC 20024
XMT HMCS HALIFAX
BT
UNCLAS //N16170//
SUBJ: INTERNATIONAL ICE PATROL (IIP) BULLETIN
SECURITE
CCODE/1:31:04:01+1200:00/AOW/IIP/CCODE
1. 211200Z JUL 94 INTERNATIONAL ICE PATROL (IIP) BULLETIN.
REPORT POSITION AND TIME OF ALL ICE SIGHTED TO COMINTICEPAT VIA CG COMMUNICATIONS STATION NMF, NMN, INMARSAT CODE 42, AND ANY CANADIAN COAST GUARD RADIO STATION. ALL SHIPS ARE REQUESTED TO MAKE UNCLASSIFIED SEA SURFACE TEMPERATURE AND WEATHER REPORTS TO COMINTICEPAT EVERY SIX HOURS WHEN WITHIN THE LATITUDES OF 40N AND 52N AND LONGITUDES 39W AND 57W. IT IS NOT NECESSARY TO MAKE THESE REPORTS IF A ROUTINE WEATHER REPORT IS MADE TO METEO WASHINGTON DC. ALL MARINERS ARE URGED TO USE EXTREME CAUTION WHEN TRANSITING NEAR THE GRAND BANKS SINCE ICE MAY BE IN THE AREA.
2. THE ICEBERG, GROWLER, AND RADAR TARGET POSITIONS ARE BASED ON ESTIMATED DRIFT. DATE OF SIGHTING IS IN PARENTHESIS FOLLOWING THE POSITION. ALL DATES ARE JULY UNLESS OTHERWISE INDICATED.
3. ESTIMATED LIMIT OF ALL KNOWN ICE: FROM THE NEWFOUNDLAND COAST NEAR 4635N 5310W TO 4425N 5100W TO 4415N 4700W TO 4500N 4300W TO 5100N 4035W TO 5200N 4100W TO 5700N 5500W THEN EASTWARD.
THE ICEBERG LIMIT NORTH OF 52N IS OBTAINED FROM ENVIRONMENT CANADA'S ICE CENTER OTTAWA.
4. NO SEA ICE SOUTH OF 52N.
5. SOUTHERN AND EASTERN MOST BERGS ESTIMATED AT: 4550N 4338W(16), 4459N 4738W(15), 4450N 4743W(15), 4450N 4744W(15), 4536N 4358W(12), 5114N 4134W(12), 4633N 4313W(06), 4454N 4817W(17).
6. RADAR TARGETS ESTIMATED AT: 4721N 4358W(18), 4718N 4356W(18).
7. THE FOLLOWING RADAR TARGETS ARE OUTSIDE THE LIMITS OF ALL KNOWN ICE: 4627N 5415W(19), 4609N 5330W(19), 4705N 3830W(14).
8. THERE ARE MANY ICEBERGS AND GROWLERS NORTH OF 4500N AND WEST OF 4400W WITHIN THE LIMITS OF ALL KNOWN ICE.
BT

Figure 4. 211200Z JUL 94 International Ice Patrol (IIP) Bulletin.

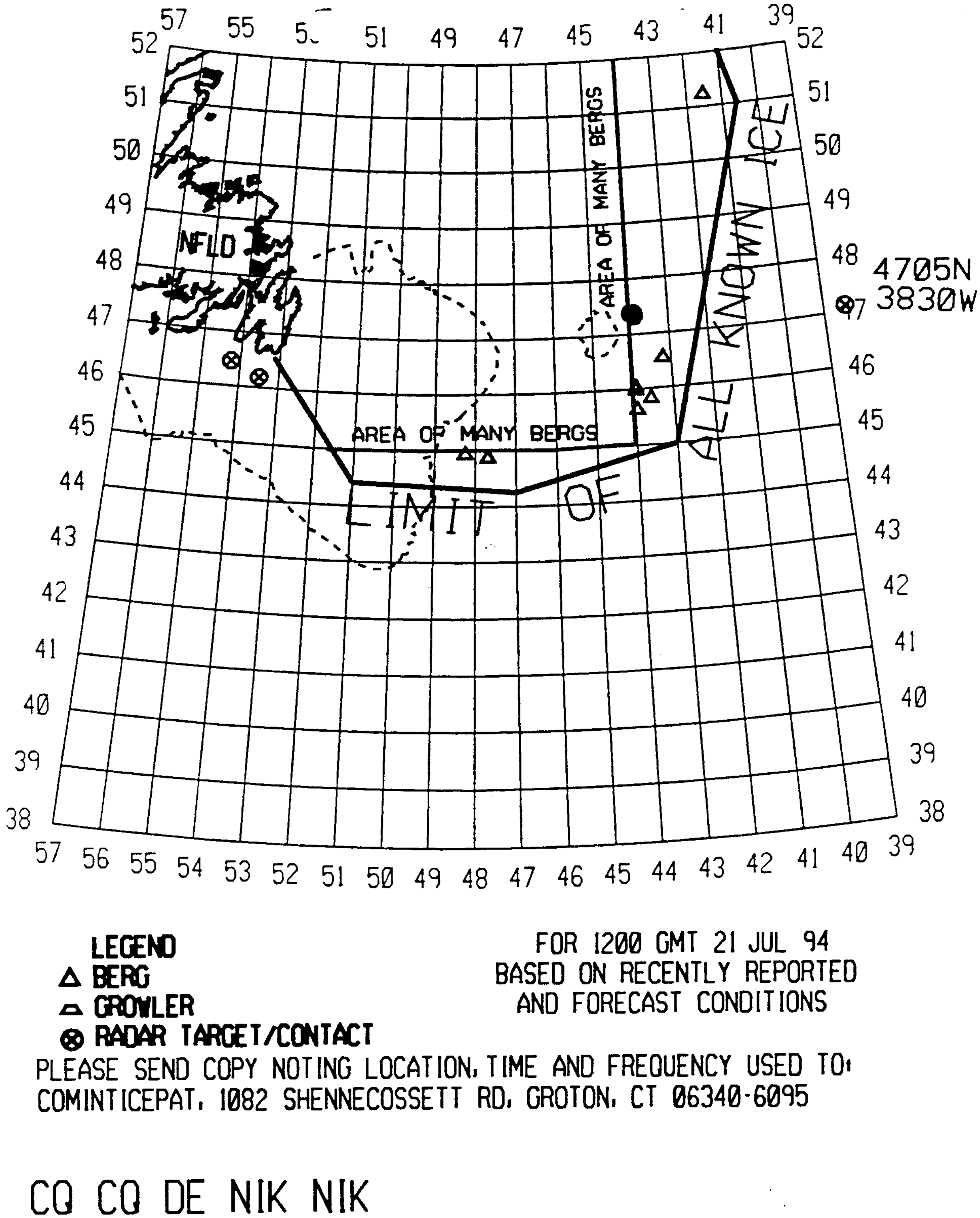

Figure 5. 1200 GMT 21 JUL 94 International Ice Patrol (IIP) Facsimile Chart.

4.5 Processing Requirements.

4.5.1 *Data and information process flow.* The data and information process flow described above is summarized in Figure 6. Note that the AM Analysis and PM Analysis blocks could be further broken down to account for the data handling, preprocessing, quality assurance, addition/resight analysis, prognosis runs, deletion analysis, and LAKI evaluation.

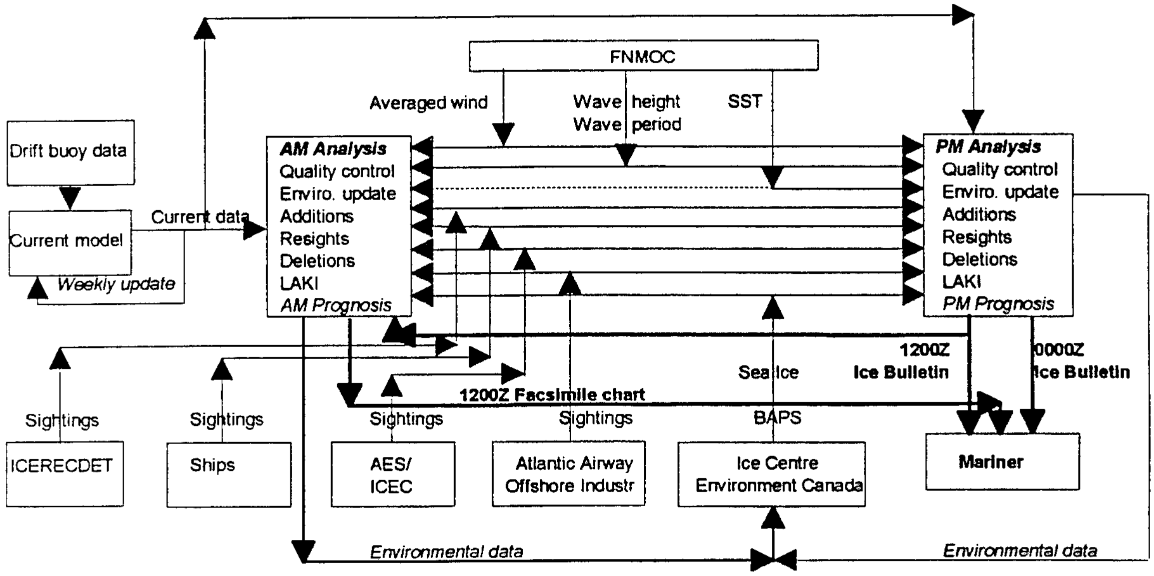

Figure 6. IIP Data and Information Process Chart.

4.5.2 *Processing times.* Estimates of processing times were obtained by limited observation and discussions with experienced DWOs. For each Internet message (wind, wave, SST, and sighting reports), it appears to require 4-5 minutes of preprocessing on the PC and 7-8 minutes of quality control after the message is transferred to DMPS. The conversion time for the environmental messages appears to average 12-15 minutes, during which time, no other analysis can take place using DMPS or the particular PC. Thus, all processing of Internet messages is sequential. Ship sighting reports submitted directly to CIIP must be processed to convert them to the proper format for entry into DMPS. This process can be very time consuming, taking an average of 1-2 minutes to convert each iceberg/radar target sighted. Some vessels report very large numbers of sightings during the peak ice period. Depending on the time available before the next product deadline, the DWO may or may not be able to process all of the sightings. Scanning the original messages provides sufficient input to ensure that sightings near the LAKI are entered.

After the environmental data and sighting reports have been transferred to the DMPS, the additions/resight/deletion analysis can take place. First, an analysis run is conducted to provide the most recent position and melt state of the icebergs. The workload for the additions/resight/deletions analysis is dependent on the numbers and locations of the sightings. For a reasonable sighting report, an experienced DWO can complete the resighting in 5-10 minutes per message. The run times for the analysis and prognosis runs are dependent on the number of active icebergs. Although the runs typically cover 12 hour increments, these times are achieved by advancing the drift and deterioration in six hour blocks. It is estimated that an active file of 400 icebergs will require approximately 15 minutes to complete an analysis run while an active file of 1,400 bergs will require nearly an hour of run time on the VAX.

When the prognosis runs are complete, the DWO requires another 10-15 minutes to identify the Limits of All Known Ice and the Area of Many Icebergs. In the AM Analysis, this is followed by preparation of the facsimile chart which requires an additional 20-25 minutes to prepare/label and set up for transmission. Similar time requirements exist for the PM Analysis for preparing the 0000Z and 1200Z ice bulletins.

4.5.3 *Processing equipment*. The core processing system is an INTERGRAPH computer system with high resolution graphical displays using a modified VAX computer as the main processor. This system operates the iceberg Data Management and Prediction System (DMPS). The system was placed into service for the 1993 ice season. The DMPS was developed from the iceBerg Analysis and Prediction System (BAPS) which was developed for ICEC. In addition to the INTERGRAPH, a system of PCs and the use of the Coast Guard Standard Terminal provide additional support for processing.

The display design is very functional and conveys a significant amount of information to the DWO in a meaningful way. Two screens are active: one provides the messages and commands/menus, while the other provides a display of the region of interest. A mouse and mousepad provide the mechanism for selecting functions. The graphical display screen is characterized by icons and color displays to convey critical information. There is a zoom capability and the ability to selectively display various characteristics to minimize the visual interference. In addition, data stores with entity characteristics can be displayed to facilitate analysis.

The major problem with the present system is the processor speed and no ability to accomplish multiple processing. Otherwise, the system appears to be very functional. The present system operation includes frequent backups of working documents. Standby products are maintained in case there are system problems that would stop its normal functioning. Working copies of the system file are maintained for use on a PC if necessary. During 1994, there have been three system failures that required PC processing. A maintenance contract is in effect which is supposed to result in rapid repairs. The IIP is on the CGHQ 5 year IRM plan for a replacement system. No work has been accomplished to date with respect to developing specifications for a new system.

5.0 Iceberg Detection and Remote Sensing

5.1 Iceberg Detection Sources.

As described in section 2.3, the IIP receives reports of icebergs and radar targets that may be icebergs from numerous sources. Present sources of iceberg and/or radar targets include: IIP's aerial reconnaissance by its ICERECDET; the Canadian Atmospheric Environment Service (AES) aerial reconnaissance using its own aircraft and contract with Atlantic Airways; the Canadian Department of Fisheries and Oceans (DFO) aerial reconnaissance provided by the contracted Atlantic Airways; the NOAA/U.S. Navy Joint Ice Center (from a variety of DOD sources); ICEC (relays of ship sightings and BAPS); ships passing through the ice area, and other miscellaneous sources. The sightings received from those sources which were entered into the IIP models are summarized in Table 1. Note that these sightings include all icebergs, growlers, radar targets, and sightings identified as resights. The data are a measure of IIP model workload. The Atlantic Airways (both DFO and AES) and miscellaneous sightings are combined under "Other Air." The Table 1 data are plotted in Figure 7.

Table 1: Iceberg and Radar Target Sightings Entered into IIP Models, 1988-1994.

	1988	1989	1990	1991	1992	1993	1994
IIP	854	1039	1140	1503	685	1056	1066
Other Air	131	269	408	393	1493	3908	3407
AES	638	256	136	192	159	1031	1817
Ships	501	873	1287	2237	745	1475	1845
BAPS	0	205	4	0	82	556	1311
DOD	15	256	171	35	3	0	0
Other	47	91	10	9	3	32	0
Total	2186	2986	3156	4370	3170	8058	9446

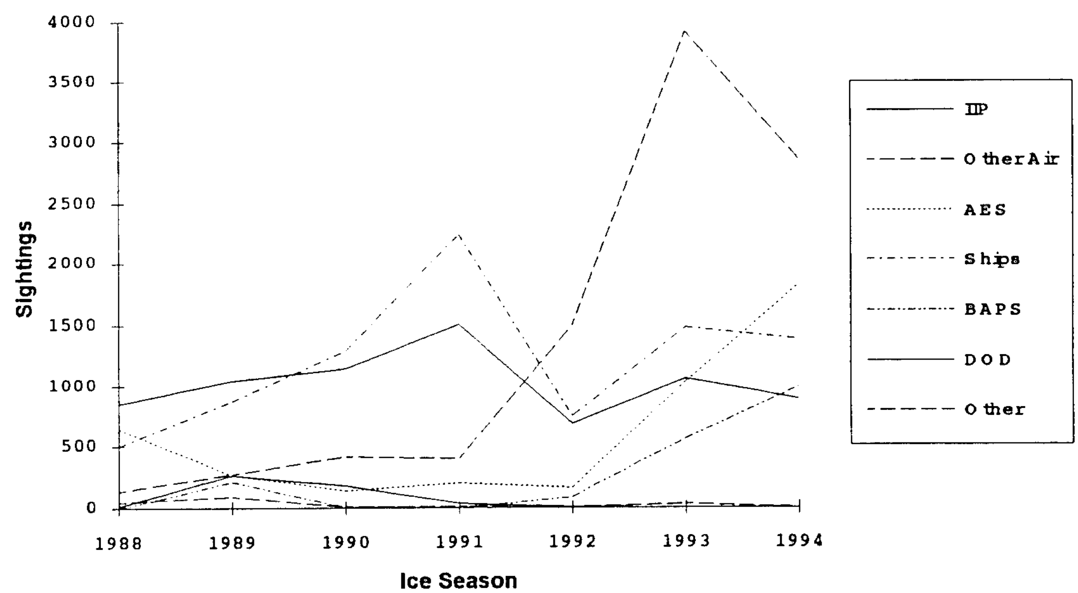

Figure 7. Iceberg and Radar Target Sightings Entered into IIP Models, 1988-1994.
* Through July 13, 1994.

In interpreting the data, note that 1988 and 1989 were light ice years, 1990 and 1992 were heavy ice years, and 1991, 1993, and 1994 were extreme ice years. Thoughout the period, the data indicate that the IIP and ships have been relatively constant sources of sighting data. AES has accounted for an increase in sightings in the past two years, and within this period, Atlantic Air, under DFO contract, (included in "Other Air") has recently increased its activity and is a major factor in the increase in sightings in 1993 and 1994. With the introduction of the DMPS at IIP in 1993, it became feasible to receive iceberg position data directly from BAPS which accounts for another portion of the recent increase.

The key factor identifying a detection requirement is the number of **icebergs** below 48°N. These are compared with the number of sightings in Table 2 for 1988 through 1994 (as of July 13, 1994). Note that these data do not include growlers, radar targets, or sightings that were resighted as icebergs.

Table 2: Icebergs S of 48°N Entered into IIP Models, 1988-1994.

	1988	1989	1990	1991	1992	1993	1994
Icebergs S of 48°N	187	301	793	1974	876	1753	1765
Sightings	2186	2986	3156	4370	3170	8058	9446

Icebergs either drift south of 48°N or are sighted south of 48°N. The sources of those icebergs and whether sighted or drifted south of 48°N are indicated in Table 3 for 1994. This provides some basis for identifying the present efforts supporting iceberg detection.

Table 3: Source of Icebergs S of 48°N, 1994.

1994*	IIP	Other Air	AES	Ships	BAPS	Total
Drifted S of 48°N	45	143	164	84	24	460
Sighted S of 48°N	244	524	180	357	0	1305

IIP was responsible for detecting 16%, Atlantic Air detected 37%, AES detected 21%, and ships detected 18% of the icebergs. Although the IIP was responsible for the smallest percentage, the particular icebergs were generally the ones of greatest importance --those in the vicinity of the Limits of All Known Ice. A detailed analysis of those icebergs that entered the region between the Area of Many Icebergs and the Limits of All Known Ice would provide stronger evidence on the criticality of the input from the several sources.

5.2 Visual and Remote Sensing Capabilities for Iceberg Detection.

5.2.1 *Commercial ships.* Ships transiting the area are requested to report the positions of ice and icebergs to CIIP or ICEC. Their sightings may be visual or radar. The observer's experience greatly affects the quality of the information provided.

5.2.2 *Canadian AES.* ICEC employs two ice reconnaissance aircraft. A Dash-7 turboprop normally is used on the east coast of Newfoundland operating near the sea ice edge. It is equipped with side and top bubbles for visual observation and a real aperture CAL SLAR. The aircraft is owned by Transport Canada and operated under contract with Bradley Air Services, Inc. Three Environment Canada Ice Services Specialists staff the aircraft. The second aircraft is a Challenger jet provided under contract with Intera Technologies, Ltd. It is equipped with two MacDonald-Dettwiler IRIS SARs imaging a 100 km swath on each side of the aircraft. It is staffed completely with Intera personnel. Both aircraft have a downlink system that allows in-flight transmission of digital radar imagery.

5.2.3 *Atlantic Airways.* Atlantic Airways conducts aerial reconnaissance of the fishing fleet on the Grand Banks under contract to the Canadian Department of Fisheries and Oceans. Atlantic Airways is also contracted directly by AES to conduct ice reconnaissance. In addition to visual observation capability, the aircraft is equipped with a Litton APS-504(v)5 search radar that provides significant coverage of ice in their area of observation. In 1992-1993, Atlantic Airways was the largest contributor of sightings to the IIP.

5.2.4 *IIP ICERECDET.* Because of the distances involved, the IIP deploys an Ice Reconnaissance Detachment (ICERECDET) periodically for the primary purpose of patrolling the Limits of All Known Ice. The IIP ICERECDET presently uses a HC-130H aircraft equipped with a pair of Motorola AN/APS-135 Side Looking Airborne Radars (SLARs) (two antennas mounted in pods on either side of the fuselage, with common signal processing) and one nose-mounted Texas Instruments AN/APS-137(V) Forward Looking Airborne Radar (FLAR). Observation windows allow visual observation of icebergs. The ICERECDET also uses a HU-25B aircraft equipped with a Motorola AN/APS-131 SLAR. The ICERECDET deploys from St. John's, Newfoundland. The use and performance of the AN/APS-135 and the AN/APS-137 radars are discussed in detail in the following sections. The AN/APS-131 SLAR is installed as part of the AIREYE system on the HU-25B. The AN/APS-131 is very similar to the AN/APS-135. However, its antenna length is half of the length of the AN/APS-135 (2.4 m v. 4.8 m) with the result that it has a lower azimuth resolution (0.8° v. 0.47°). In a side by side operational comparison, Alfultis and Osmer (1988) concluded that the AN/APS-131 SLAR was nearly as effective as the AN/APS-135 SLAR when appropriate operating parameters were used. (Growlers were not considered in the experiment.) The difficulty in using this sensor on a regular basis, however, lies with the platform on which it is installed. The HU-25B has a relatively limited range of 750 nm with a nominal endurance of three hours which is not sufficient to permit regular examination of the LAKI. Only in very special circumstances can the HU-25B be used for IIP ice reconnaissance flights. In 1992, only 16 sorties for 42.2 flight hours were flown.

5.3 ICERECDET Operations.

5.3.1 *Search mission planning and coverage*. Multiple, essentially daily (with allowance for aircraft maintenance and crew rest) sorties are performed during a nominal nine-day mission (every two weeks) to St. John's. Each sortie follows a preplanned flight path, the surface track of which is determined by the senior ICERECDET representative on the mission. Fight path planning is manual, with computer (PC) tool assistance. Because of generally restricted visibility, the altitude of the flight path is procedurally constrained to be above the 6000 ft. lower boundary of controlled airspace, and is normally at or near this limit. The sorties of a single mission collectively supply coverage of a swath following the boundaries of the (model predicted) Limits of All Known Ice, and extending, in searched surface area, from about 25 nm beyond this line to as far inside the line as can be covered for the combined sorties while satisfying fuel constraints.

5.3.2 *Operator/radar interface and data recording*. Iceberg detections for each type of radar depends on human pattern interpretation of the CRT display associated with the system. During each track search segment, the SLAR and FLAR radar controls and displays are each manned by a crew member experienced in the operation of the device. When the display of either radar (both SLARs are controlled from a single console) indicates a potential surface object, the responsible operator makes a decision as to the validity of the detection, its categorization as iceberg, ship, or radar target, and, for objects adjudged icebergs, the size category (growler, small, medium, large, and very large) and iceberg type. The operator then manually enters this information into a log of detected objects. During this process, each operator normally communicates orally with the other, and may, particularly in the case of initial FLAR detection, alert the other operator as to the presence and location of detections. While reporting of FLAR detections to the SLAR operator is useful, reporting of SLAR detections to the FLAR operator is of relatively less utility, since objects not detected by the FLAR operator can not be locked on to permit the Inverse Synthetic Aperture (ISAR) mode to be utilized. It is possible that, in a dense target environment sortie, the SLAR operator could assist in the selection of targets for preferential FLAR lock-on. However, the delay in SLAR processing may not permit this either.

FLAR lock-on requires operator placement of a cursor on the search display, which is variably illuminated by the sea clutter returns. A separate small CRT is used to present a pre lock-on range profile which is bracketed by parallel horizontal bars. The SLARs are consistently operated in the 27 nm full scale mode (1/500000 scale factor), and at the maximum PRF. Right and left side SLAR images (two film strips, 4.5 inches wide, developed in real time from CRT outputs, with dot density proportional to the log of the imaged dBms) take the form of small (.5 mm by 2 mm or more, depending on range) lozenge or lens-shaped dark regions elongated parallel to the aircraft motion, reflective of the limiting .47 degree azimuthal resolution of the SLAR. Image details pointed out by operators as a basis for categorization of an image as a ship included, on a SLAR image, an image extension significantly thinner than the main image, associated by the operator with a ship-borne radar antenna mounted aft of the ship. The central one-half of SLAR images on one or both sides are frequently uniformly gray to dark gray due to Bragg scattering from the sea surface. The outer half of SLAR images typically exhibits alternate bands of sea clutter and radar shadows on the sea surface. In some cases, one side of the film will be almost uniformly dark gray while the other side is almost totally unexposed due to a surface clutter viewing angle sensitivity. SLAR operators make adjustments to both antenna azimuth boresight and image saturation at their discretion.

FLAR inverse synthetic aperture (ISAR) images, when obtainable, are extremely unstable in the crossrange direction, taking the form of undulating bands (period of 4-8 seconds) of light and dark spots. Operator discrimination of a ship target was, in one case, based on the identification of a familiar (to the operator) pattern characteristic of a conning tower.

Each radar has aircraft motion compensation subsystems, and an independent navigation system. The AN/APS-137 FLAR provides a latitude/longitude and velocity readout on the auxiliary display for any cursor-selected object in track, while the AN/APS-135 SLARs provide for film display of latitude and longitude lines, from which object coordinates are estimated manually. Navigation errors are not insignificant (a nominal 5 nm is assumed for recorded positions), and may create erroneous correlations in a target-rich detection environment. Object resightings on subsequent flight path legs do not form the basis for additional operator log entries if correlation is considered adequate, but may result in reclassification or sizing of the object. Log entries are in pencil, and the latest sighting coordinates/time on a correlatable resighting is substituted as the sole log entry for the object. Subsequent to completion of the mission, the IIP senior officer reviews the logs of the radar operators, may supply additional changes or corrections, and merges the logs to create a unified list of sighting coordinates, times, and object category and size.

5.4 Search Effectiveness.

5.4.1 *Search patterns and probability of detection.* Patrols are conducted using a Papa Sierra parallel search pattern with a track spacing of 25 nm. The SLAR range scale is set at 27 nm so that the SLAR coverage is nearly 200%. The purpose of the 200% coverage is to try to ensure that small icebergs and growlers are detected and to provide a means of determining target movement and aid in identification of a radar target as an iceberg. Typical search patterns are illustrated in Figure 8. Where possible, tracks are oriented in a N-S or E-W direction (or at least cardinal headings) to facilitate georegistration of the sightings which is accomplished manually.

The track spacing and SLAR characteristics result in almost one-third of the search area having a 100% coverage rather than 200% coverage and no opportunity for the SLAR operator to assess target motion and assist in identification of icebergs. There appears to be no recorded analysis of the probabilities of detection over the search area. This assessment is important for determining the risks associated with the current search procedure.

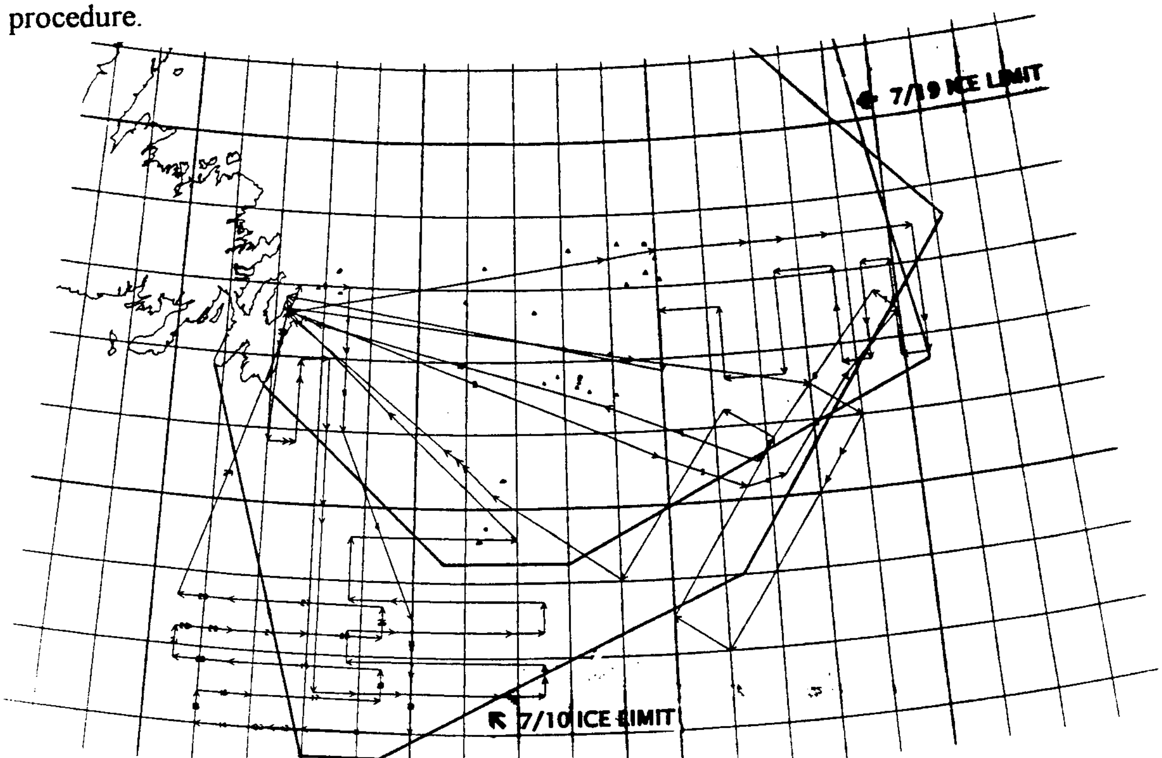

Figure 8. Ice Reconnaissance Search Patterns.

5.4.2. *Studies of AN/APS-135 and AN/APS-137 iceberg detection and identification probability.* Current IIP capabilities in regard to iceberg detection, identification, and sizing are most reliably determined from available documentation describing search sorties performed under controlled conditions where truth data is available from surface vessels. Two studies pertaining to the AN/APS 135-SLAR are available: the BERGSEARCH'84 evaluation performed by CANPOLAR consultants for the Canadian government, in which several air surveillance radars were evaluated (Rossiter *et al.*, 1985), and another study by IIP personnel and the CG R&D Center (Robe *et al.*, 1985). Ezman *et al.* (1993) conducted an evaluation of the AN/APS-137 FLAR that provides some insight regarding operational performance.

The BERGSEARCH'84 study examined five imaging radars, including the AN/APS 135-SLAR (Rossiter *et al.*, 1985). Surface truth data was obtained from a dedicated surface vessel and aerial cameras flown at low altitude in a small commercial aircraft. A variety of wind, viewing angle, and wave height conditions were encountered over the six day period of observation. Much of the data for this radar was unfortunately discarded because of inappropriate operating conditions. Results applicable to current operating conditions include:

- At 100 km range and 12 km altitude, the AN/APS-135 achieved 100% detection of surface truthed bergs classified Medium (51-60m or larger). Of 13 " Small Icebergs " (<50m), only four were detected. Although the 100 km range is not used by the IIP, these data suggest that large targets are detected with high probability.

- The "Gross Target Counts" (size not available) for the AN-APS-135 at the 25 km swath width actually employed, for a 4 kft flight path altitude, were approximately one-half of the estimated truth total, implying a detection probability of less than 50% for growlers, bergy bits, and small bergs combined.

The 1985 IIP SLAR study evaluated only the AN/APS-135 for detection capability of bergs and small boats (Robe *et al.*, 1985). Accurate truth data was collected by object size. For the conditions of present operation, in seas up to 2 meters, for alerted operators, the Small Iceberg target detection probability was estimated at nearly one hundred percent, while growler (3 m to 15 m) and small iceberg detection probability was nearly 95%. Detection probabilities for seas higher than 2 meters and/or unalerted operators were substantially lower, approaching 0-10%. as in the BERGSEARCH'84 study. The possibility of optimistic results, and of results not characteristic of the operational mode is discussed in this report.

The 1991 AN/APS-137 FLAR evaluation involved HC-130 flights over a four day period and utilized altitudes and search ranges on either side of present FLAR operating conditions (Ezman *et al.* 1993). Truth data was supplied by a surface vessel (USCGC BITTERSWEET). On each of the four days, one surveillance flight covering the entire area of interest was carried out by an AN/APS-135 SLAR equipped HC-130. At the 32 nm, 6000 ft range setting nominally employed in present operations, the AN/APS-137 was found successful in four of four opportunities, and, over all flights, was summarized as detecting 48 of 54, and correctly identifying 39 of 54 truth targets. Positions of truth targets, SLAR detections, and FLAR detections associated with this test, in relation to flight tracks, are , however, supplied in this report, and are found to be at variance with the FLAR summary. In particular, a count of truth data targets v. SLAR detections indicate a possible underreporting of truth objects (e.g., May 21 data includes three truth targets, but eight large, four medium, and one small berg in a single one degree latitude by two degree longitude region.). The possibility is introduced in the report that SLAR detections were consistently overreported because many true correlations were identified as new targets due to drift in the aircraft inertial measurement unit. Doubling that could be produced by such an error is found in some, but not all of the apparent overcounts. For the May 21 target group described above, two FLAR flights with identical altitudes and range scale settings found, respectively, twelve and three of the thirteen SLAR targets, but the summary data for this region was two correct out of three visually observed truth objects.

The composite results for the two radars from all sources of this type are thus:

- The AN/APS-135 SLAR detection probability for icebergs lies somewhere between the BERGSEARCH'84 and IIP results for small bergs, bergy bits, and growlers, and is approximately 1.00 for medium and larger icebergs, based on either study. The probability of SLAR misclassification of an iceberg as a ship may be as large as 50%, based on other IIP documents.

- The FLAR detection and correct classification probabilities are 88% and 72%, respectively, based on visual truth data (Ezman *et al.* 1993), but may be substantially lower if SLAR sightings from this same study are used as truth data. (A brief reanalysis is included in Appendix A which suggests a detection probability of 78% vice 88%.) It is understood that other FLAR studies exist that suggest better search performance; however, low lock-on probabilities were also experienced on the sorties actually observed by a team member. There is no experimental evidence, based on limited data, that the FLAR is highly successful at iceberg vs. ship classification by imaging. The capability of the FLAR to discriminate *moving ships* correctly is essentially equivalent to its detection (lock-on) capability against these targets, since any locked-on object is tracked, and a velocity becomes available for display. This does not solve the problem with adequate confidence, however, since icebergs may nonetheless be (mis)classified as slow-moving ships.

5.5 Theoretical Detection/Classification Performance of the AN/APS-137 FLAR.

5.5.1 *System characteristics.* The AN/APS-137 FLAR is a state of the art X-band marine surveillance radar developed by Texas Instruments. It operates in either a search mode (real aperture) or an imaging mode (inverse synthetic aperture, ISAR). There are three variations of search: search mode (wide-area searches), navigate mode (wide-area search with low antenna scan rate), and periscope mode (short range, low altitude, for small targets). The operating parameters are summarized in Table 4.

Table 4: AN/APS 137 FLAR System Parameters

Search Mode	Range Scales (nm)	Peak Power (kW)	Scan Rate (RPM)	Pulse Width(sec) /PRF	Beam Width (deg) Az/Elev	Carrier Frequency (GHz)	Wave form
Periscope	8,16,32	500	300	.5μs/2000	2.4/4	9.05-10.55	LFM
Search	8,16,32,64, 128,200	500	60	.5μs/400	2.4/4	9.6-9.7	LFM
Navigate	1-200	500	6	.5μs/400	2.4/4	Variable	PRN
Image	N/A	500	N/A	.5μs/mode	2.4/4	9.6-9.7	LFM

LFM = Linear Frequency Modulation (Chirp)
PRN = Pseudo Random Noise

5.5.2 *Search modes.* The AN/APS-137 FLAR employs traveling wave tubes (TWT) for high peak power and high resolution waveforms. The 9.05 - 10.55 GHz swept band for the chirped pulse provides a range resolution of about 0.10 meters, and approximately 16 pulses are integrated per scan (scan to scan integration may also be performed). The high resolution waveform produces substantial reduction in single pulse clutter cross section variance, since scatterer returns for the frequencies of the chirped pulse are integrated. With a vertical beamwidth of only 4 degrees, the system is designed to view both sea and targets at near-grazing incidence angles. The 2.4 degree azimuth beamwidth is illuminating a large patch of sea water; at, for example, 30 km, a swatch 1254 m by 0.10 m, for an illuminated area of 125.4 m^2. The nominal mean backscattering coefficient is, however, no larger than about $10^{-3.5}$ at X-band (Sittrop, 1977), and may be much smaller, so that the clutter mean cross section per illuminated range bin is only about 0.04 m^2. The principal clutter rejection device is thus low incidence angle.

Under these conditions, it is known that the clutter spectrum is better characterized by a Weibull or log-normal distribution, so that single pulses may provide spikes well above the mean clutter cross section. The standard procedure for a high range resolution radar is to set the single bin detection threshold to provide an adequately low false alarm rate over the all the range bins, which determines the single-bin S/C for detection, and the consequent theoretical probability of detection performance for the system. Such a computation is appropriate where the theoretical clutter backscattering coefficient is reliably known from measurement, preferably supported by theoretical predictions. This is, however, not the case in the region of FLAR (or, for the most part, SLAR) operation). Skolnik (1990) (Chapter 26) cites experimental errors as great as 10 dB for measurements of this parameter. Although recent theoretical advances are obtaining good agreement with measured coefficients in the 0-60° incidence angle range, extension to higher incidence angles has not proven possible. For example, Fung (1994) does not include updated versions (or even the original versions of his own earlier (1977)) results for backscattering at low incidence angle and simply omits this regime. The earlier results were used in the BERGSEARCH'84 (Rossiter *et al.*., 1985). There is, moreover, evidence from SLAR mapping of what may be long-period wavelength (100s of meters) swells that are producing radar shadows over large areas; these are probably hiding low-lying bergs and growlers from both SLAR and FLAR.

The disappointing performance, relative to the SLAR, in detecting small bergs (which is suggested by the studies, and is experienced by ICERECDET personnel) is at first somewhat difficult to understand in the light of the advertised capability of the system, which, according to Jane's (1994), is Periscope mode detection (of periscopes) at up to 32 km range. (Comparison of target characteristics alone is relevant to understanding the AN/APS-137 performance for ice targets, since clutter return is similar in size and spectrum for periscope and ice detection. However, periscopes are hard targets while ice and life rafts are not.). The fact that the entire periscope will, in this mode, probably appear in one or two 10 cm range bin implies a cross section of about perhaps 0.10 m^2 or more in one bin.

Comparison with typical iceberg X-Band cross sections for narrow-band radars is essentially impossible, since an entire berg is rarely viewed in a single bin for this radar. An iceberg will have returns for each 10 cm bin from both surface and volume elements contained in that bin. A berg that presents as much as 2.5 m^2 (assuming -10 dB m^2/m^2 at or near normal incidence; see Figure 9) of presented, near normal surface aspect in a single range bin, regardless of gross size, is thus required to provide a single pulse signal to clutter ratio equivalent to the periscope (which is, moreover, required to extend a greater distance above the mean ocean surface in heavy seas). Figure 9 presents backscattering coefficients for multi-year sea ice and is used as an approximation to estimate the effects for glacial ice, which is known to have different radar reflectivity. In Figure 9, the decline in cross section with angle of incidence approximates a cosine dependence until about 60°, but is steeper thereafter, implying that the radar cross section drops off like the colloquial cross section of the berg normal to the sightline out to about 60°, implying a strong contribution from bubble scatterers. Range bin cross sections subsequent to the first few will be larger in normal colloquial cross section area, but will have interior (bubble) scatterers partly due to greatly attenuation by absorption and scattering, depending on the depth, and are thus more dependent on surface scattering to achieve return. Medium to large bergs will nevertheless frequently present sufficient surface area at reduced aspect angles to exceed the required threshold. Considerations are similar in the Search mode, for which each downrange cell is about 0.75 meters, and the number of pulses integrated per scan is also 16. The single pulse S/C will not be as good for this mode, but target cross section variability will be reduced, perhaps explaining the subjective lack of difference in performance in these modes as observed by operators.

5.5.3 *Possible sources of FLAR performance improvement.* Ocean backscattering cross section variation with aspect angle and wind direction may be adequately compensated in the system design for metal targets, but flight path planning to minimize this parameter could be used to achieve increased performance for low cross section iceberg targets for the AN/APS-137. The maximum achievable improvement for one meter seas at 20 knots is about six dB (Fung model results with the crosswind direction providing minimum backscatter; downwind and upwind results are similar (Fung, 1994)).

Although clutter samples are substantially decorrelated by the high resolution waveform, additional decorrelation is probably achieved at side aspects (which would yield 8 decorrelated samples at the side aspect even without the high resolution waveform, because of the Doppler spread from front to back of the clutter patch. Each FLAR pulse is, in fact producing a clutter sample of reduced cross section variance because of the chirped waveform, but the side aspect can additionally improve pulse to pulse decorrelation.) This implies that potential targets not detected from a front aspect should be reexamined if possible at the ± 90° aspect.

FLAR operation in the Navigate mode should provide superior clutter rejection at the expense of 6 degree per second search. Although the number of samples is the same for each mode, the Navigate mode frequency diversity provides more complete clutter decorrelation.

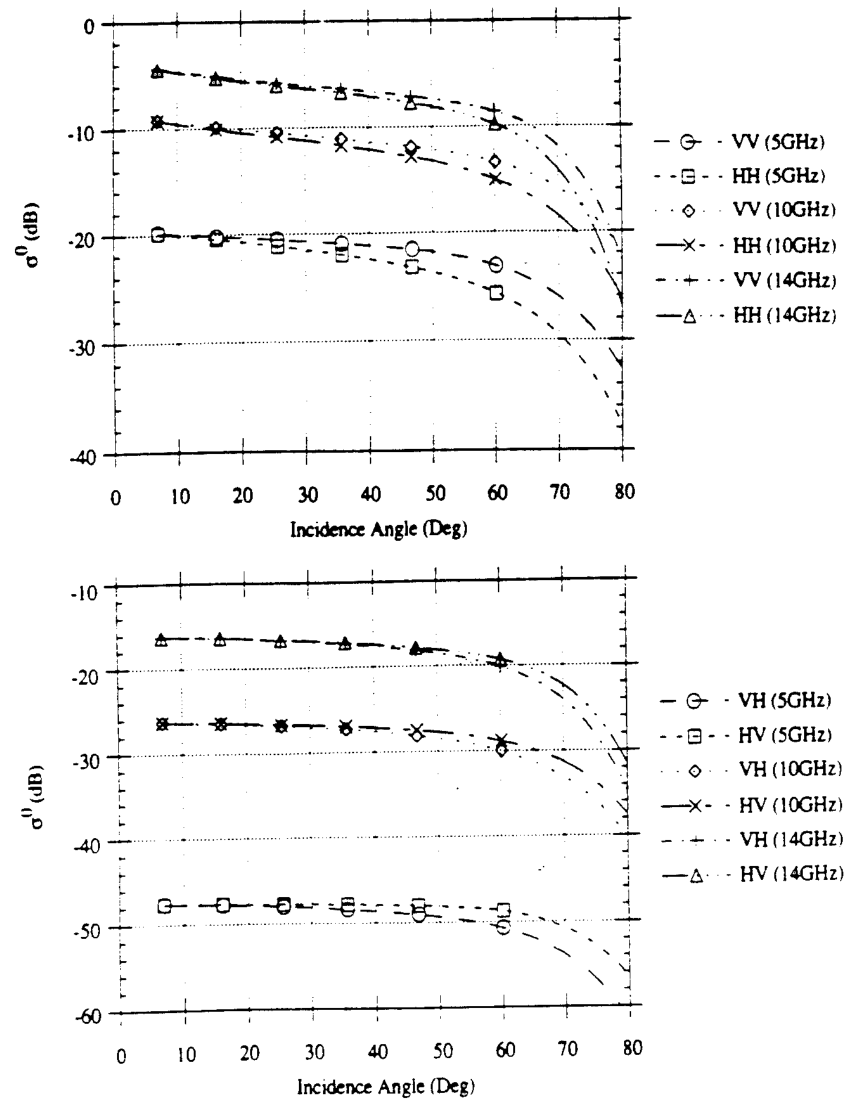

Figure 9. Multi-Year Sea Ice Backscattering Coefficients (Fung, 1994).

It is possible that the unique dynamic characteristics of iceberg motion arising from relatively small separation of the center of mass and center of buoyancy can be exploited to improve/stabilize iceberg images only on the FLAR display. A shortcoming of this approach is that the small fraction of bergs with very high bubble density may not exhibit the anticipated dynamic characteristics.

5.5.4 *Imaging mode*. Imaging mode results are disappointing for the FLAR, as described above. Severe distortion is producing images in the form of undulating bands of pixels of various brightness for both bergs and ships. The advertised performance for this imaging mode is adequate to perform ship typing and assess battle damage (Jane's, 1994).

The performance being achieved in the current operational mode is clearly not this good for bergs or ships, suggesting a mismatch of operating conditions to system design. The system must effectively establish the parameters of a matched filter, measuring and subtracting the unwanted frequency components to make ISAR work (Skolnik, 1990). The present image is suggestive of a raw ISAR image, in which the crossrange cell to Doppler frequency assignment does not vary periodically with the observed target rotation frequency to produce a stable image. Discussions with Coast Guard personnel at Coast Guard Air Station Elizabeth City, NC indicate that this type of image is, in fact, routinely observed, and that the Jane's description of the images in the fleet imaging mode is not standard. It is averred that image classification by an experienced operator is a high confidence event, but that operator skill and knowledge of the system is essential to achieve the current high level of performance. Note that time spent in the imaging mode takes away from detection opportunity time.

5.6 Theoretical Detection/Classification Performance of the AN/APS 135-SLAR.

5.6.1 *System characteristics*. The AN/APS-135 SLAR is an X-band radar that scans the sea surface in a direction normal to the aircraft flight path. The radar image is displayed on a CRT as well as displayed and recorded on 23 cm dry process negative film. System parameters are included in Table 5.

Table 5: AN/APS 135 SLAR System Parameters

Peak Power	200 kW
Carrier Frequency	9.250 (± .40) GHz
Pulse Width	.2 (± .02) μs
Pulse Repetition Frequency (PRF)	375 or 750 (1/sec)
Antenna Azimuthal Half-Power Beamwidth	0.47 (degrees, one-way)
Antenna Shaped Coverage in Elevation	-1.5 to -45 (degrees)
Peak Gain	38.3 (including radome loss)
Depression Angle of Beam Peak	1.5 (degrees)
Polarization	VV
CRT Spot Size	1.15 mils (to 1.80 mils)
Film Resolution	20 lines per mm

5.6.2 *Detection*. At the currently utilized 2 to 27 nm ground range half-swath, AN/APS-135 theoretical search performance is also dominated by clutter rejection capability. At the 1/2 degree beamwidth, the SLAR is, at the minimum (2.24 nm) range, illuminating a 34m wide by 30m ($1020m^2$) long patch, which, from the Fung Model (Figure 10), for 13 knot winds yields a backscatter coefficient of -28 dB m^2/m^2 at 63.5 degrees upwind for a cross section of $3.2m^2$. It would thus be necessary for a berg to have an area, viewed from above at 63.5° (using Figure 9, for HH polarization), of about $63m^2$ to achieve a single-pulse signal to clutter ratio of 1. This, fortunately, is not necessary for two reasons:

(1) Since the aircraft is moving, substantial clutter decorrelation is obtained because of the differential Doppler across the clutter patch. A d meter aircraft forward motion produces a change $\Delta R = xd/R$ in a clutter patch that is originally at distance R perpendicular to the track and x downtrack from the original aircraft position. For d = 25 m, the screen displacement is equal to the film resolution of .05 mm. The system must effectively be integrating over the (approximately 140, at 250 knots) pulses received during this motion. For a scatterer at the trailing outer edge of the illuminated patch (assumed temporarily to be the 3 dB beamwidth) the ΔR during the 25 meter motion is about .20 meters, or more than six complete wavelengths, so that the round trip phase shift is about 25 π radians, or 12.5 cycles. This corresponds to a Doppler spectrum spread (front to back of beamwidth) of $\Delta f_D = 134$ cyc/sec (independent of range). From Skolnik (1990), the implied correlation time is $T_i = 0.65/\Delta f_D = 0.0049$ sec and the equivalent number of <u>independent</u> samples is the total integration time, 0.1866 sec (at 250 knots), divided by T_i, or 38 samples. If the pulses were coherently integrated, a substantial deduction in clutter power would take place. For incoherent integration, the variance of the clutter image from screen point to screen point is greatly reduced (accounting for the uniform gray appearance of the screen), and the return is very nearly proportional to the previously computed patch cross section, for <u>each</u> pulse. This accounts for the uniform gray, rather than speckled, appearance of the screen clutter. Targets are, in general, substantially smaller than a beamwidth in extent, and thus are consistent with perhaps a few independent samples; the radar cross section behavior is, however, somewhere between Swerling 1 and Swerling zero (nearly constant for short times) because of the volume scatterers. The region of screen spots characterizing the target image as a whole should thus, approximately, reflect the sum of the radar cross sections of the clutter and target, with some intensity variation near the image center, where the small target phase center to clutter phase center displacement provides the least phase shift change during spot integration.

(2) The visual detection mechanism provides sub-clutter visibility. A berg of only $12.7m^2$ actual presented area, as viewed from above, will produce a twenty percent (+2 dB) change at minimum range, relative to the background clutter return, as computed above. If the dynamic range of the log-proportional photographic image is only 20 dB, a ten percent increase in image exposed dot density (for the negative image) occurs. This may well be visible and recognizable to the trained operator, provided the image is well scrutinized. Since an alerted operator cannot be guaranteed in the operational case, this condition represents a theoretical maximum.

As groundrange increases slightly, the sea clutter coefficient drops slightly faster than the ice backscattering coefficients (for the top ice surface). Figure 9 yields a top surface coefficient decline of -4 dB at 70°, corresponding to a slant range of 2.91; Masuko *et al.* (1986) predicts a decline of -3 dB to -31 dB for X-band, HH sea clutter at this incidence angle. Since the clutter patch width increases by about 30% (1 dB), a 2 dB drop in clutter is anticipated. (The subjective appearance of the screen suggests no change, however.) The drop in ice top surface backscatter coefficient may be partly compensated by increased contribution from the side. Thus, something between less than a 1 dB (30%) increase in berg area is needed to preserve the ten percent intensity margin.

From 70° to 85° incidence, Skolnik (1990) suggests a decline of about 3 dB in backscattering coefficient for "medium" seas (about 15 knots; the comment in Skolnik (1990) is, however, " the variability of sea echo data is great, and does not warrant the precision with which Figure 3 is drawn"). At 85°, the range of 11.5 nm produces an increase in clutter patch length sufficient for a 6 dB increase, so that an increase in clutter cross section of 3 dB is anticipated. In the same interval, the top surface backscattering coefficient declines by 18 dB, so that an increase of 21 dB, to about 1600 m^2, would be necessary to achieve the required intensity margin based on top surface alone. This is consistent with detection of very large tabular growlers only. A presented side area of about $40m^2$ near normal or about $60m^2$ at a mean incidence angle of 45° is, however, sufficient to meet the detection requirement. That some growlers and small bergs may not produce an adequate side + top cross section to be detected is apparent.

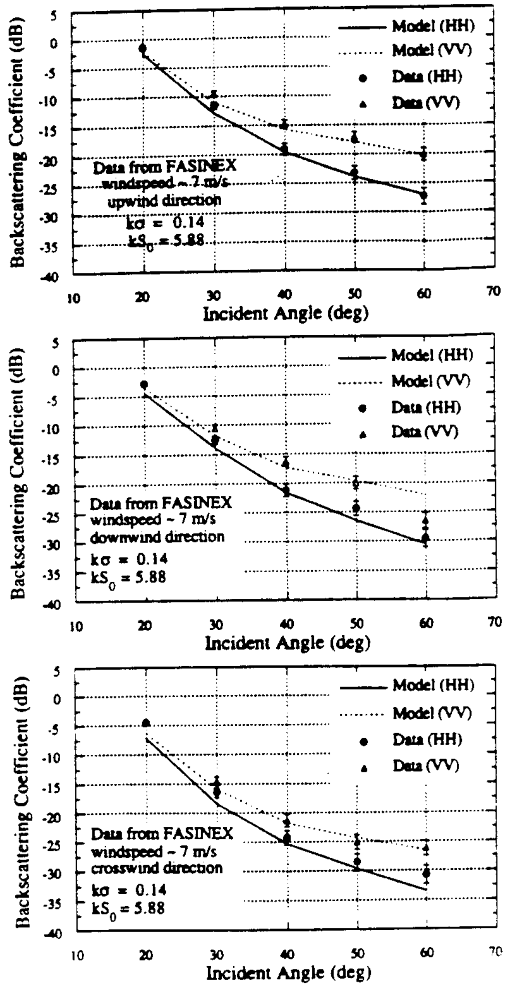

Figure 10. Typical Ocean Backscattering Coefficient at X-Band (Fung, 1994).

Beyond about 85°, the backscatter coefficient theoretically (Skolnik, 1990) drops rapidly enough to compensate for the length increase. At the 27 nm range, the clutter patch is 386 m wide by 30 m long (11580 m^2) and the angle of incidence relative to the sea surface is 87.9°, so that the sea backscatter coefficient is down by (very approximately) -40 dB for the upwind, 20 knot case. This condition creates a very small backscattering coefficient for the ice top surface as well, but berg sides may be well imaged. The observed image on the SLAR display implies that the clutter cross section is, in very large (hundreds of meters) patches, much brighter than the implied -40 dB coefficient would imply. These alternate with light regions of approximately the same size, which are white on the negative, may be radar shadows large enough to partially obscure growlers. The dark (high clutter) SLAR patches are approximately as dark or darker than the 85° incidence region. At the reduced top surface ice cross section expected for this range (-35 dB or less), growlers and bergs will only be visible in the anomalous, high clutter regions if the unsubmerged (and visible, submerged) presented cross section (in the colloquial sense) approaches 100 m^2. In regions of apparent low clutter at maximum range, side aspect areas as small as 5-10 m^2 are probably detectable.

At higher wind velocity (about 30 knots), Masuko *et al.* (1986) suggests about a +5 dB increase in backscatter coefficient near the inner search boundary, which yields a 37 m^2 top aspect area, or about 20 m^2 side area for detection, by the previous criterion. Data beyond 70° incidence for this velocity suggests a less rapid decline (only about 1 dB to 85 °), so that an equivalent side area of nearly 100 m^2 is necessary for detection at 12 nm range. Requirements beyond this range are uncertain.

The above computations for upwind SLAR performance are improvable by about 5 dB for crosswind conditions, as noted previously for the FLAR.

5.6.3 *Imaging*. SLAR imaging is compromised principally by the 0.47 degree (power, one-way) azimuth beamwidth. The form of images, and hence the ability of the AN/APS-135 SLAR to distinguish icebergs from ships, depends not only on this parameter, but on the threshold and saturation dBsm values. A principle means of distinguishing ships is the achievement of saturation dot density over a single, .06 mm width corresponding to the 30 meter single-pulse return. It is possible that this effect may not be observed if the threshold has been set too low, permitting bergs to also achieve saturation rapidly. The robustness of imaging guidelines within operator-permitted panel adjustments may warrant brief investigation.

5.6.4 *Obsolescence*. The AN/APS-135 SLAR is technologically obsolescent and is no longer available from Motorola. The key elements required for its continued use are the existence of processor heads and a supply of dry film for recording the SLAR images. At present, the Coast Guard has six spare processor heads and a supply of dry film in refrigeration at CGAS Elizabeth City. It is expected that the existing equipment will no longer be available after the 1996 ice season. Nonetheless, the above analysis may lead to operational improvements during the next ice seasons and also provide specification guidance for a replacement system if that is a selected alternative.

5.7 Initial Assessment of Iceberg Detection/Classification Capability.

The following conclusions regarding iceberg detection and classification effectiveness for present operations are justified, based on the preceding material:

- SLAR detection probability is, in principal, quite high even for small bergs, except in the region from approximately 20 to 27 nm, where large-scale backscattering coefficient variation and radar shadowing may be taking place. Operator inattention and screen adjustment for optimum performance may reduce this probability in many cases. SLAR classification probability is unknown.

- The present FLAR operational mode may not be providing extremely high detection and lock-on capability against small bergs and growlers (based on actual results in an observed sortie, and other indirect evidence)

- FLAR search and lock-on performance may be better for look directions perpendicular to the aircraft track, where the signal to sea clutter ratio is somewhat improved beyond the high resolution capability because of the differential Doppler spread over the patch. Restrictions on on-scene time may limit this approach.

- FLAR operation in the Navigate mode should be considered/investigated, if track and velocity display are possible in this mode, since 160 decorrelated clutter samples are available at the full pulse width.

6.0 Iceberg Location Prediction using Drift and Deterioration Models

The IIP drift model moves icebergs through the IIP operation area while the deterioration model melts the icebergs over time until it is considered safe to remove the particular iceberg from the IIP plot and cease active tracking and reporting. In addition to iceberg position and size data, both of IIP's models require substantial environmental input data. The drift model requires marine surface data for its drift predictions which includes ocean currents, surface winds, and initial iceberg size and shape. The deterioration model requires sea surface temperature, wave height and wave period data along with initial iceberg size. These data requirements are in part fulfilled by FNMOC. The IIP provides its own ocean current data, either historical or from realtime surface drift buoys, and its own initial iceberg sighting data specifying location, size, and shape. In the following sections, we review the sources and accuracy of the environmental data, and the operation and accuracy of the drift and deterioration models.

6.1 Environmental Data.

6.1.1 *Current data.* The mean current data base used by the IIP for the drift model is established with a traditional IIP grid of 20 minutes of latitude and longitude, with a finer 10 minutes of longitude in the so called offshore branch of the Labrador Current that flows south along the edge of the Grand Banks. Formerly, the mean current data base was formed from hydrographic data collected during over 100 surveys of the Grand Banks region from 1934 to 1978. Mean current charts were constructed based on the distribution of mean dynamic typography originally for April, May, June and July. Monthly variability proved to be small and the four mean charts were merged into one. The data base for currents for the drifting of the icebergs was then simply computed geostrophic currents based on the single historical distribution data set of dynamic heights.

Drifting buoy current data are currently obtained from WOCE ocean drifting buoys, generally using a drogue set to represent the 50 meter depth. They are deployed from Coast Guard HC-130 aircraft and satellite tracked. Various drifting buoys have been used on a routine basis since 1979 (e.g., TIROS Ocean Drifters). The resulting data have been used on a realtime basis to replace certain parts of the historical mean current field as appropriate for the drift prediction of icebergs of opportunity. Approximately 10 drift buoys have been deployed during each ice season, with cost being somewhat of a limiting factor. This technique has the ability to provide a much better and realtime representation of the ocean currents as measured by the drift buoy than would normally be available using the historical currents for the model's drift predictions.

Through the intervening years, a considerable amount of drift buoy data has been accumulated in the IIP area allowing a permanent modification of the historical mean current field with this measured drift information. The modification to the historical data base was commenced in 1989 and continues to date. (See Murphy, Hanson, and Tuxhorn, 1990.) However, IIP is planning on a complete replacement of the historical mean current field (modified) with the data that have been obtained from more than 175 drift buoys. Some of the drift data has been supplied by the Canadian Department of Fisheries and Oceans.

Realtime drift buoy data, as presently obtained, allows the direct use of the measured mean currents in the vicinity of a drifter buoy for the first week of completed observations. During the second and third week, as the buoy moves out of a particular area, the historical operational data set gradually replaces the drifter information until the data set returns to its original form in the computer. When the drift buoy is in a particular area, the drift buoy current data is considered far superior to current data calculated from dynamic heights. The new historical current field can be easily added to with the use of additional drifters each season.

The new mean current data, as provided by the drifters, continues to allow only mean drift calculations to be performed. As indicated above, these estimates are much better than would be obtained using the historical mean. However, the great temporal variability of the currents in the IIP area is not reflected in the mean data. It is important that this variability, rapid changes in speed and direction over a time frame of only several hours, be weighed in attempting to understand as well as modify existing drift techniques. Nonetheless, in the absence of the more useful realtime currents, this new historical current data base from drifter data forms the heart of iceberg drift predictions. Realtime drift buoy information, obtained either by a purposeful drift buoy drop, or by serendipity in an area of iceberg concern would be expected to result in a much better drift prediction along with greater trajectory detail. Realtime data near an iceberg being drifted by the model tends to provide additional confidence in that actual currents are being used vice "historical mean currents" which by definition may never exist at any given time. Increasing the number of drifters used during an ice season would provide much better coverage and usefulness of the realtime current data.

6.1.2 *Wind data.* Wind data for the drift model is supplied by FNMOC every 12 hours with a forecast out to 36 hours. It is in the form of an averaged marine wind field for a height of 10 meters above the ocean. The data is provided with a grid spacing of 155 kilometers (84 nautical miles) and reported to 1.0 meters per second. Comparative on-scene tests have shown that the Navy supplied wind data is consistently higher than observed winds. One comparative test showed that the speed difference between the Navy's wind and the observed wind from a Coast Guard surface vessel, when normalized by the observed winds, gave an average error of 48 percent (Anderson, 1984). Since that time, FNMOC has modified its model and more recent comparisons have not been made.

6.1.3 *Sea surface temperature (SST) data.* Sea surface temperatures are supplied by FNMOC. The temperatures represent the sea temperatures at one meter below the surface and are produced every 24 hours and reported to 0.1 °C. The grid spacing of the data provided is 35 kilometers (19 nautical miles). The IIP supports the Navy's sea surface temperature program through the use of Air-deployable eXpendable BathyThermographs (AXBTs) provided by METOC and deployed by the ICERECDETs. In addition, the drifting current data buoys also provide sea surface temperature to the Navy. These data are used within the Navy's predictive sea surface temperature data program, but the extent to which they are used cannot be quantified or necessarily noticed in the digital sea surface temperature product supplied to IIP for their models. Comparative surface temperatures made from IIP ships have resulted in surface temperatures being an average of 1.3 °C warmer than reported in the Navy data and 0.6 ° C warmer than METOC forecasts (Hanson, 1987).

6.1.4 *Wave data.* Wave data are also supplied by the FNMOC. The value of wave height and wave period are provided every 12 hours. These data are hindcast as well as predicted by the Navy based on their wind fields, on a grid spacing of approximately 235 kilometers (127 nautical miles), and then interpolated to a grid of approximately 140 kilometers (76 nautical miles) and supplied to IIP. Comparative studies with IIP surface ship observations have averaged 0.9 meters (3 feet) lower and with periods averaging 4.6 seconds shorter than heights and periods predicted by the Navy (Hanson, 1987). METOC wave height forecasts were 0.8 m higher than observed. Since those comparisons, FNMOC has provided sea height and sea period (in June, 1988). IIP used these data in 1988 and model comparisons showed improved performance (Hanson, 1988).

6.1.5 *METOC data*. An additional data source on a more regional scale can be obtained from the Canadian Forces Meteorological and Oceanographic Center (METOC), Halifax, Nova Scotia. These regional scales have a grid spacing on the order of 50 to 100 kilometers (27 to 54 nautical miles). Products supplied are surface thermal observations, mainly based on interpretations of ship observations, and wave heights produced from an ocean wave model which is qualitatively blended with ship observations. Comparative studies with IIP observed data suggest that the accuracy of these products is on the order of those supplied by the Navy as indicated above, with SST slightly more accurate since they are sourced primarily from actual sea surface observations. These regional products are not presently being used as digital inputs in either the drift or deterioration model. Based on very limited observations, IIP has recognized that they may at times be superior to those supplied by FNMOC, if they were obtainable in direct model input digital form.

6.1.6 *Evaluation*. Although there have been several validation studies to compare data provided by the Navy with realtime surface truth data, the studies have been of very short duration with only a dozen or less data points for each study. Recent modifications of the FNMOC models may be providing better data, but no observations have been made to confirm this. Some data is very sparse within the IIP operation area and requires interpolation to be useful with the smaller grids used by the IIP models. The interpolation creates another source of error in estimation with an impact on the accuracy of the drift and deterioration model results.

6.2 Iceberg Drift Model.

6.2.1 *Model summary*. The iceberg drift model used by IIP was completed and tested in 1980 (Mountain, 1980). Its format and use remains essentially the same to date. The fundamental drift model balance is between iceberg acceleration, air and water drag, the Coriolis acceleration and a sea surface slope term which describes the mean ocean currents. The resulting differential equations are solved on a digital computer. The model is driven by an ocean water current as input data and combined with a calculated depth and time dependent local wind driven current. The model is operated every 12 hours using the supplied environmental input, and drifts all icebergs within the IIP operations area included in its realtime data set.

Input information for the model also includes mass and cross sectional area of each drifting iceberg. This is determined either visually or inferred from remote sensing equipment. Sensed or sighted icebergs are placed into one of four size categories (growler, small, medium, and large with no upper limit) which also automatically sets the mass and cross-sectional areas to the characteristic values for the designated size category. One of two specific shape classifications, tabular or non-tabular, is also made when a visual sighting occurs. Tabular or non-tabular icebergs have different cross-sectional area values for each size category. Because of their sail area and potential underwater shapes, tabular and non-tabular icebergs tend to drift differently and are modeled as such when this information is available. The model basically operates by dividing the subsurface shape of the iceberg into four draft layers, each with its own cross sectional size and depth. This causes the iceberg's drift movement to be controlled to some extent by its underwater shape. Unfortunately, that shape is seldom known. Icebergs whose size are unknown are assumed to be medium icebergs; those whose shape are unknown are assumed to be non-tabular icebergs.

6.2.2 *Drift error estimates.* The IIP estimates that the initial position error is 5 nm regardless of sighting source and that model drift error increases linearly in 5 nautical mile per day increments for each 24 hours of additional model drift up to a maximum radius of 30 nautical miles. This maximum error of 30 nautical miles occurs after 5 days of drift. There is no increase in the maximum 30 nautical mile error estimate regardless of how long the iceberg is drifted within the IIP operations area. If an iceberg is resighted, the drift error calculation is restarted. Icebergs south of 40°N are assumed to have a daily drift error of 10 nm, accumulating over a period of 5 days to a maximum error of 55 nm. Icebergs are deleted from the data set of the model if they drift outside of the operations area bounds of the model, or have reached a deteriorated size which is 125 percent smaller than their initial size at the start of their drift or 150 percent smaller if they are limit setting icebergs.

6.2.3 *Model validation.* Initial model tests in 1980 used the tracks of 2 large tabular icebergs, a large pinnacle iceberg, and a freely drifting satellite-tracked buoy (Mountain, 1980). The drift durations were from 3 to 25 days. Results ranged from approximately a 5 nautical mile error for a 3 day drift to a constant 50-80 nautical mile error in the 25 day case. The assumed cause for the error in this test was stated to be inaccurate wind and current data inputs to the model.

In 1985, drift model tests were held in several different parts of the IIP operations area (Murphy and Anderson, 1985). Four case studies were performed using the drift model. The objectives were twofold: first, to test the accuracy of the drift predictions of the model, and second, to investigate how the accuracy changes when on-scene, observed data of wind and current are used to drive the model, instead of the provided, so called system data either from the Navy or IIP mean current files. In addition, this test had the advantage of measuring the actual size of the iceberg that the model is drifting as well as noting its shape, making adjustments to these as the drift predictions occurred regardless of the input or source data protocol used. None of the 4 case studies drifted for longer than 4 days.

In 3 of the 4 cases, the drift of the icebergs as depicted by the model using the system data had location errors ranging from 40 nautical miles after a 2.5 day drift, 30 nautical miles after a 3.3 day drift, and 45 nautical miles after a 4 day drift. These all exceed the standard drift error assumed by the IIP of a maximum of 30 nautical miles after a drift of 5 days. The 4th case study drift did remain well within the standard drift error and did not exceed an error of more than approximately 11 nautical miles over a 4 day drift.

Better performance results from the model were realized when using the observed data for all four case studies, instead of the automatically provided system data. The better performance level generated was simply measured by the fact that the predicted drift of the icebergs during this maximum 4 day period remained within the drift error allowed by IIP. Unfortunately, in 3 of the 4 cases, the icebergs drift error from model predictions remained very close to the maximum drift error allowed by IIP. Only in one case was the predicted iceberg drift position error well within the accepted limits. Projecting a drift experiment such as this for a total period of 2 weeks, or 3 times as long as these case studies, suggests that the drift errors would continue to generate and become even larger, perhaps much greater than those generated during the very first comparison drift model tests conducted in 1980.

6.2.4 *Evaluation.* In analyzing the several comparative drift studies conducted since 1980 and reported in the IIP Bulletins, and using the maximum accepted IIP prediction drift errors as a basis, one must conclude that the standard system data as now used on a routine basis for modeled drift predictions is not satisfactory in its present form and can lead to gross errors, greater than the 30 nautical miles maximum now assumed by IIP, in the location of drifting icebergs. Furthermore, even with a surface vessel on-scene collecting observed data for direct input into the drift model including actual size measurements and visual shape evaluations, the model results push the boundaries of the accepted 30 nautical miles maximum drift error. Based on the trends in the various drift results, if the tests were continued beyond the 4 days, the model error would exceed, if not greatly exceed the 30 nautical miles maximum drift error after a period of 10 days of predictions even with using the best on scene, observed data available.

6.3 Iceberg Deterioration Model.

6.3.1 *Model summary.* The iceberg deterioration model used by IIP was completed and initially tested in 1983 (Anderson, 1983). It uses sea surface temperatures, wave height and period, and initial size. Progressive deterioration of the iceberg is quantified by its waterline "length" by definition. There are four size categories: growler, small, medium, and large with no upper limit. The model initially uses the maximum waterline length for the size category reported. If an iceberg is resighted, the waterline length is set to the maximum for the size reported in the resighting. Icebergs for which no size category is reported are assumed to be medium icebergs.

The model considers four forms of deterioration: insolation (sun heating), buoyant convection (vertical circulation of the water), wind forced convection (drift movement through the water), and wave induced (wave washing of the subaerial surface). All of these forms of deterioration are caused by heat exchange with the ocean water which may or may not be warmer, or above freezing for the glacier sourced, fresh water ice. The model equations applied with a 6' wave height, 10 sec wave period, and 25 cm/sec relative velocity (SST unknown) result in 84 percent of the iceberg's deterioration being attributable to wave induced melting; approximately 14 percent due to wind drift of the iceberg relative to the water bathing it; and less than 2 percent related to sun heating and vertical circulation along the iceberg's submerged surface.

Wave washing and melting within the predictive model then requires good information as to the temperature of the water washing over the iceberg's surface and the intensity of this turbulence as created by, and quantified by the wave height and period. If no other process were involved and the algorithm for wave melting is correct, along with good input data, knowing the melt rate to within 84 percent could be quite satisfactory. However, model comparison tests conducted in 1983, with all other parameters held constant, showed that a 100 meter iceberg length took 179 days to melt in -1 degree C water compared with 20.5 days in 3 degree C water (Anderson, 1983). Input data errors of 1 degree C variance from actual sea surface temperatures can therefore produce melt errors on the order of 40 days for this 100 meter berg length. These results suggest that sea surface temperatures are the most critical parameter. Note that the only melting component that depends on the size of the iceberg (waterline length) is wind forced convection melting. Thus, deterioration can be computed after the waterline length has decreased to zero. Icebergs are removed from the model when 125 percent of their original waterline length has been melted if they remain within the bounds of all known ice, unless they are limit setting icebergs for the region of all known ice in which case they are retained by the deterioration model until 150 percent of their waterline length has been melted.

6.3.2 *Model validation*. In 1987 the IIP conducted a deterioration study using 6 icebergs, observed and tracked by a surface vessel (Hanson, 1987). The time of observation on each iceberg ranged from 2.1 days to 6.3 days. The objectives of this study were to compare iceberg deterioration predictions derived from environmental data collected in situ to inputs available from operational data centers, the so called system data, normally used in routine iceberg deterioration predictions. Conclusions that operational data provided by the Navy was on average 1.3 degrees C colder than that actually observed, the wave heights averaged 0.9 meters higher than observed, and the periods were on average 4.6 seconds greater than observed. The 6 iceberg cluster averaged 379 cm/day melt rate of their waterline length using observed wave erosion values, while using the operational data provided by the Navy produced a melt rate on average of 531 cm/day. The overestimation of the predicted wave height was blamed on the significant overestimation of the melt rate, even though the predicted temperatures also averaged 1.3 degrees C colder, which would tend to slow the melt rate. If this type of overestimation is typical, coupled with the maintenance of limit setting icebergs until they have melted to 150 percent of their original waterline length, would tend to produce offsetting errors of similar magnitudes and produce safety margins by default, which is not always good practice. The actual observed iceberg length changes as compared with the model predictions made as part of this test were inconclusive due to the time constraints, (i.e., the observation period should have been on the order of 2 to 3 weeks rather than 2 to 6 days.)

6.3.3 *Evaluation*. With potential predicted melt rates with errors of 152 cm/day of water line length, or as stated by IIP a 38 percent total melt error, coupled with the additional specter of the uncertainty of initial iceberg sizes and characteristic lengths, tends to undermine the believability of the deterioration model. Basically, as defined by IIP the small to medium to large definition of characteristic iceberg lengths approximately doubles with each increasing size category starting at 60 meters. If the initial iceberg characteristic length is known, then a 38 percent melt error can be compensated by the 50 percent increase in melt size allowed by the model before the iceberg's removal from IIP's active list of icebergs for limit setting icebergs. Non limit setting icebergs in general have only a 25 percent increase in melt size and may be pulled from the active list before deteriorated if errors as great as 38 percent occur. However, if the limit setting iceberg's size was underestimated by only one category, the size category doubling as defined could allow an iceberg on the order of 35 percent of its original underestimated size to remain a menace while being removed by the model from further consideration. For example, if a large iceberg with a category length of 225 meters was underestimated as a medium iceberg with a category length of 122 meters, and deteriorated to 150 percent of its original size, this underestimated iceberg would loose 183 meters of waterline length and be deleted from the model, but would actually still remain an iceberg menace with a length of 42 meters. If the underestimation is made with a medium iceberg, a 32 meter long iceberg would still remain. These sizes fall between a defined growler of 16 meter characteristic length and a small iceberg of 60 meter characteristic length. Without question, they remain the more difficult icebergs to resight from the air, and potentially difficult for a surface vessel to detect by radar, especially in a seaway.

Although there have been several studies comparing modeled deterioration with observed deterioration, none of the IIP analyses or reports indicates that a complete sensitivity analysis of the deterioration model has been conducted. In particular, sensitivity of wave height estimates and their interaction with the initial size estimate requires further exploration. For example, in the 1987 evaluation, FNMOC wave heights were 0.9 meters above the observed wave heights. If the average wave height was 2.0 meters (actual wave heights are not included in Hanson, 1987), the wave induced melting is increased by almost 35% per day. That error compounds rapidly on succeeding days.

6.4 Initial Assessment of Drift and Deterioration Models.

There are obvious limitations on the data which is operationally used on a daily basis. Based on reported evaluations, the three most important pieces of data are sea surface temperatures, the drift currents near each iceberg, and the physical characteristics of each iceberg being model drifted and deteriorated. As little as one degree C of sea water temperature can result in the development of gross errors in the predicted melt rate of each iceberg. If accurate sea surface temperatures were available to within 0.5 degrees C, more reliable melt rates would be generated. Direct, realtime currents provided by specifically deployed satellite tracked drifters are far superior to using any historical mean currents in the drift model, even if they are updated mean drift currents gathered over the long term from drifter data. Last, the size and shape, both above and below the water must be better known before more effective use can be made of better temperature and current data. Mass size, sail area, keel depths and shapes, as well as horizontal dimensions all play an integral part in both the drift and deterioration modeling efforts. The best available environmental data is almost useless without a better description of the subaerial and subsurface details of the iceberg. Each of the predictive models substantially operates through the forces and heat transfers applied to the iceberg's irregular surface and size. Without the detail knowledge of this surface and size, the models must operate on some approximation, and the degree to which that approximation differs from the real thing will greatly influence the degree of accuracy of the predictions.

The availability of the required data must be weighed against the structure of the existing models to evaluate the combined effect. There is a strong indication that the present drift and deterioration models being used cannot be supplied with sufficiently accurate data. In comparison, the present National Weather Service predictive weather models, corrected and updated on a 3 hour basis and using numerous reporting sites and a variety of satellite sensing, still have difficulty predicting the details of the weather over a 24 hour period. We may presently be at the best prediction ability for the IIP models as they are presently formulated and the data remotely sensed. Actual field tests, and there have been only several, tend to indicate that when actual on scene observations are made, giving the best environmental data collectible along with relatively accurate initial characteristics of the icebergs, both drift and deterioration prediction accuracy confidence levels are still low in the short term of 5 days or less and even lower in the long term of 2 weeks. Operationally, if the so called "estimated" iceberg size and shape obtained from presently available remote sensing techniques are used, it would appear that the drift and deterioration prediction confidence levels in the short term must be handled using large error estimates, but in the long term these confidence levels and the error estimates are completely unknown.

Data accuracy and availability impacts the degree to which drift and deterioration model refinements may be necessary. At present, the drift model depends critically on the estimated size and location of the iceberg. The currents and wind in the vicinity of the iceberg as acting on the characteristic mass and shape of the iceberg determine the drift and new position. The size category changes based on a resighting, and when indicated by the deterioration model. The only iceberg characteristic involved in the deterioration model is the waterline length, which is assumed to be the maximum for the given size category (even if an observed waterline length is reported). However, a 50% error in waterline length for a nominal 100 m iceberg results in a maximum 11% error in the wind forced convection melt which comprises less than 15% of the total melt. Given the other system errors, this apparently large error has relatively no impact on the deterioration model result.

7.0 Personnel Requirements, Organization, and Workload

7.1 Personnel.

The personnel allowance for the IIP is indicated in Table 6. The total allowance is 16 officer, enlisted and civilian personnel. The officers assigned to the IIP typically have advanced degrees in oceanography. Senior officers generally have had a previous assignment at the IIP or have had an otherwise close working relationship with the IIP. The average officer and enlisted tour is three years.

Table 6: IIP Personnel Allowance and Functions.

Billet	Responsibility	Allowance
CDR (O-5)	Ice Patrol Commander	1
LCDR (O-4)	Deputy Commander Senior Watch Officer Senior Ice Observer	1
LT (O-3)	Ice Patrol Officer Duty Watch Officer Senior Ice Observer	1
LT (O-3)	Science Officer Duty Watch Officer Senior Ice Observer	1
MSTCS (E-8)	Duty Watch Officer Senior Ice Observer	1
MST1 (E-6)	Duty Watch Officer Senior Ice Observer	2
YN1 (E-6)	Administration	1
MST2 (E-5)	Watchstander, Ice Observer	3
MST3 (E-4)	Watchstander	3
Civilian (GS-14)	Chief Scientist	1
Civilian (GS-11)	Computer Specialist Computer Systems Manager	1

The knowledge requirements for the IIP are unique among Coast Guard commands. Assignment and rotation of duty watch officers/senior ice observers to the IIP by Commandant requires careful attention because of the training and qualification process. While it may be possible to qualify an officer as an SIO during one or two ICERECDETs, it may require as many as four ICERECDETs to similarly qualify a new enlisted SIO. Qualifying as a DWO is generally easier because there are many people nearby who can assist with any problem. The DWO performs the quality assurance checks described above as well as makes resighting decisions before updating the DMPS. Although there are many tasks to be performed and there is a large volume of data to be processed during the height of the ice season, the Daily Watch Checklist provides an excellent guide. The SIO's responsibility on an ICERECDET is partly administrative (planning the patrols, preparing messages) and partly an art that requires experience to develop the expertise to observe and interpret the radar images. There is no comparable checklist to develop the expertise to identify and classify ships and icebergs with the existing SLAR and FLAR sensors. It requires experience that can only come with repeated observations and time.

Unit training for ice observation and watchstanding procedures is an ongoing activity. Weekly training takes place throughout the ice season with heavier levels near the beginning of the season. During the off-season, it is necessary for the MSTs to engage in rate training, which often requires periods of TAD at a Marine Safety Office, in order to develop the skills necessary for advancement in rate. The assignment at IIP is clearly an out of rate assignment with respect to the skill levels required for the rate.

7.2 Organization.

Because of the small size of the unit, there is no complex organization. However, there are numerous duties assigned to individuals. The key assignments are indicated in Table 1. The most important organizational concerns involve the actual operation of the IIP on a daily basis. CIIP has developed a comprehensive set of instructions which direct the day to day activities of the IIP. These directions are contained in CIIPINST M3120B, *Standing Orders for IIP Operations Center Duty Personnel* and are not repeated here. The essential watch organization is described in section 3.6 above.

The watch procedures are directed at preparing the IIP products as described in previous sections. A copy of the Daily Watch Checklist for the ice season (Appendix N in CIIPINST M3120B) is included in this report as Appendix B.

7.3 Workload.

7.3.1 *Watchstanding.* When an ICERECDET is deployed, three watchstanders and four Duty Watch Officers (not including the Deputy Commander) are available for watches. This leads to a one in four rotation for DWOs and an one in three rotation for watchstanders. Rotations are necessarily shortened when a DWO or WS is in training. During the ice season, the opportunity to take leave is severely restricted, both as to the number of personnel on leave simultaneously and to the amount of leave taken (maximum of one week). Duty personnel will typically spend about 10-12 hours in the IIP Operations Center and be available by telephone or beeper during the remainder of their 24 hour watch. Watchstanding requirements are relaxed during the off-season, but leave and training absences continue to restrict the ability to reach a one in six watch rotation.

7.3.2 *ICERECDET deployment.* As indicated above, an ICERECDET generally deploys for approximately nine days during a fourteen day period. One SIO and three or four watchstanders constitute the IIP staff component of the ICERECDET. Under good weather conditions, five patrols will be conducted during the deployment. The duration of a typical patrol is 8-10 hours long. The ICERECDET personnel rotate among the SLAR, FLAR, and visual observer functions. The SIO oversees the operation and makes the determinations as to the identification/classification of radar targets. Present policy allows one day of compensatory time following the return from an ICERECDET deployment.

7.3.3 *Off-season IIP requirements.* When the ice season officially ends, there is a significant requirement for evaluation and analysis of the past season as well as preparation for the upcoming ice season. The officer and civilian personnel listed in Table 6 have very specific responsibilities. Enlisted personnel are assigned to assist in a major portion of the data analysis. The magnitude and quality of the off-season work is reflected in the various analyses included in the C-188-NR series, other related research reports, and papers presented at professional meetings. The majority of the seminal analyses of ice movement and management in the vicinity of the trans-Atlantic shipping lanes has been accomplished by IIP personnel or IIP supported/directed efforts.

7.3.4 *Other marine science activities.* A total examination of IIP personnel workload requires some identification of the level of work required to support other programs. MST Rate Training supports the Marine Safety program. Because the Coast Guard no longer has an oceanographic unit, a number of functions for other programs requiring oceanographic expertise are occasionally assigned to the IIP. Marine science support to other missions includes quality control of the FNMOC Gulf Stream current product that is entered into the Coast Guard CASP program, serving as a point of contact for Self Locating Data Marker Buoy (SLDMB) data in support of Coast Guard Search and Rescue, pollution drift support, and special projects requiring oceanographic expertise. It is estimated that an average of 5-10% of the IIP personnel resources are used on non-IIP marine science activities.

7.4 Relationships with other Agencies.

The acquisition and distribution of ice information as described in previous sections requires that IIP establish and maintain close working relationships with a number of organizations and agencies. A key liaison is with the Atmospheric Environment Service of Canada which operates ICEC. The existing computer system at IIP was initially designed for their use and the DMPS is an adaptation of the BAPS program. This close coordination has substantially reduced the development costs for IIP equipment and software. In addition, AES provides important iceberg sighting information to the IIP. Similarly, the Canadian Department of Fisheries and Oceans, through its contracted service with Atlantic Airways, provides substantial sighting data to IIP. Other major external relationships include the Navy/NOAA Joint Ice Center, FNMOC, and NLMOC. The primary nature of these relationships involves the acquisition of environmental data used in the drift and deterioration models. The nature of each specific relationship is dictated by the purpose of the activity, often requiring frequent contact and facility visits.

The IIP maintains significant liaison with numerous communications facilities, most of which are listed in section 2.5. The most important relationship is with Coast Guard

Communications Station Boston NMF/NIK which broadcasts both the facsimile chart and the ice bulletins.

Key internal (Coast Guard) relationships include the First Coast Guard District, the Atlantic Area Operations Staff, the Program Manager, and Coast Guard Air Station Elizabeth City. A very important internal relationship is with the Coast Guard Research and Development Center. The IIP relies on the R&DC for a significant amount of personnel and administrative support, including procurement activities. The IIP is a tenant in the R&DC facility with housekeeping responsibilities only in the designated office spaces. Beyond this physical support, the R&DC has developed a significant expertise in areas relevant for the IIP through its close working relationship over the years. Maintaining this liaison with the R&DC and its key personnel contributes to the effectiveness of the IIP operation.

8.0 Cost and Reimbursement Considerations.

The purpose of this section is to present an initial overview of IIP costs and the presently used accounting procedures. It is based primarily on the information obtained during the IIP site visit. A more detailed cost analysis is part of the remainder of Phase 1 and Phase 2 of the IIP Mission Analysis.

8.1 Cost Accounting.

As discussed in section 3.2, Regulation 6 of Chapter V of SOLAS '74 provides for participating governments to share the cost of operating the International Ice Patrol. The managing Government (the United States) must provide an annual accounting of costs and identify the proportionate share for each contributing government. In order for the Coast Guard to provide a cost accounting to the Department of State, CIIP is tasked by Commandant (G-NIO) letter 3145 dated October 11, 1988 to provide a cost breakdown for the ice season. The cost report includes aviation fuel costs, lodging and travel costs for IIP personnel and travel costs for AIRSTA personnel, and a number of expense categories: leased transportation, leased space, deicing, drift buoys, drift buoy data processing, CG-188-NR printing, IIP Operations, and IIP Research.

These costs are submitted to the financial management division at Coast Guard headquarters. To the IIP reported costs are added personnel costs, maintenance and operational support of the aircraft, and a general administrative expense. The costs are then sent to the Department of State where they are prorated for the contributing governments.

It is illustrative to track the cost generation, particularly to identify the cost drivers and also to the activities for which cost data is available in anticipation of an activity based costing scheme. The IIP reported costs are included in Table 7.

Table 7: IIP Reported Costs, 1993.

Item	Category	Cost
1	HC-130H flight hours	586.6
2	HU-25B flight hours	63.6
3	HC-130H fuel costs	420,795
4	HU-25B fuel costs	18,605
	Costs:	
5	Contract Lodging	49,896
6	IIP Travel	44,593
7	CGAS E City Travel	87,000
8	CGAS Cape Cod Travel	7,500
	Expenses:	
9	Leased space/flight services (E City)	35,293
10	Leased space/flight services (Cape Cod)	427
11	Deicing	0
12	Air-drop packages for drift buoys	16,853
13	Satellite tracked buoy data processing	25,834
14	IIP Bulletins/Public Affairs	1,644
15	IIP Operations	18,119
16	IIP Oceanographic Cruise	10,245
17	Maintenance services for equipment	39,700
	Other:	
18	Telex charges (CGDONE COMCEN)	9,000
19	SLAR film (E City)	14,000
20	SLAR film (Cape Cod)	345
	TOTAL	$799,851

Item 16 is the IIP direct cost associated with an evaluation of the AN/APS-137 FLAR using USCGC BITTERSWEET for ground truth. BITTERSWEET was on patrol during 8-23 July 1993. It is not known to what extent that patrol effort was committed to the FLAR evaluation versus other oceanographic projects which may or may not have been IIP related. This analysis has not yet identified the specific function for which item 16 was incurred. During the 1993 season, ten WOCE drifter buoys were deployed. IIP estimates a data processing cost of $4,000 per buoy per season, and an air-drop package cost of $400 per buoy. Item 12 appears to be larger than expected. Item 13 is smaller than expected, but actual data processing is a function of the buoy survivability and time in the area of operations. Finally, item 19 is simply a cost recovery. The film is no longer made by Kodak and a supply is on hand at CGAS Elizabeth City. One item that appears to be missing from Table 7 is the actual cost of the WOCE buoys.

The flight hours reported in items 1 and 2 include all flights, including patrol, transit, logistics, and research. Subsequent to submission of the cost report, flight hours were adjusted to a total of 667.0 (603.4 + 63.6). Of that total, 435.3 hours (65%)

involved iceberg reconnaissance patrol. These hours were flown in 75 patrol sorties from January through July, 1993.

Adding personnel, maintenance, support, and administrative costs to these reported costs results in the program costs in Table 8. Item numbers from Table 7 are shown in the right-hand column to indicate the source of the constructed costs.

Table 8: Constructed IIP Costs, 1993.

Cost Category	Cost	Items
Aircraft costs:		
Personnel	539,200	
Fuel	439,200	3, 4
Maintenance	556,200	
Operational support	473,700	
Total aircraft costs	2,008,500	
Office of CIIP:		
Personnel	386,400	
Travel and lodging	94,500	5, 6
Leased property	35,700	9, 10
Total office costs	516,600	
Other costs:		
Buoys	16,900	12
Airborne sensor evaluation	10,200	16
Radar film	14,300	19, 20
Miscellaneous	76,200	13, 14, 17, 18
Total other costs	117,600	
Administrative expense	602,600	
TOTAL COSTS	$3,245,300	

All of the cost items in Table 7 appear to be accounted for in Table 8 except for item 15, IIP Operations ($18,119) and the AIRSTA travel costs ($94,500). It is assumed that those travel costs are embedded in the operational support of the aircraft in Table 8. It also appears that no cost was included for CGC BITTERSWEET's participation in the oceanographic cruise which was clearly an IIP activity.

Table 8 presents some interesting situations. It is not clear why there is such a difference in the personnel costs. There were 12 ICERECDET deployments of approximately nine days (11 days for CGAS Elizabeth City flight crews of 11/12) over a seven month period. The associated personnel costs are 40% higher than the personnel costs of the 16 person complement of the IIP. In this analysis, the IIP personnel costs are prorated over the duration of the "official" ice season. In the future, the entire annual cost will be assigned. It is not known whether the AIRSTA personnel costs cover only a portion of the year.

Finally, Table 9 presents comparative total cost data for 1991-1993. The three years are compared in Figure 11 and it is clear that there is little change among the years.

Table 9: Comparative IIP Costs, 1991-1993.

Cost Category	1991	1992	1993
AC Flight Hours	601.5	612.5	650.2
AC Costs	1,839,800	2,026,000	2,008,500
CIIP	518,700	545,900	516,600
Computer system/DMPS	314,300	0	0
Other costs	95,900	108,700	117,600
Administrative Expense	533,500	607,800	602,600
Total	$3,302,300	$3,318,800	$3,245,300

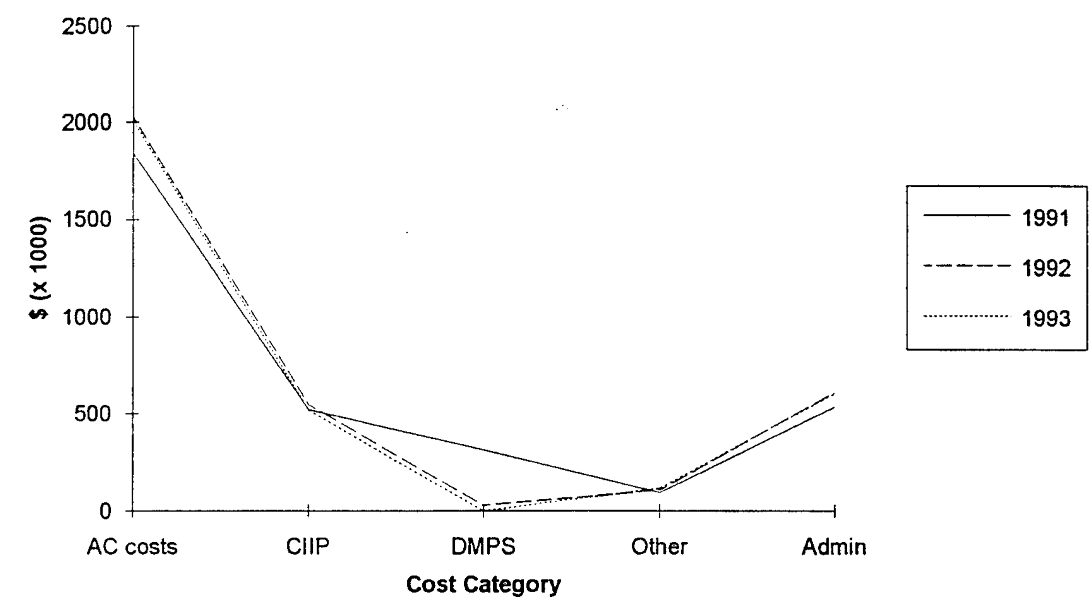

Figure 11. Comparative IIP Costs, 1991-1993.

8.2 Reimbursement of Ice Patrol Costs.

In 1993, 17 nations were contributing governments who had agreed to share the cost of operating the International Ice Patrol. The contributing governments are: Belgium, Canada, Denmark, Finland, France, Germany, Greece, Italy, Japan, Netherlands, Norway, Panama, Poland, Spain, Sweden, the United Kingdom, and the United States. The cost share is prorated based on tonnage as specified in Regulation 6 of Chapter V, SOLAS '74. The Coast Guard, through the International Affairs Director at headquarters, delivers the cost to the Department of State. Tonnage estimates are obtained and cost shares are presented to the contributing governments. For 1991, the United States' share was $535,120, or approximately 16% of the total cost of the IIP operation. The balance of $2,767,080 is billed to the other contributing governments. Payments are returned to the general treasury, but are not considered a credit for the Coast Guard. The United States share is the largest of any government, followed by Norway at $500,564 (15%). Interestingly, in 1991, Canada's cost share was $1,668. More detail needs to be obtained on the reimbursement procedures and status of payments of billed costs. It is interesting to note that in 1993, IIP received ice reports from 299 ships from 45 different countries. It appears that more countries are operating in the IIP area and presumably benefiting from the IIP service without contributing to its support.

8.3 Budgeting.

The IIP Mission Analysis must develop an understanding of how IIP activities are budgeted and how the appropriated funds are allocated to various commands and functions to accomplish the program objectives. Any modification to the accounting scheme must be able to be related to actual activities that were conducted and hopefully budgeted. This understanding and a related accounting approach will be developed during the remainder of Phase 1. At the time of this interim report, the Program Manager is developing some of this information.

8.4 Activity-Based Cost Accounting.

For purposes of evaluating alternatives, an activity-based costing approach offers a number of advantages, the most valuable of which is the ability to assess cost impact at various activity levels. Typically, activity-based cost accounting is used to identify cost drivers and focus data collection around those drivers. This is often used as a basis for allocating overhead to the various activities. Such an overhead allocation is not an issue within the program.

For the IIP, identifying major activities is rather straightforward. The usual difficulty is the allocation of costs for entities that are supporting more than one activity. A simple model for the IIP would have four activities: collecting environmental data, conducting iceberg detection activities, estimating iceberg positions and the danger to the mariner, and disseminating this information. For example, an activity-based approach for the iceberg detection activity would include items such as the travel costs, leased space at the air stations, and SLAR film expense along with some portion of the personnel expense and administrative expense in addition to the direct aircraft costs identified above. The possibility of using such an approach remains to be explored.

9.0 IIP Mission Performance Measures of Effectiveness.

9.1 Background and Program Performance Measures.

The Coast Guard has a long history of innovation in program management and identifying performance measures. The 1993 Government Performance and Results Act provides a sharper focus by emphasizing "results, service quality, and customer satisfaction" and mandates program actions by Federal agencies. To meet this emphasis, an agency must identify and measure *outcomes* that permit an evaluation of how well a program is performing in relation to its goals and objectives. Outcomes are much more difficult to define and measure than are *outputs* which address the amount of work accomplished or the quality of the processes which result in that output. Program performance measures must be results-oriented rather than process-oriented and must address how well the program achieves its overall objectives.

The difficulty in applying this approach is the identification of appropriate objectives and outcome measures that characterize those objectives. Identification of inputs and outputs is often easier. A fundamental tenet in quality and continuous improvement is that process improvement will ultimately result in program performance improvement. This "leap of faith" enables organizations to focus on processes, which are easier to measure, and actually find overall performance increasing, particularly in manufacturing sectors. The additional focus on the customer leads to a greater emphasis on product design so that customer needs are built in from the design stage. The focus on outcomes no longer permits the "leap of faith," but demands measures that address the final results. Another factor affecting the identification and selection of outcome measures is the potential interaction with the ultimate customer and the operating environment. For example, with the IIP, the severity of the season will impact the resource usage and may affect the performance measure. Typically, it would be beneficial to normalize or standardize to account for external variability.

For the IIP, a review of the annual reports (CG-188-NR series) clearly indicates that the focus is on inputs and outputs. Some outputs (e.g., ICERECDET sightings) are actually inputs to the models which result in other outputs (e.g., ice bulletins and facsimile charts). The ice bulletins and facsimile charts are simply means of communicating another output, the Limits of All Known Ice, which is an operational description of the danger of the ice field to mariners. A number of efficiency concerns have been applied to these outputs such as reducing the cost of producing them. Nonetheless, these would appear to fall short of being true outcome measures.

9.2 Proposed IIP Mission Performance Measures of Effectiveness.

9.2.1 *MOE Workshop*. A workshop to develop mission performance measures of effectiveness (MOEs) for the IIP was conducted on March 14-15, 1994 in Groton, CT. Participants in the workshop included a number of IIP Commanding Officers (present and past), the IIP Chief Scientist, the Program Manager, and a number of R&D Center researchers. The results of the workshop have been presented to the Program Manager, but have not yet been accepted as policy.

The proposed mission and goals of the IIP developed at the workshop were presented in section 3.6.1, but the key elements as pertaining to preventing ship-iceberg collisions are repeated below.

Proposed Mission of IIP:

- Provide International Ice Patrol Service to the mariner.

Proposed Goals:

- Warn mariners of the limits of iceberg danger in the vicinity of the Grand Banks.
- Determine the limits of iceberg danger throughout the ice season.

Note that the two goals are not independent. In order to warn the mariner of the iceberg danger (first goal), the IIP must first know what that danger is (second goal). One ambiguity arises in that the first goal has no time domain whereas the second goal is limited to the ice season. It is not known whether the ice season is intended to be the "official" ice season, or whenever there is an ice danger present.

9.2.2 *Proposed program objectives.* The Coast Guard Planning Manual defines a program objective to be "a statement which describes an outcome or result of program activities or processes." The program objectives provide the meaningful target toward which the measures of effectiveness are addressed. The MOE Workshop participants developed the following six program objectives to support the Goals and Mission of the IIP.

Proposed Program Objectives:

O.1 Reduce the number of icebergs detected outside of the Limits of All Known Ice.

O.2 Increase sources of ice information

O.3 Improve the accuracy of defining the Limits of All Known Ice

O.4 Provide routine ice information at 0000Z and 1200Z and safety broadcasts within two hours of notification of an iceberg or radar target found outside of the Limits of All Known Ice.

O.5 Have no collisions outside of the Limits of All Known Ice.

O.6 Reduce the cost of defining the Limits of All Known Ice.

There are some relationships among the objectives that should be explored. For example, there will be no collisions outside of the LAKI (O.6) if there are no icebergs detected outside of the LAKI (O.1) because the LAKI are defined with 100% accuracy (O.3). Objective 2 implicitly assumes the present system or something similar. If an entity was available that would provide 100% accurate information on the location and characteristics of all ice on a continuous basis, there would be no need for other sources of information.

9.2.3 *Proposed IIP mission measures of effectiveness.* Eight measures of effectiveness were developed at the workshop.

Proposed IIP MOEs:

- M.1 Difference between the predicted LAKI and the actual LAKI normalized by the length of the limits.
- M.2 Number of icebergs reported outside of the LAKI.
- M.3 Number of ship sighting reports.
- M.4 Number of calls for the facsimile chart.
- M.5 Number of ice information sources obtained.
- M.6 Number of times broadcast objectives were not met or the difference in time between the actual time to broadcast and the standard time specified.
- M.7 Customer satisfaction measure: conduct valid user surveys at regular intervals.
- M.8 Cost efficiency: total cost to perform mission/normalization factor (to account for season severity)

The relationships among the proposed objectives and MOEs perceived by the workshop participants are illustrated in Figure 12.

		Measures of Effectiveness							
		Prediction error	Icebergs outside LAKI	Ship sightings	fax calls	Info sources	Broadcast failures	Customer satisfaction	Cost efficiency
	Reduce icebergs detected outside LAKI		X						
	Increase sources of ice info			X					
Objectives	Improve accuracy of LAKI	X							
	Provide routine and safety ice info				X		X		
	No collisions outside LAKI								
	Reduce cost of defining LAKI								X

Figure 12. Proposed IIP Objectives/Measures of Effectiveness Relationship Matrix.

Figure 12 indicates that two MOEs do not support any objective and one objective is not supported by any MOEs. This suggests that further refinement of the proposed objectives and measures of effectiveness is in order.

9.3 User Satisfaction Surveys.

One proposed measure of effectiveness is periodic user surveys to determine their satisfaction with the IIP service. In May, 1993, IIP sent a survey to 202 shipping companies whose vessels submitted ice reports during the 1992 ice season. The questionnaire included seven open-ended questions primarily regarding the use of IIP products. As of November, 1993, 26 companies had responded (13% response rate). Of the respondents, 84% always use IIP products with nearly half using the bulletin and facsimile chart, nearly a quarter of the respondents never use the fax chart, almost half use the bulletin to draw the limits, 60% had never seen an announcement of the IIP service, 76% said the IIP products meet their need (the other 24% did not respond), 24% would like to see the products broadcast more often, and half of the respondents do alter their course based on ice warnings. Most comments provided were positive. Negative comments involved NAVTEX and a need for more detail (iceberg positions). This small survey suggests that IIP is performing a valuable service and doing a good job at it.

10.0 Summary of Current Operations and Procedures

The International Ice Patrol has had the advantage over the years of working with a fairly stable environment and having access to increasingly capable technologies to understand and observe that environment and to accomplish its mission. The basic mission is unchanged since the inception of the ice patrol service. The IIP operationalizes the mission as **determining the Limits of All Known Ice along the southeastern, southern, and southwestern edge of the ice region and publishing that information to mariners in a timely fashion**. This mission involves data and information acquisition, processing, and distribution--finding out where the ice danger is for trans-Atlantic shipping and telling the mariner so as to prevent ship-iceberg collisions.

The IIP effectively captures available data on iceberg and radar target sightings from other organizations. Because of the importance of high quality information along the LAKI, the IIP deploys an ICERECDET to provide information on icebergs and radar targets in that area. The primary surveillance device is the AN/APS-135 SLAR augmented with the AN/APS-137 FLAR mounted on an HC-130H aircraft which is capable of conducting 7-8 hour sorties. Present assignment of aircraft effectively limits searches of particular geographic regions to once every two weeks. Limitations and possible methods for performance improvement have been identified for both radars in this initial analysis. One important issue which has not been addressed by the IIP and should be addressed is the frequency of revisit to an area. The detection this past year of a very large tabular iceberg significantly outside of the LAKI clearly indicates that the existing system is not perfect. A probability analysis incorporating the actual search effectiveness for SLAR searches and revisit frequency should be conducted.

A major argument for the reduced frequency of visit is the use of iceberg drift and iceberg deterioration models. While the models appear to be conceptually sound, they depend heavily on environmental data and iceberg characteristics that may have significant estimation errors. Some limited sensitivity analysis has been done on the models, but a full sensitivity analysis does not appear to have been accomplished. Moreover, it does not appear that the interaction between the models has been investigated. This requires incorporation of errors introduced/eliminated by means of the resight analysis. Before any significant expense be incurred to identify/acquire higher quality environmental data, such an analysis will provide a base for where those efforts should be emphasized.

The IIP operation is well managed. Fairly detailed procedures are established and documented. Personnel are well-trained and knowledgeable. The new (2 years) computer system greatly facilitates the processing of data. The electronic file interchange procedures in use permit effective quality assurance checks of input data. The major equipment deficiency is the processor speed on the main computer system. Personnel levels recently have been reduced to allowance levels. This appears to be adequate for continued operation, although there is little room for personnel vacancies. Costs are driven primarily by the ICERECDET which accounts for nearly 85% of the total cost of the IIP that is billed to the contributing governments.

The critical factor which is well known, confirmed by this detailed review of present IIP operations, is the role of detection. Much of the effort in the IIP has been to compensate for the deficiency in detection. The iceberg drift and deterioration models, the identification and collection of timely, accurate environmental data, and the efforts to identify current fluctuations and use realtime drifter data are meant to assist in predicting the position of icebergs based on initial positional information of unknown quality. Primary emphasis in this analysis will be on identifying alternative means of detecting, identifying, and classifying icebergs. Unless that can be done on a continuous basis, some prediction capability will be required. Although a key assumption at the kick-off meeting was that the Coast Guard will continue to manage and conduct the Ice Patrol, we will explore other possible arrangements as management alternatives.

Part of the analysis will further review the proposed MOEs. These may or may not be used in the evaluation of the alternatives to be studied in detail. That evaluation will be conducted in mid-October.

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Appendix A
Alternate Summary of the Results of 1991 IIP FLAR Study
(Ezman *et al.*, 1993)

As indicated in Table A.1, the number of detections was substantially larger than truth (visual) data for both systems. In preparing summaries in Ezman *et al.*, (1993), a conservative approach of including only the visual truth data was used. Comparison of FLAR and SLAR data reveals that FLAR detection and identification probabilities may be overestimated, since FLAR detected 79 objects of either type per sortie, while SLAR detected 102, suggesting a detection probability of approximately 78% rather than 88% as estimated in the study. SLAR overreporting is assumed to be at least offset by FLAR detected objects that were not detected by SLAR.

Table A.1: SLAR/FLAR Comparison Data from Ezman *et al.* (1993).

		Icebergs and Radar Targets			Ships		
Date	Flight	Truth	FLAR	SLAR	Truth	FLAR	SLAR
May 14	1	5	8		1	7	
	2	5	10		1	9	
	3	5	9		1	4	
	4	5		25	1		2
May 15	5	6	18		4	2	
	6	6	13		4	2	
	7	6	8		4	11	
	8	6		14	4		5
May 16	9	3	11		1	10	
	10	3	6		1	11	
	11	3	4		1	17	
	12	3		21	1		7
May 21	13	3	14		1	2	
	14	3	11		1	2	
	15	3	25		1	2	
	16	3	13		1	2	
	17	3		14	1	2	14
FLAR Total		54	155		21	81	
SLAR Total		17		74	8		28

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Appendix B
CIIP Daily Watch Checklist

DAILY WATCH CHECKLIST - ICE SEASON

______	______	______
Watch Officer	Watch Stander	Date Assumed Watch

A. Items not to be done everyday are indicated by notations in parenthesis. The day of the week indicated is the actual day the event occurs.

As an aid to completing the watch, chapter and subsection references to the Computer Documentation and/or Watch Stander's Guide are indicated in bold face in parenthesis with each applicable item in the checklist. References accompanied by **WG** indicate the reference is from the Watch Stander's Guide. All other references are from the Computer Documentation.

B. A checklist is to filled out daily and filed. Items not applicable shall be marked as N/A.

C. Watch Checklist.

1. ______ Watch officer QA review all outgoing products of the previous watch.

2. ______ Review morning messages.

3. ______ DWO and watchstander review Hotword Book and DMPS Problem Log entries since last standing watch.

4. ______ Receive and process ARGOS buoy data. **(13: B-D)**

5. ______ (When buoys in OPAREA) QC buoy data on PC. **(14: C-G)**

6. ______ (TUE when buoys in OPAREA) Transfer buoy data to DMPS. Perform currents/ interpolate phase of the current update program. Delete data points as required and reprocess. **(15: C 1-6)**

7. ______ (TUE when buoys in OPAREA) Perform currents/generate phase of the current update program. Delete data points as required and reprocess. **(15: C 7-12)**

8. ______ (MON when buoys deployed) Prepare and fax buoy trajectory charts to NAVPOLAROCEANCEN, METOC and NOAA/NOS. Post charts in display case. **(18: F)**

9. ______ (FRI) Exercise the DSRTs.

10. ______ Review and approve FAX chart.

11. ______ Send FAX chart via telecopier to NAVEASTOCEANCEN, DMAHTCNAVWARN, NAVPOLAROCEANCEN, and VON St. Johns. **(WG: App. F)**

12. ______ (MON and FRI) Send FAX chart and latest prognosis chart to LANTAREA (Aoc) and (Aoo) and G-NIO-3. **(WG: App. F)**

13. ______ Conduct drum scanner line check with COMMSTA Boston no later than 1530Z. **(WG: App. G)**

14. ______ Transmit the FAX chart at 1600Z.

15. ______ (Once per week on required day) Change Datacryptor codes at 1700Z.

16. ______ Conduct DMPS system back ups. **(12: B)**

17. ______ File Ocean Features Analysis from NOAA. File copy in Watch Officer notebook in Laptop computer bag.

18. ______ Transmit the FAX chart at 1810Z.

19. ______ (MON/WED/FRI) Download and then conduct Quality Control of FNOC Gulf Stream product. **(17: B-E)**

20. ______ Check DIALCOM prior to doing afternoon FNOC product capture for sighting information. **(App. G)** If present, transfer sighting message(s) to VAX. **(4: B)**

21. ______ Update Sea Ice Limit file from AES data. **(8: B)**

22. ______ Check messages. Convert all sighting reports to an SBM on the VAX. **(4: C)**

23. ______ Download afternoon wind product from FNOC to PC. **(6: B)**

24. ______ Create updated wind files for the PC model. **(6: C 1c)**

25. ______ Transfer the winds to the VAX and quality control. **(6: C 2)**

26. ______ As required edit, SBMs, plot the SBM, and create the MM and RMM. **(4: D)**

27. ______ Merge all sighting data received into the data base before doing prognosis runs for evening products. **(5: D and F)**

28. ______ Do afternoon 01 0000 prognosis run. **(7: C)**

29. ______ Create updated Limits. (8: C-D) Plot prognosis run file with new Limits and sea ice edge attached.

30. ______ Transfer 0000Z prognosis alphanumeric report, BERGLIMIT, ICELIMIT to PC. Prepare 0000Z products (Bulletin and NAVTEX), transmit, and receive acknowledgments. (9: B-C)

31. ______ Do afternoon 01 1200 prognosis run. (7: C)

32. ______ Create updated Limits. (8: C-D) Plot prognosis run file with new Limits and sea ice edge attached.

33. ______ Transfer 1200Z prognosis alphanumeric report, BERGLIMIT, ICELIMIT to PC. Prepare 1200Z products (Bulletin and NAVTEX), transmit, and receive acknowledgments. (9: B-E)

34. ______ Download afternoon wave/SST product from FNOC to PC. (6: B)

35. ______ Quality control wave data on PC. Transfer SST and wave data from PC to the VAX. (6: C) Quality control SST data on the VAX. (6: D)

36. ______ Transfer the SST/Wave/BERGLIMITS to AES directory, verify successful ftp. (18: E)

37. ______ Conduct PC System Backups. (12: C)

38. ______ Run UPDATE to conduct an analysis run. (7: B)

39. ______ Send via fax the 00Z and 12Z bulletins to Ice Operations Dartmouth and Ice Operations St. Johns. (WG: App. F)

40. ______ Check safe and initial sheet.

41. ______ Fill paper tray on Xerox Facsimile machine.

42. ______ Advise D1 OPCEN when leaving for evening.

43. ______ Turn on OpCen telephone answering machine.

NEXT MORNING

44. ______ Check DIALCOM prior to doing morning FNOC product capture for sighting information. (App. G) If present, transfer sighting message(s) to VAX. (4: B)

45. ______ Check messages. Convert all sighting reports to an SBM on the VAX. (4: C)

46. ______ Download morning environmental products from FNOC to PC. (6: B)

47. ______ (WED; when buoys in OPAREA) **BEFORE TRANSFERRING FNOC DATA TO VAX AND DOING MORNING RUNS**, printout current update reports and produce current field plot. Conduct quality control of produced current vectors. (15: C 13-23)

48. ______ Create updated wind files for the PC model. (6: C 1)

49. ______ Quality control the wave data on the PC. Transfer the wave data to the VAX from the PC. (6: C 2)

50. ______ Transfer the winds to the VAX and quality control. (6: C 2)

51. ______ Run UPDATE to conduct an analysis run. (7: B)

52. ______ Transfer the wave information to AES. Verify delivery. (18: E)

53. ______ Delete icebergs based on deterioration results. (melt) (5: E)

54. ______ Merge all sighting data received into the data base before doing prognosis runs for morning products. (5: D and F)

55. ______ Do morning 00 1200 prognosis run. (7: C) Update Limits. (8: C-D) Plot prognosis file with updated limits and sea ice edge data attached.

56. ______ Produce FAX chart. Use same Area of Many Bergs as evening 1200Z bulletin. (10: B-E)

57. ______ (I/S: 14th and next to last day of month). Produce graphic files for use in the production of the annual bulletin. (18: D)

58. ______ Produce 01 0000 prognosis run. (7: C) Update Limits. (8: C-D) Plot prognosis file with updated limits and sea ice edge data attached.

59. ______ Produce standby products for 0000Z bulletin. (9: B-C)

60. ______ Transfer 0000Z prognosis alphanumeric report, BERGLIMIT, ICELIMIT from the VAX to the PC. (9: D)

Comments: ____

____