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MISSION ANALYSIS SUPPORT FOR USCG INTERNATIONAL ICE PATROL

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16. Abstract

This report summarizes the Cost and Operational Effectiveness Analysis (COEA) of feasible new alternatives in management, technology and operations for the International Ice Patrol (IIP). Alternatives were restricted to existing technology and proven and acceptable management procedures. Existing and planned satellite-based surveillance systems will have little value for detecting medium and small sized icebergs, the most dangerous ones to shipping. A more powerful modern computer and data processing system will provide the capacity required for IIP to reliably track an increased number of icebergs and more accurately forecast the ice limits. Failure to upgrade the APS-135 SLAR (Side Looking Airborne Radar) with a new digital processor incurs considerable cost and performance risk. IIP would have to fly approximately 200 additional hours ($890,000) with a less capable radar to achieve the same level of mission performance. The new processor may reduce flying hours considerably if it allows the full SLAR sweepwidth of 84 NM to be used for searching. IIP is well run, from both an operations and program management standpoint. Actual costs of operating the IIP program have been under-reported in the past. All costs that were attributable to the IIP program, such as administrative costs, were not identified. Aircraft surveillance is the major component (approximately 75%) of the total program cost of the International Ice Patrol. The majority of reported costs for IIP are being recovered from the contributing SOLAS signatory nations. Ice Services Branch, Environment Canada provided cost estimates for Canadian management and operation of the IIP. This may reduce the total cost of the Ice Patrol to the international community but may not save money for the Coast Guard unless billets (people) are reduced or aircraft are laid up (which has considerable effect upon other missions). The U. S. Government would then be responsible for the share of IIP funding agreed to in SOLAS. Two new operational alternatives that may improve IIP performance are being developed, a more accurate method to predict iceberg drift that uses error ellipses (probability) and an operational aid that would help to route IIP flights. Both of these alternatives need to be developed further and then evaluated.

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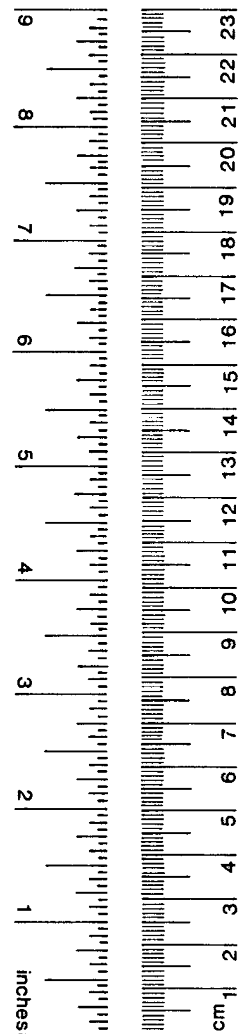
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

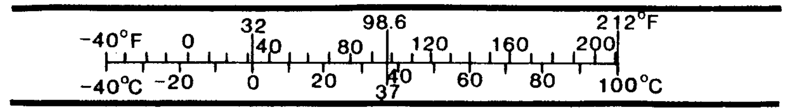
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	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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ADMINISTRATIVE INFORMATION

This report summarizes the project 'International Ice Patrol Mission Analysis Support' (9310), which was managed by the Systems Analysis Branch at the Coast Guard R&D Center. A study was done in response to a request (Reference 1) by the Ice Operations Division (G-NIO) of the Office of Navigation in Coast Guard Headquarters, to analyze new management, technological and operational alternatives for the International Ice Patrol. A contract (DTCG39-94-C-E00085) was awarded to EER Systems Corporation of Vienna, VA, to perform the detailed analyses which are documented in a series of reports (References 2-15). In addition, two new operational alternatives were developed for the International Ice Patrol. A Military Interdepartmental Procurement Request (Z51100-4-E00469) was awarded to the Operations Analysis Department of the Naval Postgraduate School, Monterey, CA to perform this additional work which is documented in Reference 17.

Organizations that provided information for this study included:

<u>U. S. Coast Guard</u>

USCG Headquarters offices, G-CBU, G-NIO-3, G-EAE, and G-OAV (Washington, DC)
International Ice Patrol (Groton, CT)
Atlantic Area, Aoa (Governor's Island, NY)
Air Station Elizabeth City (Elizabeth City, NC)
Research and Development Center (Groton, CT)

<u>Other U. S. Government</u>

National Ice Center, USN & NOAA (Suitland, MD)
Office of Maritime and Land Support; Dept. of State (Washington, DC)

<u>Canadian Government</u>

Ice Services Branch, Environment Canada (Ottawa, Ontario)

Points of contact for additional information about the study or the new operational alternatives are:

<u>Sponsoring Office</u>

G-NIO-3; Mr. Larry Jendro; 202-267-1457

<u>Managing Office</u>

R&D Center; Mr. Clark Pritchett; 860-441-2653

<u>Operating Office</u>

International Ice Patrol; Dr. Don Murphy; 860-441-2635

<u>Analysis</u>

EER Systems Corp. (University of Central Florida);
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<u>New Alternatives</u>

NPS Operations Analysis Dept.;
Prof. Alan Washburn; 408-656-3127
Prof. Rob Dell; 408-656-2853

EXECUTIVE SUMMARY

This report discusses the cost and operational effectiveness analysis (COEA) of feasible alternatives in management, technology and operations for the International Ice Patrol (IIP). The scope of this study was to address new alternatives in technology, management and operations. Alternatives were restricted to existing technology and proven and acceptable management procedures. The only significant limitation of the study was the inability to obtain information on DOD classified surveillance systems. The present management and operations of IIP were analyzed in order to obtain a baseline for comparison with the new alternatives. Promising alternatives were analyzed in detail to provide the information necessary to objectively compare them with the present ways of managing the program and performing operations.

This comprehensive study was performed from July, 1994 to June, 1995. All of the information that existed during this time frame was made available to the contractor (EER Systems). All relevant information necessary for the analysis was willingly provided by Coast Guard offices, and other organizations such as the Department of State and Environment Canada. This included reports, interviews, computer programs and formally responding to queries in writing. Coast Guard participants in the project reviewed all of the analysis products produced by the contractor. There is general agreement in the Coast Guard that the detailed reports by the contractor represent an unbiased analysis of the alternative ways to manage the IIP program and operate the mission. This comprehensive in-depth analysis (Refs. 2-15) used all of the available information. The information in this study will help analysts understand the capabilities and limitations of these new alternatives and support decision makers in choosing from among these, and other, alternatives.
A number of significant results were obtained from the study. They are summarized below. Existing and planned satellite-based surveillance systems were found to be of little value for detecting medium and small sized icebergs, the most dangerous ones to shipping. A more powerful modern computer and data processing system will provide the capacity required for IIP to reliably track an increased number of icebergs and more accurately determine the limits of all known ice. Historic data can then be archived on the system for future analyses. Failure to upgrade the APS-135 SLAR (Side Looking Airborne Radar) with a new digital processor incurs considerable cost and performance risk. IIP would have to fly approximately 200 additional hours ($890,000) with a lesser (available) radar to achieve the same level of mission performance. The new processor may reduce flying hours considerably if it allows the full SLAR sweepwidth of 84 NM to be used for searching. The resolution of the film presently used with the SLAR restricts the sweepwidth to 27 nautical miles.

The study found the IIP to be well run, from both the operations and program management standpoint. There were no apparent opportunities to significantly reduce program costs or improve mission effectiveness by changing any procedures within the scope of existing authority or budget. Actual costs of operating the IIP program have been under-reported in the past (i.e., not all of the costs in the Coast Guard that were attributable to the IIP program, such as administrative costs, were identified.) As expected, aircraft surveillance is the major component (approximately 75%) of the total program cost of the International Ice Patrol. The majority of reported costs for IIP are being recovered from the contributing SOLAS signatory nations.

Ice Services Branch, Environment Canada, provided cost estimates for Canadian management and operation[1] of the IIP. They indicated that the overall mission costs might be reduced if the Canadians were the managing[2] government for IIP. This may reduce the total cost of the Ice Patrol to the international community but may not necessarily save money for the Coast Guard unless billets (people) are reduced or aircraft are retired (which has considerable effect upon other missions). If Canada becomes the Managing Government for IIP, the United States would still be responsible for its share of IIP funding under the SOLAS agreement, based upon the tonnage shipped shipped by American flag carriers.

The results of the COEA can be used by the Coast Guard to address problems at several levels. The cost analysis shows the true cost of the IIP. It can help to answer the question of which country, the United States or Canada, should be the IIP managing government. Program management and mission analysis issues are supported by the baseline analysis of the IIP and numerous detailed analyses of the alternatives. The COEA also provides documentation that makes it easier to support new procurements such as the digital recording head for the APS-135-SLAR.

Two new operational alternatives that may improve IIP performance are being developed, a method to model iceberg drift using probability and an operational aid to help route IIP flights. Both alternatives have the potential to improve the conduct of daily operations for IIP but they have not been developed to the point that they can be evaluated.

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1 Additional information is required in order to assess the effectiveness of their surveillance method.

2 The Safety of Life at Sea (SOLAS) agreement would have to be modified in order to change the managing government.

INTRODUCTION

The mission of the International Ice Patrol (IIP) of the U. S. Coast Guard has remained essentially unchanged since the original SOLAS treaty of 1914; that is, to determine the limits of all known ice (LAKI) along the southeastern, southern and southwestern edge of the ice region around the Grand Banks of Newfoundland and to make that information known to mariners in a timely fashion. The mission of the IIP is *not* to find all of the icebergs in the ice infested area but to notify mariners of the location of the limits of all known ice so they can take the appropriate actions. This subtle distinction can lead to erroneous conclusions about the mission of the Ice Patrol and how well it is being performed. Detecting more icebergs does not necessarily reflect a higher level of performance. There can be a great variation in the total number of icebergs in any given year. To determine the LAKI, flights are made to search the area on either side of the predicted ice limit to verify its accuracy. The LAKI, by definition, is an area where there will be very few, if any icebergs. Certainly, more icebergs will be found in the interior of the limits of all known ice than outside of the border where IIP must operate a significant portion of the time.

Surveillance has always been the most expensive portion of the Ice Patrol mission. Cutters were used to guard the limits of all known ice until 1946 when they were replaced by more capable and less expensive aircraft with ice observers on board. The side looking airborne radar (SLAR) was first used for surveillance operations in 1983. Alternatives such as satellite based synthetic aperture radars (SAR) and imaging systems have been touted for years as alternatives to aircraft surveillance, but no studies have documented their feasibility for Ice Patrol applications. More cost-effective aircraft and different bases, flight paths and patrol schedules have also been tried over the years to improve surveillance. It has also been known that better forecasting techniques and environmental information can improve the accuracy of predicting the iceberg locations, but the effect of better information and methods upon overall mission performance has not been considered before.

COST & OPERATIONAL EFFECTIVENESS ANALYSIS

PROJECT OBJECTIVES

The objectives of this project were to first identify new concepts in management, technology and operations for the International Ice Patrol; then to evaluate their cost and operational effectiveness to determine if they are better alternatives for IIP. The analysis (Refs. 2-15) provides the detailed information that is needed to understand why certain alternatives show promise to improve mission performance or reduce the cost of operating and/or managing the program and others do not. Modifications or refinements of present alternatives, such as changing the schedule or number of watchstanders during the ice season, were not considered in this study. Two promising new alternatives, a tactical aid for flight planning and a significant extension of the IIP drift model were identified and development was started. A restriction on the selection of alternatives was that they had to be proven technologies or techniques, or at least logical next step extensions. For example, an imaging technique that was presented in a research paper but was not proven in practice was not an alternative that was analyzed in detail. On the other hand, a new and more powerful radar type that has been used by the Navy was an alternative that could be pursued.

ALTERNATIVES AND EVALUATION CRITERIA

The alternatives that were considered in this study fell into three basic categories; management, technology and operations. An alternative may have had aspects of more than one category, but it would be placed in a single category for simplicity. Management alternatives include ways to subcontract a portion of the work to other agencies while still having the United States retain the responsibility of being the managing government for the International Ice Patrol. New hardware and improved modeling and data processing software were included in the new technology alternatives. Since the APS-135 SLAR is becoming less reliable, more expensive to maintain and technologically obsolete, there was great interest in the operations alternatives for surveillance such as a synthetic aperture radar deployed on a satellite. Aircraft and land based radars were other surveillance alternatives that were also considered.

A number of alternatives were initially identified as possible candidates for improving the operations or management of the International Ice Patrol. All of the alternatives were subjected to broad evaluation criteria in order to be considered for detailed analysis.

Alternatives had to be:

- Technically feasible
- Likely to successfully accomplish the mission objective
- Be available at a reasonable cost[3]

The following is the list of alternatives that were analyzed in detail.

- Management of the International Ice Patrol by
  - Canada; Ice Services Branch, Environment Canada
  - United States; National Ice Center
- Technology
  - Data Acquisition Systems
  - Data Processing Systems
  - Iceberg Deterioration Model
  - Iceberg Drift Model
  - System Risk Model
- Operations (Surveillance)
  - Satellite and Non-Airborne
  - Improved Coast Guard Systems
  - Contracted to Canada
  - Managed by National Ice Center

All alternatives that were considered are presented in Reference 4 while most of the detailed analysis results are presented in References 2 and 8 to 12.

ANALYSIS PROCESS

Cost and Operational Effectiveness Analyses (COEA) have been used in DOD for some time to comprehensively evaluate the alternatives associated with new major weapons systems. Generally, an evaluation is not entirely completed due to the complexity of the problem. The combination of the various possibilities usually grows beyond the resources available to perform a complete analysis. The variable components of the problem, such as weather,

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[3] If an alternative increased overall program costs, it was infeasible, even if it would increase mission performance. Performance of the IIP is presently at an acceptable level.

reliability of new systems, unknown future threats, relative importance to other alternatives under consideration, etc., can never be known with certainty, so the best alternative cannot be specified with certainty either. The solution to these seemingly impossible problems is to provide enough information in the COEA so that analysts and decision makers can understand the relationship between system cost and performance and each of the significant variables of the problem. This information could then be used in the future when some of the uncertainties become known (or at least more certain) and the results will be more clearly defined. Managers can then make informed decisions when they temper the information in the analysis with their understanding of the economic and political situation and the organization's policy and operational tactics and strategy.

The same general philosophy must also be followed when using the results of this analysis. Some of the alternatives could not be fully evaluated because all of the information was not available at the time of the analysis. For example, a new method was proposed by SAIC Science and Engineering Ltd. of the United Kingdom to process the data from satellite-based synthetic aperture radar (SAR) to produce images of icebergs. There were a number of serious deficiencies in the information that made a complete analysis of this option impossible. The SAR satellite has not yet been launched and the characteristics of the radar have not been proven in practice. The analysis technique has not been shown to work using real data and no ground truth experiments have been run to see if the iceberg image produced by the data analysis process will in fact correspond to a real iceberg.Also, the costs of satellite data have not been established, the level of training and computer power required have not been specified, and the time to produce the iceberg image is not known at this time. But, SAIC plans to demonstrate this technology some time in the near future. Following that demonstration, some, if not all, of these uncertainties may become known and this alternative may become a viable one. At that time, a decision can be made whether or not to incorporate this technology into the IIP program.

COEA RESULTS

The COEA involved a detailed analysis of selected management, technology, and operational alternatives that covered a broad range of approaches. The focus of the alternatives was to support the basic IIP mission to *determine the Limits of All Known Ice along the southeastern, southern, and southwestern edge of the ice region in the vicinity of the Grand Banks of Newfoundland and publish that information to trans-Atlantic mariners in a timely fashion.* Accomplishing the IIP 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.

Costs

The allocated cost of the IIP for the 1994 ice season was $3.6 million, almost 75% of which was for surveillance using Coast Guard aircraft (577 flight hours). All costs are not included in that total. There is no allocated administrative cost included for the non-aircraft portion of costs. Using 1995 standard personnel costs, assuming an extreme ice season (requiring 600 flight hours) and including provision for all administrative costs, the estimated 1995 baseline cost is $4.5 million. If the IIP were discontinued, an immediate, estimated, savings of $477,000 would be realized. If the 16 CIIP personnel were eliminated, an additional $840,000 in savings would be realized. Finally, if elimination of the 600 flight hours resulted in decommissioning an HC-130 aircraft, eliminating the 11 person air crew, and reducing air station support and maintenance costs proportionately, an additional $2,070,000 in savings would occur. The balance of the $4.5 million baseline cost (approximately $1.1 million) represents administrative and aircraft depreciation costs.

The 1994 allocated cost of $3.6 million will be billed on a prorated basis to nineteen countries that have agreed to reimburse the cost of the IIP. The US share of the IIP cost in 1992 was $455,000. No Federal agency has been assigned explicit responsibility for that payment. By default, the Coast Guard is making the payment by not being reimbursed directly for the cost of the IIP service. All reimbursements from other governments are collected by the Department of State and deposited in the US Treasury. In recent years, reimbursement has run at the 60% level (including the US). Given recent changes, it is expected that 90-95% reimbursement will be achieved.

Management

The proposals for the day to day management of the IIP, that were solicited from the Canadian Atmospheric Environment Service Ice Services Branch (ISB) and the US National Ice Center (NIC), were evaluated. ISB required nine full-time equivalent staff years to accomplish the management functions with other administrative support provided by additional staff. The NIC proposal involved the transfer of ten Coast Guard personnel to form a Department at NIC. Both proposals required comparable staffing and incurred roughly comparable costs in comparison with the present IIP staffing and management costs. There were *no significant reductions in staffing levels or costs with the two management proposals.*

Surveillance

The Study included a comprehensive review of commercially available sensor systems. This review found that there are no systems in existence or planned that will provide the temporal and spatial resolution needed to replace manned airborne surveillance flights. The Canadian RADARSAT, due for launch in 1995, will provide wide swath coverage of the IIP area, but at a relatively low resolution. It may provide coverage for large icebergs, but *airborne surveillance will continue to be required* to detect the small and medium icebergs.

The ISB and NIC provided surveillance proposals. The ISB proposal focused on providing area coverage but did not explicitly identify the resulting probability of detection of icebergs. The cost of the Canadian surveillance was approximately $1.9 million to provide 420 flight hours. The proposed flights appeared to be adequate to cover the required area of interest, but the probability of detection for the given radars and search strategy were unknown. The ISB proposal included 420 patrol hours using a DeHavilland Dash-7 aircraft (1400 NM effective endurance) using the 1992 ice season as a basis. In 1992 Coast Guard aircraft logged 348 flight hours on surveillance and an additional 275 flight hours for transit and logistics. These flights primarily used HC-130 aircraft with 1700 NM effective endurance.

The National Ice Center proposed using either Coast Guard surveillance, or contracted surveillance with Canada (Atmospheric Environment Service or Atlantic Airways). The NIC costs for the latter option were very low and there are questions concerning their validity. The costs provided to NIC by ISB were much lower than the costs ISB presented to the Coast Guard in their proposal. The NIC proposal, like the Canadian proposal, did not address the probability of detection of their surveillance method. In effect, the NIC proposal (discounting the contracted surveillance option) provides an administrative structure with some additional support for the IIP with no significant reduction in cost. The ISB proposal, assuming that the proposed search strategy will achieve the required probability of detection (POD), does accomplish the IIP mission at a reduced cost as compared with the present IIP costs. The total cost for management and surveillance in the ISB proposal are $2.8 million. This is considerably lower than IIP's total program cost of $4.27M for the 1994 season. There are still open questions concerning the probability of detection of the Canadian surveillance method and the true cost of basing and supporting the aircraft.

The impending technological obsolescence of the AN/APS-135 SLAR radar on the HC-130s has motivated the search for suitable replacement surveillance alternatives, including the possibility of contracted surveillance and satellite and unmanned sensor platforms. The Coast Guard has proposed (in the FY96 budget) to replace the present dry film processor in the AN/APS-135. The new digital processor will extend the service life of the radar to 2010. It will more accurately log the positions (georegistration) of icebergs when they are detected and should offer the opportunity for enhanced image analysis. It is expected that the digital processor will also permit a reduction in the search time required to accomplish the same objective by using a greater sweepwidth. Failure to upgrade the radar incurs considerable cost and performance risk. The additional annual cost to maintain the same level of mission performance without the SLAR was estimated at $890,000 in order to provide the additional patrol flight hours required if using FLAR alone.

Technology and Models

A detailed review of the IIP iceberg deterioration and the iceberg drift models indicated that both models are generally sound. There was an inconsistency between the local wind driven current portion of the drift model and the local wind driven current used in other IIP models. Further analysis is required to resolve the discrepancy. A sensitivity analysis confirmed that the estimated position of the detected iceberg is a primary driver as a source of uncertainty in the models. The Study concluded that there is no need for more refined environmental data (e.g., wind, sea state, sea surface temperature) at this time. However, there is a continuing need for better estimates of the Labrador current and the use of drifter buoys should be continued.

An integrated risk modeling approach was developed during the study, which can be used to characterize the uncertainty associated with the location of the LAKI for the present operations. This analysis should be pursued after the drift model questions (local wind driven current) are resolved in order to evaluate the whole system, including the interactive resight function in the model execution process. Such an analysis will incorporate all major sources of uncertainty and will permit IIP to predict the probability that an iceberg will exist outside of the LAKI. The integrated risk model and analysis will permit evaluation of alternative policies and procedures.

The use of the Airborne Tactical Workstation (under development) along with Global Positioning System (GPS) navigation input on Coast Guard surveillance patrols will significantly reduce the initial iceberg position error. The rapid development and implementation of this system requires sustained support if U.S. Coast Guard surveillance continues. Although the existing IIP data processing system functions well, equipment failures and the future need to assume full software support, presently provided by Canada (ISB), as well as the potential opportunities to obtain other types of data beyond present processing capabilities, argues in favor of a new data processing system. Immediate support is required for the acquisition and implementation of the Canadian Ice Services Integrated System (ISIS) if U.S. Coast Guard surveillance continues.

RANGE AND LIMITATIONS OF COEA

The limitations of this study are in three general areas. First, information about some of the alternatives was incomplete. Alternatives, such as the method by SAIC to produce iceberg images from satellite-based SARs, were just not developed or mature enough to be able to analyze them in detail. Too many unknowns would have required a corresponding number of unfounded assumptions which is not the basis for a good analysis. A second area where the analysis is not complete is in assessing the classified systems of DOD and other Government Agencies. Conjecture in this area would have been counterproductive so these were not included in the analysis. The last limitation of the study was that not all of the ways that the Coast Guard can presently manage the program and carry out the mission were exhaustively evaluated. Some refinements to the present management and operating practices were addressed but analysis of existing alternatives was not a requirement for the contractor. The present way of managing and operating the IIP were analyzed to determine the cost and performance for comparison with the new alternatives.

An attempt was made to obtain measures of the IIP performance as seen by the members of the maritime community, the ultimate customers of IIP's services. Three distinct groups were targeted; companies that insure ships on voyages through and around the ice region, vessel routing advisory services that use IIP services as input to their products and mariners/masters who directly use the services of IIP during voyages. It is difficult to get an accurate appraisal of the value of IIP from an inquiry from mariners, the ultimate customers. Legal and financial issues are involved with insuring vessels that transit the North Atlantic during the ice season. If a ship is damaged by an iceberg, there is usually the question of "who pays?", the insurance company or the shipping company. The parties involved may not answer questions relating to IIP services for legal reasons. IIP has its greatest contact with the maritime community after one of these types of incidents, answering questions about the accuracy of the LAKI. Interestingly, an inquiry to Lloyds of London (Ref. 2) showed that one of the biggest insurance companies does not use the IIP products in their normal course of business. On the other hand, the vessel routing service Ocean Routes uses the products of IIP on a regular basis (Ref. 2). They estimate that it would cost their clients $2,500 more for each voyage to route them conservatively outside of the historical ice region if IIP services were not available. Using the IIP products saves their customers from incurring this increased cost.

A survey was sent via INMARSAT by IIP to see how their products were used in a tactical sense by vessels transiting the area that IIP monitors and ultimately guards. This is the second attempt[4] to find out how the mariners value IIP's services and products. Only a few responses were received in May 1995 before the analysis report was completed. Since then over one hundred fifty responses from mariners have been received by IIP and analysis of the data has begun. There is always a question of accuracy with any survey so drawing conclusions from this information should be considered carefully.

RECOMMENDED USE OF COEA RESULTS

This analysis used the best information available at the time. The report is complete and comprehensive with only the limitations described in the previous section. How the results are used depends, of course, upon what issue is being analyzed and/or what problem is being addressed. Many of these will involve procurements and ways to reduce costs. The results of this analysis can be used in several ways:

Policy Support

Program costs and cost reimbursement are both issues that were exhaustively analyzed (Refs. 2, 6, and 7). These reports provide the information to accurately account for all of the costs associated with IIP operations. The operating cost analysis of Coast Guard conducted management and surveillance, the costs of contracting those services, and the expected real savings to the Coast Guard if Coast Guard management and surveillance are terminated

[4] The first survey was done in 1993 by IIP.

provide a reasonable basis for evaluating the contract option. At the same time, the cost analyses present sufficient information to permit the Coast Guard to seriously explore the policy of transferring the Managing Government responsibility to Canada.

Regardless of the Managing Government, the proper amount of money can be recovered for the Managing Government from the SOLAS signatory nations (per agreement). The State Department has identified the SOLAS signatory countries that significantly benefit from the services of the IIP but have not paid to support the IIP. Similarly, any non-SOLAS countries that benefit from the IIP could be recruited by the State Department to become members of SOLAS and share some of the costs of providing the Ice Patrol services. Either action would reduce the costs for all of the present contributory nations.

IIP Mission Analysis

The results of this study can be used as part of a complete mission analysis of the International Ice Patrol. Significantly more work is necessary in measures of effectiveness, program standards and evaluating conventional Coast Guard alternatives, but the baseline analysis has been done in this COEA. The cost analysis (Ref. 6) identifies the true costs of IIP operations.

IIP Program Management

IIP and G-NIO can now identify the most significant sources of cost in the program. They can propose new management and operations alternatives (to reduce costs) and evaluate them. These alternatives could range from reduced staffing of IIP to new ways of using the drift model to determine the limits of all known ice.

Supporting Procurements

Acquisitions and Resource Change Proposals (RCP) can both be supported by this analysis. The RCP for the digital recording head for the APS-135-SLAR can be supported by Refs. 5 and 12 while the acquisition for ISIS, the new proposed data processing system, is supported by Ref. 14. Any major acquisition must first have a mission analysis report to document the requirement.

ALTERNATIVES UNDER DEVELOPMENT

Two new concepts were identified that have the potential to increase the efficiency and/or effectiveness of performing parts of the IIP mission. One was a modification of the IIP drift model to determine the spatial density of unknown icebergs. The other was a tactical aid that would help to plan Ice Patrol flights. Both concepts appeared to have significant potential value, but they needed to be developed further in order to be considered as feasible alternatives. The Naval Postgraduate School (NPS) was selected to perform the follow-on development. These alternatives are described below.

ICEBERG DETECTION MODEL

Professor Alan Washburn, a faculty member from the Operations Analysis (OA) Department at NPS, has developed a model that can be used to determine the effectiveness of IIP's reconnaissance strategy. The model more accurately forecasts iceberg drift by using error ellipses instead of error circles for the probability of their location. In the approach, past IIP flight tracks and curves that model SLAR and FLAR radars and human ice observers, are used to identify icebergs as they drift under the influence of ocean currents. The model identifies the icebergs that would have been detected by IIP flights and then determines the spatial density of the remaining (i.e., unknown) icebergs as they drift over time. NPS modified IIP's iceberg drift model to include this new method in a computer program called ICEBRG.

The model uses a simulation-based approach to estimate the number and distribution of icebergs in the IIP operating area. Individual icebergs are assigned to a grid according to a random draw from a probability distribution. Each cell then contains a mean number of icebergs. This information is then used to compute an overall density of icebergs in the region. The model then determines the density plots of the icebergs. NPS has delivered a report on ICEBRG and the FORTRAN code to IIP where it is being tested. This model has the potential to improve the forecasted position of the limits of all known ice (LAKI). Additional work is required on both the model and how to use it in order to begin to establish its value to IIP. An assessment of the model by IIP is presented in the appendix.

AIRPLANE ROUTING ALGORITHM

Planning an Ice Reconnaissance Detachment (ICERECDET) flight is complicated. Decision making is done under the pressure of time, not knowing all of the variables with certainty and the knowledge that airplanes are expensive to operate. Efficient use of flight time is very important since the costs of an HC-130 exceeds $4,000 per hour. It is not possible to plan all ICERECDET flights beforehand. The objectives of an IIP flight depend upon the results of the previous flights, the latest LAKI, the forecasted weather, airplane range and endurance, and how much scheduled flying time remains before the aircraft has to return to its home base. Flight planning is further constrained by having to file a flight plan with the Canadian authorities well before the flight is scheduled to begin. It is difficult to make changes to the flight plan after it has been filed. These requirements and constraints make any type of tool to assist with flight planning very attractive.

LT Joe Sposato, a US Navy student in the operations analysis curriculum at NPS, worked with the R&D Center and IIP to develop an algorithm to plan optimal routes for ICERECDET flights. The flight path will include as many of the desired search areas as the airplane is physically capable of reaching, without unnecessary overlap. The algorithm uses an active iceberg list, heading increments and distance between flight legs as inputs to produce the optimal flight path. The program is written in standard Pascal and runs on a 486DX2/66 Mhz computer with 16 MB of RAM. Graphics are produced using Turbo Pascal. The thesis was completed in September, 1995 and will be published by NPS in 1996.

FOLLOW-ON DEVELOPMENT

Both of these new alternatives need to be developed further and then evaluated before they can be considered for inclusion in IIP operations and management. The next step in the iceberg density model is to expand the stochastic component of iceberg location and develop a method to locate the frontier of the iceberg field based upon the location and uncertainty of the many individual icebergs. A policy for combining the iceberg frontier with the limit setting icebergs is required to determine the limits of all known ice. This method should relate the uncertainty in the iceberg location to the uncertainty in the LAKI. When this new method is developed, it should be compared with the present method that is used to determine the LAKI. The code for the optimal airplane routing algorithm should first be verified and then evaluated against past IIP flights. Following a successful evaluation, the next step is to install the algorithm on a laptop computer with a friendly user interface and test it under operational conditions.

REFERENCES

1. G-NIO "Request for R&D Support; International Ice Patrol Mission Analysis and Sensor Evaluation Study, Request #IO-02093" of 11 DEC 93.

2. Cost and Operational Effectiveness Analysis for Selected International Ice Patrol Mission Alternatives, Final Report (CG-D-19-95).

References 3 through 15 are Annexes to Reference 2 (Cost and Operational Effectiveness Analysis for Selected International Ice Patrol Mission Alternatives)

3. Analysis of Current Operations of the IIP; Annex A (CG-D-20-95).

4. Identification of Alternatives for Phase II COEA; Annex B (CG-D-21-95).

5. Probability of Detection and Classification Using USCG Surveillance; Annex C (CG-D-22-95).

6. Cost Development for USCG IIP Activities; Annex D (CG-D-23-95).

7. Cost Reimbursement for USCG IIP Activities; Annex E (CG-D-24-95).

8. Evaluation of Canadian ands National Ice Center Management and Surveillance Proposals; Annex F (CG-D-25-95).

9. Analysis of the IIP Iceberg Deterioration Model; Annex G (CG-D-26-95).

10. Analysis of the IIP Iceberg Drift Model; Annex H (CG-D-27-95).

11. Survey of Iceberg Sensing by Satellite Imagery; Annex I (CG-D-28-95).

12. Evaluation of Airborne SLAR/FLAR Capability; Annex J (CG-D-29-95).

13. Risk Management Model of IIP Operations; Annex K (CG-D-30-95).

14. Analysis of IIP Data Processing Requirements; Annex L (CG-D-31-95).

15. Review of Sensor Technology and Potential IIP Applications; Annex M (CG-D-32-95).

16. Headquarters Instruction 16050.1 (Mission Analysis Reports); 21 AUG 1992.

17. The ICEBRG Detection Model (Project Report to the International Ice Patrol) by Alan Washburn, May 1995. NPS-OR-95-004PR.

APPENDIX

Assessment of ICEBRG Detection Model

by
Dr. Don Murphy, Chief Scientist of the International Ice Patrol

Professor Alan Washburn of the Naval Postgraduate School undertook an innovative study of the effectiveness of IIP's iceberg reconnaissance, not by focusing on how many icebergs are found, but, rather, how many are missed. He developed an iceberg detection model, called ICEBRG, which estimates how many icebergs are left undetected after a given amount of reconnaissance effort. First, the model estimates the distribution of icebergs in the IIP operations area. This distribution, which is entirely independent of observations, is based on an estimate of the number and size distribution of icebergs entering the IIP operations area at 52 N and the subsequent movement and deterioration of those icebergs. Iceberg movement is predicted using the PC version of IIP's drift model. Ocean currents are from IIP's historical current database and winds are from Fleet Numerical Meteorology and Oceanography Center (FNMOC). Deterioration is modeled as a constant two meters per day reduction in the length of each iceberg.

Data from actual reconnaissance flights are used to determine which of the icebergs would have been located (detected as a radar target), identified (determined to be an iceberg), or missed entirely. The model uses the flight tracks and probability of detection and identification data for each of the sensors to determine which icebergs are detected and identified on each sortie. The actual iceberg sighting data are not used. Reconnaissance includes not only IIP's aircraft, but also those of the Canadian Atmospheric Environment Service (AES) and Department of Fisheries and Oceans (DFO). The iceberg detection model is a flexible tool that may be used to examine the effects of changes to IIP's reconnaissance practices. It could be used to assess the impact of a reduction or elimination of the AES and DFO flights or the addition of new search tactics (e.g. increased track spacing) by the IIP aircraft. ICEBRG could also be used to determine the potential contribution of new sensors or platforms to the iceberg reconnaissance effort, for example RADARSAT. This would be a matter of estimating probability of detection curves for the radar and determining the track information.

A side benefit of Professor Washburn's work is the considerable effort he put into implementing and using IIP's drift model. In general he found that the model is sound and provides reasonable predictions. However, he observed some instabilities that IIP has observed in the past. He suggested that the cause might be a mismatch between the time scales of the current and wind data. He also recommended investigating the use of techniques for solving Ricatti equations as an alternate method of solving the drift equations. Professor Washburn delivered a copy of the FORTRAN model to IIP. It has been implemented on a PC and is currently being evaluated by IIP.