UNIVERSITY - NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

UNOLS FLEET IMPROVEMENT COMMITTEE

MEETING REPORT

October 7-8, 1992
Martin Johnson House Conference Center
Scripps Institution of Oceanography
La Jolla, CA

MEETING REPORT
UNOLS FLEET IMPROVEMENT COMMITTEE

October 7-8 1992
Scripps Institution of Oceanography

The UNOLS Fleet Improvement Committee (FIC) met at the Martin Johnson House, Scripps Institution of Oceanography, La Jolla, CA. 7 and 8 October 1992. The meeting was called to order by FIC Chair, Marcus Langseth. The agenda is enclosed as **Appendix I**.

ATTENDEES

FIC Members:	Participants:
Marcus Langseth, FIC Chair	Jack Bash, UNOLS
Peter Betzer	Garry Brass, UNOLS Chair
Teresa Chereskin	Annette DeSilva, ONR
Eric Firing	Bob Knox, Scripps
Ken Johnson	Martin Mulhern, NOAA
Charlie Miller	David Wirth
Tom Royer	

APPENDICES

I. FIC Meeting Agenda
II. NSF FY 1993 Budget Report
III. NOAA Slides
IV. Hull Characteristic Study of Arctic RV
V. Revised Scientific Mission Requirements of an Arctic RV
VI. Scientific Research Priorities for an Arctic RV
VII. Glosten's letter on cost of an Arctic RV
VIII. Accommodations and Laboratory Questionnaire
IX. Outline of UNOLS Fleet Plan
X. SWATH Ocean Brochure

APPROVAL OF MINUTES:

The minutes of the 1-2 April 1992 FIC meeting held in Washington, DC, were approved as written.

UNOLS Report - Garry Brass reported on the activities of the UNOLS Council. The UNOLS Ship Scheduling Committee has been working with NOAA to provide shiptime for their TOGA TAO program in the Pacific.

ATLANTIS II/ALVIN work for 1993 appears to be healthy compared to 1992. A draft Memorandum of Agreement (MOA) for the three agencies (NSF, NOAA and ONR) outlining their commitment to the support of a Deep Submersible Facility (DSF) which will include ALVIN and ROVs has been prepared. The draft MOA includes a safety net to protect a floor level of funding during a reduced operating year. The agreement also will include a "re-compete" statement which provides for a competition for the operation of the DSF. KNORR is currently planned as a replacement for ATLANTIS II as the ALVIN/ROV support vessel. The date for this conversion will be dependent upon the timing of AGOR 25.

Garry reported that the ALVIN Review Committee has changed its name to the DEep Submergence Science Committee (DESSC) to better reflect the broader scope of the committee. DESSC will be involved in technical enhancements for deep submergence science which extends beyond ALVIN to other deep submergence tools. The committee will no longer review ALVIN proposals. Jeff Fox has been appointed as Chair.

Scheduling for the 1993 operating year has left several intermediate ships with light schedules. As the funding picture clears, the schedules will begin to firm. Most of the large ships have reasonable schedules.

A Research Vessel Technical Enhancement Committee (RVTEC) is being formed, modeled after the RVOC. The purpose of the committee is to promote scientific productivity of ocean going research programs. They will address technical support problems of the fleet, encourage information exchange among support groups, and review new technologies. An organizational meeting is scheduled for 18-19 Oct. in Washington, DC.

A UNOLS Council subcommittee reviewed the apparent shortfall in shiptime for the intermediate ships on the East Coast. They concluded that the present shortfall may be an anomalous situation and should be watched for another year or two.

AGENCY REPORTS:

National Science Foundation: Dick West was unable to attend the FIC meeting. Dick sent a telemail message from Don Heinrichs that reviewed the budget situation at NSF. This message is included as **Appendix II**. Garry Brass suggested that UNOLS will respond to the NSF discussion on basic research vs applied research.

Office of Naval Research: Annette DeSilva provided the ONR report. She is filling in for June Keller for 4-5 months while June is out on maternity leave. Annette reported that the Navy is expecting no big change to their 1993 budget. The ship construction funds for AGOR 23, THOMPSON, will end on 30 November. Contract award for AGOR 24 is expected by 12 February 1993. Congress needs to accept the budget which includes an additional $9 million for AGOR 24 construction before an award can be made. ONR is working with SIO and WHOI to develop a priority of change candidates to recommend to NAVSEA during the initial construction phase. Work continues in the legal settlement of the KNORR/MELVILLE overhaul cost overrun. Annette reported that RV WASHINGTON has been transferred to Chile but the GYRE transfer to TAMU has been delayed.

National Oceanic and Atmospheric Administration: Captain Marty Mulhern reported for NOAA. RADM Bill Stubblefield has replaced Chris Andreasen as Director of NOAA Corp Operations. Captain Don Northrup replaced David Yeager as Chief, Program Services Division and will be the NOAA representative to RVOC. Scott McKellar remains with the scheduling process.

NOAA's Fleet Replacement and Modernization (FRAM) program continues to progress. The 1993 Budget contains $30 million for FRAM. Of this, $22 million is planned for modernization and conversion of the TAGOS vessel, RV ADVENTURE received from the Navy. A replacement Great Lakes ship is planned for $3.3 million and $2 million is earmarked for critical maintenance.

The 1993 charter money has been carried over from the 1992 budget. This includes the funding for VICKERS and other UNOLS vessels. Two million dollars is planned for ALBATROSS IV maintenance and three million dollars for multibeam test and evaluation for the TAGOS ship(s). Ship life extensions are also planned for OCEANOGRAPHER and DELAWARE II. Replacement is planned for RUDE and COBB. A copy of Marty's slides are included as **Appendix III**.

STATUS OF ACTION ITEMS.

SOONS Report: Over 800 copies of the "Scientific Opportunities Offered by a Nuclear Submarine" (SOONS) report were distributed to the community. Several letters have been received in response to this publication including interest from the US Navy.

Updating the report was discussed but it was decided that we should wait for additional developments.

WHOI has been talking with Russia concerning the possibility of using a Russian nuclear submarine for under ice research. The Russians appear quite receptive. Such an arrangement would require an expensive conversion and a significant yearly operational cost. Interest in the Russian sub could stimulate additional interest in using a US sub for this research purpose.

Multibeam Comparative Study: At the April FIC meeting, we heard a presentation from Alberto Malinverno of L-DGO concerning his plans for a comparative study on commercial multibeam systems. The study was to provide potential purchasers and users with consistent measurements of actual performance of different multibeam systems. Alberto, in collaboration with John Goff, were encouraged to submit a proposal to ONR for this study. In the ensuing months Alberto has left LDGO for a position in industry and John has left WHOI. The FIC agreed to canvas the community for persons capable and willing to proceed with this much needed study.

Mid-Life Refit of Intermediate Ships:

Jack Bash provided the committee a report on the progress of mid-life refits for the OCEANUS class ships. ENDEAVOR is scheduled to be the first ship for the refit. Originally this ship was to enter the shipyard in the late fall of this year, however, this schedule will probably slip several months. The three OCEANUS ships, ENDEAVOR, OCEANUS and WECOMA are all scheduled to complete their refit prior to July 1994 when the USCG's new admeasurement rules come into effect. Presently URI holds a grant from NSF for the engineering work for all three ship refits. Each institution will then contract and schedule their ships' refit separately. Consideration is being given by URI and WHOI to determine if a two ship overhaul may be more cost effective than individual overhauls. This evaluation is presently underway. Two million dollars per ship is being planned for the refits.

Arctic Research Ship Preliminary Design Study:

The Arctic Research Ship report was provided by Tom Royer. Tom first ran a video tape of the evaluation team's trip aboard two Russian icebreakers. These were SOROKIN with the Thyssen/Waas hull form and NICKOLOV with an Odin hull form. The tape demonstrated the efficiency of the two hull forms in breaking ice. The differences were inconclusive. The Glosten Associates, Inc. have developed a Preliminary "Hull Characteristics Study for an Arctic Research Vessel" (**Appendix IV**) to assist in the evaluation process. The evaluation team plans to make their recommendation as to the preferred hull form at their next Arctic Research Vessel (ARV) Subcommittee meeting in November.

The Subcommittee has rewritten the Science Mission Requirements (**Appendix V**) for the ARV which includes the need for an A3 ice capable hull. The ship's length has grown to 320' to accommodate a 90 day endurance and 35-36 scientist accommodations. A grant for $.25M has been used to fund the Mission Requirements and the Conceptual Design study. An additional $1.5M grant has been approved to develop the Preliminary Design study and Contract Design work.

A draft of "Scientific Research Priorities for an Arctic Research Vessel" has been written as a "strawman" for developing the Communities requirements. A copy is included as **Appendix VI**. Comments and additions to this document are requested.

Construction and operating cost estimates for the new Arctic vessel have been provided by The Glosten Associates, Inc. in their letter dated 28 September 1992. A copy of this letter is included as **Appendix VII**. The construction cost rough estimate is $119M for the A3 class hull with a $32,800/day operating cost.

The State of Alaska is considering financing the construction cost for this vessel. The terms of financing are not known. More information on this, plus the hull form decision, should be available at the next subcommittee meeting scheduled for 12-13 November in Seattle. A meeting is planned to discuss the strategy for Arctic research scientific requirements during the fall AGU in San Francisco.

COASTAL WORKSHOP:

The FIC Subcommittee on Coastal Oceans is scheduling a workshop to study what facilities are needed to conduct coastal oceanography in the next century. Funding for this workshop has been approved. The original dates of 16-18 November have now been changed to 22-24 February 1993. The workshop location of Williamsburg, VA, remains the same.

CONVERSION OF KNORR TO ALVIN SUPPORT SHIP:

The committee discussed their responsibility in providing input to WHOI relating to conversion of KNORR as ALVIN support ship. It was decided that a joint FIC/DESSC subcommittee should be formed for the purpose of providing UNOLS community requirements to aid in the conversion design for KNORR. This subcommittee is to be formed at that point when the conversion decision is firm and the date of this conversion is known. Marcus will write to Jeff Fox, DESSC Chair, to convey this message.

ACCOMMODATION AND LABORATORY STUDY:

Chair Marcus Langseth and Teresa Chereskin are studying how accommodations and laboratories aboard UNOLS ships compare with those of other research ships. A questionnaire (**Appendix VIII**) was sent to members of the UNOLS community who have been on two or more different research vessels in the recent past. Fifty percent of the questionnaires were completed and returned. Some common comments were: the need to have E-mail aboard ships; number of persons per stateroom is important; number of persons per head is of concern; a comfortable and quiet library is important; some labs are more flexible than others; service on ships is as important as the accommodations.

The subcommittee felt they needed a broader input to the study. It was suggested that institution marine offices should be contacted to identify persons that go to sea regularly, such as buoy groups and CTD groups. FIC members were asked to write an essay on their own experiences with respect to accommodations and laboratories.

The subcommittee will expand the scope of the study with more inquiries and possibly send out another questionnaire. Marty Mulhurn suggested that NOAA ship users be included in the distribution. A FIC/UNOLS report and possibly a useful handbook for RV operations are the projected outcome of this study.

SEA KEEPING CHARACTERISTICS

The FIC discussed the need to develop a quantitative method for determining the sea keeping capability of ships, especially intermediate ships. The instrumentation of measuring ship movement is now being performed for obtaining better data from Acoustic Doppler Current Program (ADCP) equipment aboard ships. Eric Firing has been working on this. He has been tasked to provide the FIC with the status of this effort and how it might be adapted to glean the information necessary to better understand ships movement.

UPDATE OF THE FLEET IMPROVEMENT PLAN

Marcus Langseth led a lengthy discussion concerning the update of the Fleet Improvement Plan. This document would replace the 1990 Fleet Improvement Plan.

It was decided to divide the plan into five sections. The first would be the background of the UNOLS fleet (including its history, the role of the Fleet Improvement Committee and the FIC evolution from the Fleet Replacement Committee). The second element would include the present composition of the fleet and the fleet as it is expected to look like in five years. It would also include non-UNOLS assets that scientists use, as well as non-ship assets. These first two sections would be Mark's for action.

The third section would look at the academic fleet over a time period of twenty years. We would look at the on-going major programs such as WOCE, RIDGE, JGOFS etc, projecting them into the future. Charlie Miller was tasked to look into this. Next would be the needs for coastal oceanography. This segment of oceanography seems to be expanding rapidly. Don Wright is to take this section for action. Arctic research should also be included and is being tasked to Tom Royer. Finally, this section should include new and exotic technical advances that might impact the way oceanography will be conducted. This section has yet to be assigned.

The fourth part of the study will look into funding of the fleet. It will include the past and current usage vs availability of ships as well as the current and future cost of operating the fleet. Mark and Jack Bash will be responsible for this section. This will be followed by sources of funding, both traditional and non-traditional. Peter Betzer, Ken Johnson and Teri Chereskin will take on this tasking.

Finally, the recommendations of the study will include what the committee sees as the fleet composition at the turn of the century. It will also include the modes of operation or the best ways to utilize the anticipated resources. Finally, the study will recommend methods for monitoring the fleet and its needs. Assignments for this section will be made as the main body of the study develops.

An outline of the new fleet plan is included as **Appendix IX**. Members were encouraged to commence work on their sections and circulate a draft via Telemail by late January 1993.

NEXT MEETING:

The next FIC meeting has been planned for 8-9 March 1993 in St. Petersburg, FL. This meeting was adjourned at 1645 hrs on 8 October 1992.

On 9 October the FIC was invited by Don Keach of the University of Southern California to take a short cruise aboard their 72' SWATH ship "Chubasco" and to tour the ship yard of SWATH Ocean in San Diego. Most of the FIC members were able to accept this invitation.

The cruise aboard "Chubasco" proved to be most informative allowing the committee to see the maneuverability and spacious facilities of the SWATH. Unfortunately the weather did not cooperate. The winds were calm and seas slight preventing the ship from showing its greatest asset, that of being sea-kindly. It was possible, however, with the limited movement experienced to translate that into a sense of its action in a more robust sea. The committee was impressed with the ship and the possibilities it allows.

A tour through the SWATH Oceans shipyard was likewise impressive. On the ways were two SWATH vessels under construction. One was a 65' pilot vessel and the other a 90' custom long range sportfisher. The quality of workmanship and the unique features of SWATH construction were noted. Details of MBARI's 115' SWATH, that is soon to be started at this yard, were discussed. The community should watch closely the performance of this ship as a prototype for additional SWATH ships in the academic research fleet. A copy of the SWATH Ocean brochure is included as **Appendix X**.

A special thanks goes out to USC and SWATH Ocean for the opportunity to tour their ships and facilities.

APPENDIX I

Tentative Agenda
UNOLS Fleet Improvement Committee
October 7 & 8
Scripps Institution of Oceanography

Convene at 9:00 am

1. Greetings and meeting logistics - Mark Langseth/Jack Bash
2. Approval of minutes of the April meeting and meeting agenda.
3. UNOLS council report (July meeting) - Jack Bash
4. Agency Reports
   NSF - Dick West
   ONR - Keith Kaullum
   NOAA - Martin Mulhern
5. Status of action items- Mark Langseth
   SOONS update
   Multibeam comparative study-
6. Mid-life refit of intermediate-sized ships - Jack Bash/Dick West
7. Arctic Research Ship Preliminary Design Study - Tom Royer
   - New Science Mission Requirements
   - Feedback from community
   - Plans and strategies
8. Coastal Oceanography Workshop - Don Wright

Thursday Oct. 8 9:00 am

9. Review of shipboard laboratory facilities and accommodations - Mark Langseth/Teri Chereskin
10. Update of the Fleet Improvement Plan-Mark Langseth

    Reports from subgroups.

13. Other business

APPENDIX II

From : rwest at nsf12
To : Teri Chereskin fax# 8-619-534-0704 at FAX
Richard West FAX# 357-7621 at FAX
Subject : NSF Budget Info for FIC

Message Contents

NSF FY 1993 BUDGET
Ocean Sciences Summary

Overview

The FY 1993 budget for NSF is $2.733B which is $294M less then the administration request. Budget increases are provided for the Education and Human Resources account ($465M in FY 92 to $487M or 4.7%), Instrumentation and Facilities (Buildings) ($33M to $50M or 51.5%), and the Antarctic programs ($193M to $221.4M or 14.7%). The Research account, which includes Ocean Sciences, decreased by $13M from $1.872B to $1.859B. This is $353M less than the request.

Capital Issues

The research account identifies specific amounts for capital items which must be accommodated within the available funds ($68.5M total). Included is $1.5M for engineering and initial construction of an Arctic research vessel with the comment "that in view of on-going budget constraints leasing an Arctic research vessel may be the preferable approach." Additional comments require the ship to be "American-built".

Impacts

Specific budget allocations have not been determined for NSF divisions yet. This process will not be completed until the initial report of the Commission on the Foundation's Future is available. A mid-December 1992 time frame is projected. The most likely outcome is a budget for Ocean Sciences that is several percent lower than the FY 1992 level of $178.8M. This will mean that major growth/expansion of the Global Change programs will be deferred at least one year and research fleet operations costs will be closely examined. International commitments to the Ocean Drilling Program will be met along with the plans to provide mid-life refits to the oceanus-class research vessels.

D.Heinrichs
05 Oct. 92

APPENDIX III

<u>Fleet Replacement and Modernization (FRAM)</u>

Approved by Department of Commerce (5000 DAS)

ONCO

- User requirements
- Critical maintenance
- Small boats (40-65 ft.)

SPO (Systems Program Office)

- Specifications
- Design
- Construction

FY 94 Budget Request (DOC level)

- $ 4.0 M for Charter Support cut
  - May be restored at some later point

FY 93

CONFERENCE REPORT - NOAA FY 93 Budget

Fleet Modernization	$ 30	M
T-AGOS Conversion		
Replace Great Lakes Research Vessel		

Estimates

T-AGOS Conversion	$ 22	M
GLRV	3.3	
Critical Maintenance	2	
	$ 27.5	M

Carry forward of funds to FY 93

Charter	$ 1.5	M
Critical Maintenance	2	
ALBATROSS IV Repairs	2	
SPO Support (Specs/Design)	8	
ADVENTUROUS T & E	3	

FY 93 Activities

Repairs

ALBATROSS IV

Test and evaluation, swath mapping

ADVENTUROUS (T-AGOS)

RTE planning ongoing (Shipyard work in FY 94)

DELAWARE II

OCEANOGRAPHER

Development of specifications begins

RUDE and COBB replacements

Development of requirements

DISCOVERER RTE

FAIRWEATHER RTE

Small boat

GLRV specification and design development

Critical Maintenance

APPENDIX IV

Hull Characteristics Study
for an
Arctic Research Vessel

PRELIMINARY

Volume I

Conducted pursuant to the research ship requirements
of the
University National Oceanographic Laboratory System (UNOLS)

Under the direction of the

University of Alaska
Fairbanks, Alaska

August 1992
File No. 9243

THE GLOSTEN ASSOCIATES, inc.
CONSULTING ENGINEERS SERVING THE MARINE COMMUNITY

600 Mutual Life Building
605 First Avenue
Seattle, Washington 98104-2224

Phone: 206-624-7850
Facsimile: 206-682-9117
Telex: 882053

THE GLOSTEN ASSOCIATES, inc.

CONSULTING ENGINEERS SERVING THE MARINE COMMUNITY

25 August 1992
File No. 9243
Serial No. 0018

Dr. Thomas C. Royer
Institute of Marine Science
University of Alaska Fairbanks
Fairbanks, Alaska 99775-1080

Subject: Preliminary Hull Characteristics Report

Dear Tom:

Enclosed please find Volumes I & II of our preliminary report on the hull characteristics of the ARV.

As directed by the Subcommittee last July, we have investigated what size vessel would meet the revised science mission requirements. Our findings are summed up in the executive summary contained in Volume I.

Volume II contains the appendix to the report. It includes a complete copy of the HSVA report regarding candidate hull forms and their estimated performance in level ice. Also included in Volume II is a copy of the latest SMR for reference as well as some comparative vessel data and a bibliography.

We look forward to discussing the report with the members of the Subcommittee this Thursday.

With best regards.

Yours very truly,

THE GLOSTEN ASSOCIATES, INC.

DIRK H. KRISTENSEN, P.E.

DHK:ld

Enclosure: Preliminary Hull Characteristics Report, Volumes I & II

cc: Knut Aagaard)
Vera Alexander)
E.R. Dieter)
R.P. Dinsmore) All with enclosures
Robert Elsner)
Marcus G. Langseth)
Sharon Smith)
Al Sutherland)

Hull Characteristics Study

for an

Arctic Research Vessel

PRELIMINARY

Volume I

Conducted pursuant to the research ship requirements
of the
University National Oceanographic Laboratory System (UNOLS)

Under the direction of the
University of Alaska Fairbanks
Fairbanks, Alaska

Dirk H. Kristensen
Project Manager

John A. Springer III
Project Naval Architect

Duane H. Laible
Principal-in-Charge

File No. 9243
August 1992

THE GLOSTEN ASSOCIATES, inc.
CONSULTING ENGINEERS SERVING THE MARINE COMMUNITY

600 Mutual Life Building
605 First Avenue
Seattle, Washington 98104-2224

Telephone: 206-624-7850
Facsimile: 206-682-9117

HULL CHARACTERISTICS STUDY
TABLE OF CONTENTS

1. Executive Summary

The UNOLS Arctic Research Vessel Subcommittee has revised the science mission requirements (SMR) of the proposed vessel. This was done in response to comments from the science community on the original concept design report of 1991. The revised SMR describes a vessel of significantly greater science capabilities and ice worthiness. As part of a renewed conceptual design effort, The Glosten Associates, in conjunction with their ice technology subconsultant, HSVA, were tasked in July with estimating what size vessel would be necessary to fulfill the requirements of the revised SMR. This report summarizes our investigations to date concerning this issue.

The revised SMR outlines in broad terms the desired operating areas the vessel would be expected to function in. The most stringent requirement is the capability to operate independently, for short periods, in areas of the Central Arctic Basin. In terms of the regulatory requirements of the American Bureau of Shipping (ABS), this translates to a vessel holding a minimum classification of Ice Class A3.

A brief review of available technical literature describing the Arctic operating areas of interest leads one to the conclusion that the environment is highly variable. Although an A3 ice classification will, in the eyes of the classification society, allow short excursions into some areas of the Central Arctic Basin, as well as year-round operations in the Bering Sea, **there can be no guarantee that actual environmental conditions during the specific time of desired operation will allow this**. This means that if a particular science mission requires the vessel to be at a specific place in the Arctic at a specific time, there is a significant risk that existing ice conditions would not permit transit. Even with an escort, the ability to arrive at a specific place at a specific time is highly questionable. It is of some interest to note that if the vessel is escorted by an ice class A4 or higher vessel, the operating areas allowed by either an A2 or A3 vessel are identical. An A3 vessel escorted by an A5 or higher ice class vessel (such as the Polar Class icebreakers) could, **theoretically**, operate year-round in the Central Arctic Basin (this is 7 more months of operation than an A2 vessel with similar escort). However, there can also be no doubt that the additional horsepower and size of an ice class A3 vessel will result in a significantly more flexible vessel with greatly extended operational windows in the Arctic.

Science missions relying on escort by higher capability icebreakers are not seen as desirable due to scheduling and cost implications as well as practical science operations aspects.

The principal dimensions of the vessel are driven by the propulsion plant installation, i.e., the required science spaces are not a determining factor for principal dimensions. A vessel meeting only the science space requirements would be approximately the size of the AGOR 23, e.g., a 270' by 52.5' by 26.5' vessel. However, the propulsion plant installation as well as the fuel volume required to meet ice class and endurance requirements result in a significantly larger vessel.

In describing vessel size, cubic number, i.e. the measure of volume that the hull envelope encloses, is a rational measure of comparison. Visualizing how cubic number relates to vessel dimensions can be difficult. Therefore, we have assumed hull principal dimensions that reflect form factors of more-or-less conventional vessels. The principal dimensions shown below for the A3 and A2 versions of the ARV are used throughout this report. However, it should be noted that these vessel dimensions may change depending on the hull form recommendations of HSVA. In particular the optimum length-to-beam ratio may result in a vessel of reduced length and increased beam (a smaller L/B ratio is related to improved maneuvering in ice). The AGOR 23 has been included in the table for comparison purposes. Again, the AGOR 23 is more or less representative of the size vessel that would be required to meet **only the science space requirements** of the revised SMR.

	AGOR 23 Thomas G. Thompson	ARV Ice Class A3	ARV Ice Class A2
Length, Overall	273'-2"	320'-0"	300'-0"
Length, Waterline	252'-8"	305'-0"	280'-0"
Beam	52'-6"	70'-0"	64'-0"
Depth	26'-5"	34'-0"	30'-0"
Draft, Baseline	17'-0"	24'-0"	20'-0"
Displacement	3528 LTSW	8900 LTSW	6300 LTSW
Cubic Number	5,900	14,200	11,500

This report contains a brief discussion of the various structural design philosophies currently promulgated by regulatory agencies offering ice classifications. It appears that the new structural requirements outlined in "Proposals For The Revision of the Arctic Shipping Pollution Prevention Regulations", published by the Canadian Arctic Shipping Pollution Prevention Regulations (CASPPR) represent the most rational criteria available for vessels operating in the ARV's intended operating arena. In fact, these regulations must be complied with if the vessel is to operate in the Canadian Arctic.

The first conceptual design report (1991) suggested that substantial structural weight savings, and therefore increased deadweight capacity, may be possible if a Thyssen/Waas hull form were utilized. This is not entirely obvious if some derivative of this hull is used, however, we hope to investigate this area further during the upcoming conceptual design cycle.

The preliminary report on hull forms and performance predictions from HSVA is included in the appendix of this report. HSVA have investigated two candidate hull types: "modern conventional" hull forms employing a wedge shape bow; and Thyssen/Waas derivative hull forms. HSVA proposes certain modifications to existing Thyssen/Waas technology in order to make the vessel more maneuverable in ice leads and to reduce the amount of spray generated in open water. Both hull forms offer significantly better ice performance than existing conventional forms such as the Canadian R-Class or the American Polar class ice-breakers. Although no conclusive recommendations regarding hull form have been reached at this time, the selection of appropriate candidate hull forms will be the first order of business during the upcoming conceptual design cycle.

The HSVA report also discusses and recommends several possible features for improved maneuverability, including:

- Reducing the Length/Beam ratio as much as possible
- Employing a "downward breaking" hull form around the ship's waterline
- Heeling tanks for decreasing the turning diameter
- High performance rudders
- Bow thruster

This report concludes with a recommended course of action for the conceptual design cycle. We have been tasked by the ARV subcommittee with completing a new concept design and design report by 1 December 1992. In order to accomplish this we require the subcommittees input on the following key decisions:

- Will the vessel be an A3 class?
- Will the vessel be required to have a 90 day endurance or a 75 day endurance?
- Refined mission profile

The appendices to this report are contained in volume II. Included in the appendix is a copy of the current SMR; a table comparing the principal features of the ARV with existing similar vessels; and documentation of the endurance model used to determine fuel capacity requirements. As previously stated, the HSVA preliminary report on hull forms and performance prediction are included in the appendix.

Also included in the appendix is an annotated bibliography of some key published references that have been reviewed in the process of producing this report.

2. Operating Environment

The identified areas of operation for the ARV are the seas adjacent to Alaska (Bering, Chukchi and Beaufort), the Canadian Arctic Archipelago (including the Northwest Passage) and areas of the Eastern Arctic (Greenland Sea, Davis Straight and the Svalbard Archipelago). An ABS Ice Class A3 vessel would permit operations in all these areas. There would be some restrictions to these operations. Note that, in practice, seasonal conditions could further limit operations of the ARV.

Specifically, an Ice Class A3 vessel would be allowed to operate independently for short voyages into the Central Arctic Basin from July through September, independently around the Arctic offshore shelf from July through December and year round in first year ice. If escorted by a higher class vessel (A4 or greater), the ARV would be allowed to undertake longer operations in the Central Arctic Basin from July through November and year round operations in the Arctic offshore shelf.

ABS defines the Central Arctic Basin as all of the multi-year ice covered waters of the Arctic Ocean and Arctic Seas to the north from the boundary of the stable Arctic pack ice zone. The Arctic offshore shelf is defined as the Arctic waters within landfast and shear ice zones off the shores of continents, archipelagoes, and Greenland. The following table summarizes the ABS restrictions for an A3 vessel in terms of the identified areas.

Area	Independent	A4 Escort	A5 Escort
Bering Sea	Year around	Year around	Year around
Chuckchi Sea			
Offshore Shelf	July - December	Year around	Year around
Central Arctic	July - September	July - November	Year around
Beaufort Sea			
Offshore Shelf	July - December	Year around	Year around
Central Arctic	July - September	July - November	Year around
East Siberian Sea			
Ostrov Vrangelya	July - September	July - November	Year around
Canadian Arctic (see Note)			
Northwest Passage	July - December	Year around	Year around
Offshore Shelf	July - December	Year around	Year around
Central Arctic	July - September	July - November	Year around
Davis Straight	Year around	Year around	Year around
Greenland Sea			
Offshore Shelf	July - December	Year around	Year around
Central Arctic	July - September	July - November	Year around
Svalbard	July - December	Year around	Year around

Note: Operations in the Canadian Arctic are regulated by CASPPR and are subject to additional restrictions.

The current Canadian Arctic Shipping Pollution Prevention Regulations (CASPPR) restrict vessel operations to pre-approved zones. A Canadian Arctic Class 4, the anticipated classification for the ARV, would allow access to most of the Canadian Arctic archipelago and transit of the Northwest Passage between July 15 and December 31. Note that, due to recent experience involving significant damage to approved vessels, these rules are in the revision process. Of particular interest is the proposed revision of the ice zone concept to incorporate actual ice conditions on a scheduled basis. This technique for matching ship capability to actual route conditions is currently used by the Russians. A given vessel will not be guaranteed access to specific locations at specific times in the Canadian Arctic if the proposed regulations are enacted.

As noted, a given classification will not guarantee access to specific areas in the Arctic at specific times. This is due to the wide range of conditions which could occur at any given place and time in the Arctic. The following quotations from various sources give a qualitative feel for the Arctic environment.

J. Stubbs and M. Cook, Rules Applicable to the Design of Polar Icebreaking Vessels, SNAME Icetech '90.

> *"...much less is known of the [Arctic] environment in quantitative terms to assist in the ice class selection process. What has been established about polar ice conditions and how they influence ship design is that:*
>
> *-First year level ice ranges in thickness between 0 and 2 metres. This is twice that experienced in sub-arctic conditions and the ice is much stronger;*
>
> *-Fragments of much harder glacial ice are commonly seen floating in open water or are embedded within ice flows; and*
>
> *-Hard multi-year ice, with an average consolidated thickness of 3 to 4 metres is often prevalent in some areas of the polar regions for long periods."*

R. Voelker and F. Sedold, Ice Conditions along Alaskan Marine Transportation Routes", SNAME Icetech '90.

> *"Access to the Beaufort Sea by ships with little or no ice strengthening is possible in the months of August and September provided ice concentrations of less than fifty percent are acceptable for transit. If ice concentrations of ten percent or less are required, then a transit would be possible only in September. However, seasonal winds, air temperatures, and currents greatly influence the location of the ice edge. Multiyear ice floes occur and transits in this region by unstrengthened ships should be attempted only with care."*
>
> *"At a position 60 miles north of Prudhoe Bay, the icebreaker* Polar Sea *became trapped in an active shear ridge during the evening of November 21 and was able to free herself only after 5 days of effort."*
>
> *"Icebreaking ships that are designed for year-round capability in the north Bering Sea should have the capability of breaking four feet of level ice ..... Ships for year-round operation in the Chukchi Sea should be based on a much greater icebreaking capability than the Bering Sea."*
>
> *"Rubble ice floes occur throughout the Bering and Chukchi Seas and frequently stopped the POLAR Class icebreakers."*
>
> *"Ships transiting the north Chukchi Sea should expect to periodically encounter multi-year ice, but at a low frequency of encounter."*

C. Daley, Strength Requirements in the Proposed CASPPR, SNAME Icetech '90.

> *"Multi-year ice is the most significant hazard for ships transiting the Canadian Arctic."*

H. Soininen, Development of Ice Model Test Into a Reliable Tool for Icebreaking Ship Design, SNAME Icetech '90.

> *"Ice fields without any ice pressure due to wind are rare and usually found only at land fast ice close to coasts. On the open sea there are always dynamics due to wind and current. It may become extremely severe, as was the case in October 1983 at Wrangel Island [Ostrov Vrangelya], where an entire Soviet fleet was trapped."*

The preceeding quotes give some feel for the rigors of the Arctic environment in terms of areas where the ARV is currently intended to operate. Unrestricted, independent operations in the identified areas of the Arctic will require ice capability significantly beyond that described in the current SMR. A vessel with ABS Ice Class A3 will effectively be at the whim of seasonal conditions in terms of where and when it can be operated responsibly. This will complicate the trip planning process in that it will be difficult to plan very far in advance and there will always be a risk of not getting to the desired location. A means for effectively utilizing the vessel would be to have specific trips pre-planned so that they can be completed when favorable conditions occur.

A highly capable escort vessel might alleviate this problem in terms of environmental restrictions but will incur additional restraints. The use of an escort vessel to assist with a science operation has several additional drawbacks. It is inefficient to use two vessels to perform a one vessel job. This would, at a minimum, double the cost of a science operation. An escort is of limited use in a pressured ice field. The path cleared by the escort can, and commonly does, close in on the escorted vessel making an extensive and time consuming freeing operation necessary. Finally, there are very few U.S. icebreakers with the capability required to escort vessels into the Central Arctic Basin. This lack of available escort vessels could also hamper planning and execution of science missions.

3. Vessel Size

Three factors have a major influence on the vessel's size; the installed horsepower, the endurance and the science requirements. Of these factors, horsepower and endurance are related in that the fuel required to meet an endurance requirement is directly related to the horsepower of the machinery plant. The science requirements, such as number of scientists, clear deck space and laboratory space are separate factors as regards the vessel's size.

The horsepower and the type (direct diesel, diesel electric, turbine etc...) of the machinery plant determines the size of the machinery spaces and is related to the volume of fuel required. The necessary horsepower is based on the desired performance in open water and ice. In this case, performance in ice is the driving factor. Both regulatory requirements and analytical estimates are used to determine a suitable horsepower during the early stages of the design process. Model testing and more refined analyses are used to obtain improved estimates as the design evolves.

We have chosen to follow ABS guidelines for determining a suitable horsepower. Based on the intended operations, an ABS Ice Class A3 has been specified. This ice class would lead to a nominal requirement of 18,000 horsepower. Provision is made for adjusting this value to account for the performance capabilities of a given hull design. In our case, it seems reasonable to assume that a 16,000 horsepower machinery installation would be sufficient for obtaining the desired A3 classification based on a modern, more efficient hull design. However, we have conservatively assumed an 18,000 horsepower propulsion plant for this early stage of the conceptual design.

If more restricted operations are acceptable, an Ice Class A2 could be used. It should be noted again that, given an A4 escort, the A2 vessel would be classified by ABS for the same range of operations as an A3 vessel, but that, without an escort, it would have significantly less capability for operations in ice. The nominal required power would decrease to 9,000 horsepower which, again, could be further reduced for an efficient icebreaking hull design. This reduction in power would lead to an equivalent decrease in fuel requirements for a given endurance requirement.

Based on empirical data for similar vessels, we have estimated the underdeck volume required for the machinery spaces. Approximately 180,000 cubic feet will be required for the 18,000 horsepower vessel. This value drops to 85,000 cubic feet for the 9,000 horsepower vessel.

Currently, a 90 day endurance is specified for the ARV. By basing the vessel close to the desired area of operation, a similar science capability could be obtained with a decreased endurance requirement. Based on discussions with the ARV subcommittee and on review of available literature, the 90 and 75 day missions have been broken down as follows:

	90 Day		75 Day	
	Days	Fuel (LT)	Days	Fuel (LT)
Open Water (avg. 9.9 knots)	20	824	14	577
Towing (1' level ice)	12	248	10	207
Stationkeeping (ice)	20	236	16	189
Ice Docked (drifting)	10	29	10	29
Ice Transiting (3/4 power)	18	1171	15	976
Full Power Icebreaking	10	828	10	828
Totals	90	3336	75	2806

The fuel values were calculated using estimated horsepower values for each mode of operation and utilize a specific fuel consumption of 0.36 lbs/BHP-hr. The volume required to enclose the estimated quantity of fuel is 138,000 cubic feet for a 90 day mission and 116,000 cubic feet for a 75 day mission. An additional volume of cofferdams is required in way of the fuel tanks in order to operate in the Canadian Arctic (per CASPPR). This volume is estimated to be 50,000 cubic feet for a 90 day endurance vessel and 42,000 cubic feet for a 75 day endurance vessel.

The open water transit fuel requirements were adjusted for anticipated seas. Using this information, an average power requirement for open water operations is calculated. Note that the probability distribution used is an assumed value and can be refined once specific routes are identified. Open water resistance, wind resistance and wave resistance are calculated using computer software.

The number of days for the open water transit portion of the mission is based on the estimated time to reach the ice edge from the vessel's base of operations. For the western area this was assumed to be the distance between Seward and the Bering Straight and for the eastern area the distance between Boston and the Davis Straight.

Sea State	Probability	Speed (Knots)
0	0.000	14
2	0.057	14
3	0.197	14
4	0.283	12
5	0.195	9
6	0.175	7
7	0.076	5
8	0.017	2
Average Value		9.948

Power required for breaking level ice is estimated using basic analytical techniques and can be refined using model tests and/or more refined analyses. We have assumed a hull similar to the Canadian R-Class icebreakers for the ARV due to the similarity in gross dimensions and the availability of ice resistance data for this class of vessels. Based on data provided by HSVA, the vessel can break level ice 5 feet thick at a speed of 1.5 knots or ice 4 feet thick at a speed of 3.3 knots when operating at full power (18000 BHP). We have assumed 3/4 power for ice transit in order to account for the variable nature of such an operation. The vessel could encounter open leads, level ice of varying thickness, multi-year ice, ridges of variable depth and a large number of other ice conditions during transit operations.

Additional power requirements (ships service) are estimated based on the number of people on board and the type of operations being performed and are estimated to be an additional 650 BHP.

An estimate of the fuel required to meet the specified endurance is then calculated using the estimated fuel consumption of the power plant, the estimated total power requirements and the duration of operations.

We created a computer model for calculating the required fuel based on this methodology. The resulting quantities of fuel required for nominal ABS class A3 and A2 vessels and endurance requirements of 90 and 75 days are summarized in the following table.

Class	Horsepower	90 days Fuel (gal's.)	75 days Fuel (gal's.)
A3	18,000	1,031,000	867,000
A2	9,000	672,000	553,000

The vessel's size can be decreased if the endurance requirement is reduced to 75 days. The volume reduction would be approximately equal to a length reduction of about 12 feet of midbody for the A3 vessel and 11 feet of midbody for the A2 vessel.

The quantities of other consumables, such as potable water, dry stores and lube oil, are estimated utilizing standard conceptual design values. Some of these items are linked to the number of scientists on board and as such are interrelated with the science requirements.

Consumable	90 Day Mission		75 Day Mission	
	Weight (LT)	Volume (ft^3)	Weight (LT)	Volume (ft^3)
Fresh Water [1]	110	4,200	92	3,500
Lube Oil	24	1,000	20	800
Dry Stores	15	24,000	12	21,000
Cold Stores	8	7,800	7	6,500
Aviation Fuel	32	1,600	32	1,600

The desired laboratory space and open deck space are used to determine the minimum length and breadth of the main deck. The current SMR specifies 4,000 square feet of interior lab space and 3,000 square feet of exterior deck space. This compares with the scientific space provided on the *R/V Thomas Thompson*. This is a 273' vessel designed to support 28 scientists in fixed accommodations and an additional 8 scientists in portable vans for a mission of 62 days. This is equivalent to the number of scientists specified in the SMR for the Arctic Research Vessel. Based on the space devoted to science, we feel that the *Thompson* (see the following table) is the smallest vessel which could meet the science related requirements identified in the SMR. In fact, due to the increased endurance and ice related performance requirements, the minimum size vessel to meet the entire SMR will be considerably larger.

The principal characteristics of the *Thompson* and the A3 and A2 ARV concepts are summarized in the following table. An A2 vessel with an endurance of 75 days represents the smallest vessel which could meet the science requirements, other than ice capability, of the current SMR.

Vessel	Thompson	ARV Class A3	ARV Class A2
Length Over All	273.2	320	300
Length Waterline	252.7	305	280
Beam	52.5	70	64
Depth	26.5	34	30
Design Draft	17	24	20
Displacement @ DWL.	3,528	8,900	6,300
Endurance	62	90	90
Propulsion, BHP	6,000	18,000	9,000
Science Party	35	35	35
Lab Area	3,925	4,000	4,000
Deck Space Aft	2,300	2,000	2,000
Deck Space Side	1,200	1,000	1,000

4. Hull Form

HSVA, The Glosten Associate's ice technology subconsultant, was tasked with reporting on potential hull forms suitable for the ARV and estimating the performance associated with these hulls in the ice conditions dictated by the SMR. A complete copy of their preliminary report on this subject is contained in the appendix. A brief synopsis of their commentary regarding hull form is summarized here. Performance predictions of the candidate hulls are discussed in section 5.

Two general hull types were chosen by HSVA for investigation: a combination open water/ice-breaking hull described as a "wedge bow ice breaker"; and a Thyssen/Waas derivative hull. Both types have advantages and disadvantages within the following areas of operation deemed important for the ARV:

- Speed versus propulsion power in open water
- Sea-keeping behavior
- Level ice-breaking capability
- Maneuvering capability

All of these characteristics are significantly affected by the bow shape. The bow area, at the waterline, accounts for 70% to 80% of the total resistance in ice as well as having a significant impact on seakeeping qualities. Typical stem angles for ice breakers range from 12 to 45 degrees with most being around 20 degrees.

For a "modern conventional wedge bow" hull form (fig. 3.4-3.6 in the HSVA report), the following features are recommended for improved ice performance:

- Small stem angles in the waterline area and large stem angles above and below the waterline in order to reduce the length of the bow.

- Small buttock angles and large frame and waterline angles to increase the vertical component of ice breaking force.

- Incorporation of an ice clearing wedge similar to that of the SOROKIN and ODEN.

Additionally, HSVA has the following recommendations relating to turning ability and maneuvering in ice:

- Incorporate reamers for improved turning ability.

- Improved stern shape consisting of large frame angles to improve the ice breaking ability of the stern.

- Reduce the length/beam ratio as much as possible.

- Install heeling tanks. These can reduce the turning diameter considerably.

- Utilize high performance rudders.

- Install a bow thruster.

HSVA recommends the following modifications to the Thyssen/Waas type candidate hull in order to improve performance in ice and open water:

- Incorporation of "wave absorbers" similar to the intermediate runners on the SOROKIN but in this case located entirely above the ice-breaking waterline. These are intended to reduce slamming impact loads. Additionally, it is claimed that the centerline and outboard ice-breaking runners act as wave impact absorbers.

- A "spray spoiler" is incorporated into the bow. This appears to be a bow overhang with a concave surface on it's underside that would presumably act as a deflector for spray.

- A relatively high (18' at station 1) ice wedge is incorporated to clear ice. The sole plate of this wedge is suggested as a good, ice-free, location for transducers or clean water intakes. A bow thruster could be located immediately aft within the wedge.

- A reamer is incorporated to improve the turning ability. To further improve the maneuverability in ice it is suggested that the bottom of the reamer be sloped inboard such that a side force can be developed when the reamer strikes an ice floe thereby producing a steering effect on the ship.

5. Performance Prediction

It should be realized that predicting the performance of ice capable ships is a relatively new endeavor. Modern analytical and model testing techniques essentially date from the 1950's. Because performance prediction techniques are in their infancy and because actual operating environments are not of an easily modelled homogeneous nature, the accuracy of performance predictions methods are not nearly as accurate as their "open-water" counterparts. In reviewing current literature on the subject, the estimated error from model tests to full scale has been claimed to range anywhere from ±20% to ±100% with 20% being the most commonly mentioned value.

Most performance prediction methods, both analytical and model tests, are essentially based on predicting the performance of a vessel in continuous motion in level ice. The performance in ridges, hummocks, etc. are not as amenable to analysis due to the high degree of variability of these features in nature and can only be predicted in a relatively elementary fashion.

Typically, the performance of new vessel designs are estimated using analytical techniques at the conceptual design level. As the design progresses to the preliminary and detail design level, model tests are performed, sometimes in conjunction with additional analytical techniques.

The greatest value of the performance predictions are not necessarily in determining precisely how a vessel might perform in an actual ice environment (the number of environmental variables is large: ice thickness, ice strength, snow cover, temperature, ridges, hummocks, brash, re-frozen channel, etc.), but more as a tool for comparing the design with existing vessels whose level ice performance is known.

HSVA Performance Predictions

HSVA has employed a semi-emperical technique, Lindqvist's method, to predict the performance of the candidate hull forms in various level ice thicknesses. To validate the method HSVA calculated the resistance of two vessel's whose full-scale ice performance has been documented, the RADISSON and the MUDYUG. The RADISSON is a conventional hull while the MUDYUG is a Thyssen/Waas hull. By assuming some logical values for friction coefficients and thrust deduction, HSVA was able to find good correlation between the predicted results and the full-scale values.

The following key assumptions were made for the resistance prediction procedure:

- Friction coefficient between hull and snow covered ice is 0.1. Snow cover of 0.1 m (4") was used in all cases.
- Twin screw, controllable pitch, 4 bladed propellers of 3.8 m (12.5') diameter were assumed.
- A power of 13 MW (17,300 HP) with 500 kW (700 HP) transmission losses was assumed. Total installed propulsion power is 18,000 HP.
- Thrust deduction due to ice/propeller interaction was estimated from the full scale trials of the RADISSON to be between 0 and 38% at a speed range of 4 to 7.5 knots. For the conventional hulls a maximum efficiency loss of 20% was used.
- A maximum efficiency loss due to propeller/ice interaction for the Thyssen/Waas hulls was set at 5%. This was determined from model and full-scale test results.

Based on the foregoing assumptions, HSVA estimated the level ice performance of two existing; two "modern conventional"; and three Thyssen/Waas hull forms as follows:

Vessel	Bow Type	Stem Angle	WL 1/2 Angle	Ice Wedge
Existing Hull Forms (Modified to ARV dimensions)				
R-Class	Conventional	15 deg	12 deg	No
Polarstern	Conventional	20 deg	25 deg	No
Modern Conventional Hulls				
MOCO-1	Modern	20 deg	xx deg	Yes
MOCO-5	Modern w/balcony	15 deg	xx deg	Yes
Thyssen/Waas Hulls				
TW-12	Flat	12 deg	90 deg	Yes
TW-16	Flat	16 deg	90 deg	Yes
TW-20	Flat	20 deg	90 deg	Yes

From the performance graphs provided by HSVA we can estimate the approximate power levels required for the various hulls at a similar operating condition. The following table shows estimated propulsion horsepower required for moving the vessel through 4 feet of level ice at 3 knots. The reduction in thrust due to propeller/ice interaction has been estimated at approximately 20% for the conventional and modern conventional hulls and 5% for the Thyssen/Waas hulls.

Vessel	Approximate Horsepower Required for 4' ice @ 3 knots
R-Class	17,800
Polarstern	17,000
MOCO-1	16,000
MOCO-5	15,400
TW-12	11,500
TW-16	12,300
TW-20	12,900

It must be kept in mind that these estimated horsepowers represent uniform level ice-breaking and do not necessarily relate directly to the power that may be required in actual full scale operating conditions.

6. Hull Structure

a. Introduction

Historically, empirical methods and simple reinforcement of standard open water hull structures have been used as means for development of ice capable vessel structures. Recent operating experience involving icebreakers in the Canadian Arctic has led to the conclusion that a more rational approach is required for their structural design. Of special concern are the nature of the environmental loads (level ice, ice ridges, multi-year ice, glacial ice) and ice/ship interaction. Following is a discussion of current design methodology, regulatory requirements and hull form as related to ice capable vessel structural design.

b. Design Methodology

A typical method for the development of ship structures is to identify the geographical operating area, determine environmental loads associated with this area, determine acceptable strength criteria, identify geometric constraints and design structure using the information collected. This method is currently being applied to USCG icebreaker designs and is incorporated into the proposed revised CASPPR. We propose to use this methodology through use of the proposed revised CASPPR regulations for development of the ARV's structural design.

The loads specifically applicable to ice capable vessels are impact loads due to ramming, impact loads due to ice collisions, pressure loads due to breaking ice and pressure loads due to being beset in ice. In addition, the structure must be adequate for the hydrostatic, hydrodynamic and wave bending loads associated with operations in open water. These loads are generally much lower than those associated with ice interaction.

Ice loads are currently estimated using a number of techniques including model testing, full scale testing and analytical methods (empirical, semi-empirical and purely analytical). Identification of the area and season for operations is imperative in determination of suitable ice loads for the development of the structural design. Based on the current mission profile for the ARV, the design pressure for the bow plating per the proposed CASPPR would be about 3500 psi and for framing about 750 psi [1].

Efforts have been made to develop design loads based on a probabilistic/ statistical description of ice in a manner similar to that used for determining wave loads in open water. While this method is theoretically correct, the limited environmental data available greatly reduces the level of confidence in the resulting loads.

Current design practice for the structure of icebreaking vessels allows for some amount of permanent deformation due to design ice loads. The magnitude of this deformation is kept well below construction tolerances so as to avoid degrading hydrodynamic performance. This plastic design criteria is applied to both shell plate and frames. Experience with vessels operating in ice has led to an increased concern over the stability of frames against tripping and buckling [1]. Determination of frame stability is becoming a standard part of the structural design process.

c. Regulatory Requirements

The predominant icebreaker strength philosophy among regulatory agencies is to base scantlings on the pressures associated with breaking level ice of varying thicknesses. This philosophy is followed by ABS, Lloyds, Det Norske Veritas, Russia and the Peoples Republic of China.

The Finnish-Swedish Ice Class Rules, which incorporate analysis of ice damage experience in the Baltic, have been adopted as optional rules by ABS, Lloyds, Bureau Veritas and the Nippon Kaiji Kyokai. This philosophy utilizes estimated ice pressures in terms of ship characteristics. The Soviet and Polish regulations have a similar philosophy for determining icebreaker strength and include regular notices based on current ice conditions to restrict vessel operations.

As noted earlier, the USCG employs a "rational" design system based on environmental data and plastic design techniques for the development of icebreaker structures [2,3].

The existing CASPPR identifies ice zones to improve structural compatibility with areas and seasons of operation. The proposed revised CASPPR (not yet in force) take this ice zone concept a step farther, in a manner similar to the Russians, by restricting access on the basis of prevailing ice conditions. Further, the proposed regulations incorporate recent experience into methods for determining the strength of structural members. Both the existing and proposed regulations focus on preventing pollution in the Canadian Arctic. This is a different objective than that of the regulatory agencies whose concern is primarily for the safety of the vessel and crew.

Due to the very different philosophies of the various regulatory guidelines, comparison between any given authority and another is a difficult process. A method which has been used is to design the structure for a specific vessel utilizing each of the codes to be compared. A good example of the application of this technique can be found in the Ship Structure Committee Report " A Rational Basis for Selection of Ice Strengthening Criteria for Ships" [3]. This effort concluded that:

> The existing CASPPR regulations were the most conservative for level ice less than 4' thick.
>
> For thicknesses greater than 4', the Finnish-Swedish Rules are the most conservative.
>
> The load carrying capability of the rule transverse frames is considerably less than that of the rule shell plating.
>
> In general, there is poor agreement among the various regulatory bodies.

Note that this comparison was performed prior to the completion of the proposed revised CASPRR.

Many of the regulatory requirements for icebreaker structure are difficult to apply properly to a given vessel due to insufficient information relating the criteria to areas and seasons of operation. In addition, the scantlings developed from many of the current regulations for an icebreaker's structure result in an imbalanced structural system. Specifically, the shell plate will have a much greater ability to withstand ice loads than the supporting frames. Most of the failures documented for existing ice vessels are related to framing [3,4].

Of the regulatory guidelines available for review, the proposed CASPPR have been identified as the most realistic in terms of icebreaker structure. Unfortunately, we cannot easily identify what class the ARV would be under the proposed regulations, however, for operations in first year ice up to 2 meters thick (6.5 ft.) a CAC4 ice class would be appropriate. Using the existing CASPPR, an Arctic Class 3 vessel would allow limited access to the central Arctic Basin.

Note that significant damage has occurred to CASPPR Arctic Class vessels operating in approved ice zones. This is one of the main reasons for revising the existing CASPPR. The damage has been related to extreme ice conditions not predicted for the specific ice zones and to structural deficiencies relating to frame stability [4]. In addition, the existing regulations do not adequately relate ice loads to vessel displacement [4].

d. Influence of Hull Form on Structure

Recent investigations and full scale testing indicate that alterations in hull form can reduce the loads associated with icebreaking. Specifically, it has been found that utilizing bending and/or shearing to break ice requires much less force than the crushing mechanism employed in classical icebreaking shapes. The spoon bows developed by Wartsila and CANMAR utilize a shallow entry to facilitate the bending mechanism for breaking ice. The Thyssen/Waas hull form utilizes a combined shearing and bending mechanism to break ice. It is likely that scantlings for both of these hull designs can be lighter than those required for a conventional icebreaking vessel which employs crushing to break ice.

e. Conclusions

The conceptual structural design for the ARV can best be done utilizing the requirements outlined in the proposed CASPPR. In fact, for operations in the Canadian Arctic, it will be necessary to meet these requirements. Once the hull structure's design is developed, it can then be submitted to ABS for approval. This submittal will need to demonstrate the strength of the vessel's structure in terms of icebreaking/transiting capability and must include drawings and supporting analyses. Based on a review of the proposed CASPPR and ABS rules, a vessel designed to meet ARV mission requirements and the proposed CASPPR will have a hull structure equivalent to ABS Ice Class A3.

Although some new hull forms require less hull strength for breaking ice, the scantling and associated weight reductions cannot be quantified at this time. Reducing scantlings below regulatory guidelines has been successfully accomplished, however, there is an increased risk of structural damage and obtaining regulatory approval will be considerably more difficult.

f. References

1. Daley
   Strength Requirements in the Proposed CASPPR
   1990, Proceedings of SNAME ICE-TECH, Paper X

2. Daidola, Sheinberg
   A Procedure for the Structural Design of Icebreakers and Other Ships Navigating in Ice
   1988, Transactions of SNAME, Vol. 96

3. Coburn, Debford, Montgomery, Nawwar, Dane
   A Rational Basis for the Selection of Ice Strengthening Criteria for Ships
   1981, Ship Structures Committee, Report No. SSC-309

4. Churcher, Blanchet, Johansson
   Ice Load Criteria for Arctic Vessels
   1990, Proceedings of SNAME ICE-TECH, Paper W

7. Conceptual Design

As with the May 1991 effort we anticipate proceeding through a conceptual design "spiral". The conceptual design report would discuss the primary areas of interest affecting the overall design of the vessel. Subjects that will be discussed in some detail would include the following:

- Principal dimensions and capacities
  A refinement of the gross volumes assumed in this report would be undertaken. Science spaces, storage spaces, accommodation, tankage, etc. will be defined.

- Resistance, propulsion and seakeeping
  The open-water and ice resistance, as well as seakeeping performance of the two candidate hulls will be refined as much as possible using analytical methods. Refined mission profiles, to the extent they may be estimated, will be used in further developing fuel consumption estimates.

- General Arrangements
  A drawing package showing conceptual general arrangements will be developed. The deck arrangements for the two candidate hulls may be somewhat different due to differing L/B ratios. This will be discussed in the design report.

- Propulsion and auxiliary machinery
  A discussion of options for main propulsion machinery, e.g., diesel electric, direct drive, CP propellers, etc. will be developed. A recommendation will be made in the report as to which propulsion scheme would best satisfy the requirements of the ARV.

- Economic Analysis
  A conceptual level construction cost estimate and an estimate of operating cost will be reported on.

- Preliminary/contract design
  An outline of the preliminary design effort, including a recommended model test program will be developed.

APPENDIX V

REVISED
SCIENTIFIC MISSION REQUIREMENTS FOR AN ARCTIC RESEARCH VESSEL
July 1992

Preamble

A conceptual design of an Arctic Research Vessel was completed in May 1991 and distributed to the several hundred members of the Arctic science community for their comments. As part of the University-National Oceanographic Laboratory System (UNOLS) Fleet Improvement Committee (FIC), the Arctic Research Vessel (ARV) subcommittee is continuing the design process for the construction of an Arctic Research Vessel. The previous design was based on the February 1989 UNOLS Scientific Mission Requirements for an Intermediate Ice-Capable, General-Purpose Oceanographic Research Vessel. On the basis of the responses to that design and recent developments in Arctic science, the Scientific Mission Requirements have been refined by the ARV subcommittee. UNOLS now requests that the science community respond to these modified requirements to assist in the next step of the design process. We plan to complete the revision of the SMR in late August and to complete a modified ARV conceptual design within the next few months, followed shortly by the preliminary and final designs. Funds for the design process have been included in the 1993 federal budget request for the NSF and the plan calls for funds for the construction in FY 1994 and FY 1995. The ship could be outfitted and sailing in 1996.

The major changes in the ARV SMR are an increase in the ice capability and the number scientists that the ship will accommodate. Since these two factors are essential in controlling vessel size, the ship able to accomplish these requirements will be substantially larger than the one presented in the original 1991 conceptual design. The revised SMR follows and the UNOLS FIC ARV subcommittee would appreciate your comments on this version. We will attempt to incorporate them into the next design stages as we have done previously.

The American Bureau of Shipping ice classification of A3 in this version of the SMR would allow the vessel to operate independently in the central Arctic basin (multi-year ice) for short term, short distances from July through September and in the Arctic offshore shelf from July through December. This is an increase from the A2 classification of the conceptual design which would have offered no ability to operate independently in the central Arctic basin and would allow independent operation in the Arctic offshore shelf from August through October. When escorted by an A5 or greater vessel, the A3 ARV could operate in the Arctic basin at other times of the year whereas an A2 could not.

The ARV subcommittee suggests the A3 ice classification based on a balance between the desires of the Arctic science community and the ability of the United States to build and operate the vessel. Clearly, the ultimate vessel would be a nuclear powered ice breaker capable of reaching the North Pole at any time. We feel that that is not a technical or political reality. At the other extreme, a vessel with a modest improvement of the ice capabilities of R/V *Alpha Helix* is not compatible with the science mission.

As the size and cost of the vessel increase, the technical and political risks also increase. For example, the "rule" horsepower for an A2 vessel is 9000 horsepower whereas an A3 ice capability requires 18,000. The actual horsepower requirements are subject to a number of factors influenced by hull geometry. An unconventional hull form such as a Thyssen/Waas hull might permit a special approval for less horsepower for a given ice rating. We plan to use recent technological advances to obtain the maximum ice capability at the least expensive cost. With regard to political risks, endorsement of this vessel by the U.S. Arctic science community will be imperative to obtain congressional funding for its construction, especially in light of the problems that other large science programs have been having in the political arena.

As the next step in the Arctic Research Vessel construction, please review these Scientific Mission Requirements and send your comments to myself or one of members of the ARV subcommittee. Your comments will be most useful if sent by 17 August 1992 but since the design is evolving they will continue to be useful throughout the process.

UNOLS FIC ARV subcommittee

Dr. Knut Aagaard
NOAA/PMEL
7600 Sand Point Way NE
Seattle, Washington 98115
(206) 526-6806 K.AAGAARD

Dr. Vera Alexander
Institute of Marine Science
University of Alaska Fairbanks
Fairbanks, Alaska 99775-1080
(907) 474-7531 V.ALEXANDER

Ms. E. R. Dieter
Ocean Sciences
National Science Foundation
Washington, D.C. 20550
(202) 357-7837 E.DIETER

Capt. R. P. Dinsmore
Woods Hole Oceanographic Institute
Woods Hole, Massachusetts 02543
(617)548-1400 WOODS.HOLE

Dr. Robert Elsner
Institute of Marine Science
University of Alaska Fairbanks
Fairbanks, Alaska 99775-1080
(907) 474-7795 ALASKA.INST

Dr. Marcus G. Langseth
Lamont-Doherty Geological Observatory
Palisades, NY 10964
(914) 359-2900 M.LANGSETH

Dr. Thomas C. Royer
Institute of Marine Science
University of Alaska Fairbanks
Fairbanks, Alaska 99775-1080
(907) 474-7835 T.ROYER

Dr. Sharon Smith
Brookhaven National Laboratory
Building 318
Upton, NY 11973
(516) 282-2835 S.SMITH.SHARON

31 July 1992

UNOLS Fleet Improvement Committee

ARCTIC RESEARCH VESSEL SCIENTIFIC MISSION REQUIREMENTS July 1992

Size

- The size ultimately is determined by the requirements. However, it is intended that this be a high endurance, Class I, ship which has significant ice capability. Draft restrictions will be determined by the propulsion and seakeeping requirements.

Endurance

- Ninety days; providing the ability to transit 30 days at cruising speed, 30 days station work and 30 days hotel service. 15,000 mile total range. A typical cruise might involve 45 science days of which 10 days might be using full power in the ice.

Ice Capability

- The ship should have the ability to operate in continuous first year ice and of maintaining a speed of 3 kts in 3.5-4' continuous ice cover and capable of transiting 7' ridges by ramming. This corresponds to American Bureau of Shipping A3 ice classification. This would allow independent, short term, short distance entries into the central Arctic basin (multi-year ice) from July through September. It could operate in the Arctic offshore shelf from July through December. When escorted by a vessel with an ice classification of A4 or greater, it could operate in the central Arctic from July through November and at all times in the Arctic offshore shelf. With an escort vessel of ice rating of A5 or greater, this research vessel could operate in the Arctic basin at other times of the year. These abilities are approximate and would depend on local conditions. The ship must be able to withstand being beset by ice. It should also conform to Canadian specifications for ice worthiness. The operating temperature range should be from -40 to 40°C.

Accommodations

- Thirty five scientific personnel in two-person staterooms. Twenty four to twenty six crew berths with thirteen being single staterooms. Provide a science library lounge with conference room capability. Provide a folding bulkhead in the library/conference room. There should be a science office with a chart table. Provide for a general ship's office. Provide a mud room with washer and dryer on the main deck. Provide a properly outfitted exercise room. All public spaces will be common use, that is, no segregation of scientists and crew.

Speed

- 14 kts cruising; 12 kts sustainable through Sea State 4. Speed control to plus/minus 0.2 kts in the 2-7 kts range and plus/minus 0.1 in the 0-2 kts range.

Seakeeping

- Maintain science operations with the following spee n the following sea states:
  - 12 kts through S.S. 5
  - 9 kts through S.S. 6
  - 7 kts through S.S. 7

- Emphasis is to be on accelerations in vessel coordinates, deck wetness and slamming. Motion displacements are secondary. The vessel features are to be designed to minimize the effect of spray icing.

Station Keeping

- Maneuver in ice leads and maintain station in ice so as to allow deployment of instruments over the side or stern. In open seas, maintain station and work in sea states through S.S. 5. Emphasis on ice operations will limit high performance station keeping, but vessel should have thrusters or equivalent maneuvering devices to maintain stations at best heading in 25 kt winds and one kt current. Thrusters should be installed with due regard to sonar and echo sounding requirements. The method used for deploying instruments in ice over the side or stern is to create a lee with this vessel. This means that the vessel must have the ability to "crab" sideways. Both sides of the vessel must be visible from the bridge. This implies bridge wings.

Deck Working Area

- Spacious stern working area of 3000 sq ft minimum with about 1000 sq ft enclosed (minimum of 10 ft clearance overhead) for weather protection. Contiguous waist-level work area along one side 8 x 100 ft minimum to allow piston coring. Provide for deck loading up to 1500 lbs/sq.ft. and an aggregate total of 100 tons. Highly flexible to accommodate large and heavy equipment. Removable bulwarks in selected locations. Dry main working deck not greater than 7-10 ft above the waterline. Usable clear foredeck area to accommodate specialized towers and booms extending beyond bow wave. All working decks accessible to power, water, air and data and voice communication ports. A "Baltic" room with door is to be provided. Deck hatches should be hydraulically actuated and dogged. Provide space for incubators near to the location of the isotope van. Considerations should be made to minimize ice build-up on superstructure and hull during severe icing conditions. All weather decks should be provided through the provision of heat or deck surfaces such as wood to allow for sure footing during freezing conditions. Exterior decks should be cambered to provide for proper drainage. One inch bolt downs, on a 2 x 2 ft grid are to be installed on all working decks and hold decks.

Cranes

- A suite of modern cranes to handle heavier and larger equipment than at present: (1) to reach working deck areas and off-load vans and heavy equipment up to 20,000 lbs; (2) articulated to work close to deck and water/ice surface; (3) to handle overside loads up to 5000 lbs 30 ft from the side and up to 10,000 lbs closer to the side; (4) usable as overside cable fairleads for towing at sea; (5) a crane rated for manned egress onto the ice surface. Have articulated cranes on both corners of the aft working deck for over-side work. Arrange these cranes so that they can work in tandem.

Winches

- Oceanographic winch systems providing fine control (0.5 m/min), load compensation, constant tensioning and constant parameter following. Cable with multiple conductors and wire monitoring systems with inputs to laboratory panels and shipboard recording systems. Local and remote controls. Ability to string two wires at the same time at all overside handling locations.

- Permanently installed general purpose winches should include:
  - Two hydrographic-type winches capable of handling 30,000 ft of wire rope electromechanical cable having diameters from 1/4" to 3/8".
  - One heavy winch complex capable of handling 40,000 ft of 9/16" wire /synthetic fiber rope; or 30,000 ft of 0.68 electromechanical cable (up to 10 KVA power transmission) or fiberoptics cable. This is envisioned as one winch with multiple storage drums that could be interchanged.
  - Additional special purpose winches may be installed temporarily at various locations along the working decks. Winch sizes may range up to 30 tons (140 sq ft) and have power demands up to 300 hp.
  - Sheltered winch control station(s) located for optimum operator visibility with reliable communications to laboratories and ship control stations.
  - Two capstans to be located on the aft working deck.
  - All winches should be located below decks to limit their exposure to weather.

Overside Handling

- Various frames and other handling gear to accommodate wire, cable and free launched arrays, one of which should have a maximum hoist capacity of 30,000 lbs. Matched to work with winch and crane locations but able to relocate as necessary.

- Stern A-frame to have a 20 ft minimum horizontal, 25 ft vertical clearance; 12 ft inboard and outboard reaches.

- Heated staging and sampling area with overhead rail and 15 ft clearance at an optimum overside working area.

- Capability to operate overside handling rigs along the forward and aft working decks.

- Sheltered control stations to give operator protection and operations monitoring and be located to provide maximum visibility of overside work.

Towing

- Capable of towing large scientific packages up to 10,000 lbs horizontal tension at 6 kts and 25,000 lbs at 2.5 kts. Capable of towing in ice-covered seas and protecting those packages while towing.

Laboratories

- Approximately 4000 sq ft of laboratory space including: Main lab area (2000 sq ft) flexible for frequent subdivision providing smaller specialized labs;

Analytical Lab (300 sq ft) with no exterior bulkheads and stable temperature control and Wet Lab (300 sq ft), both located contiguous to sampling areas; Electronics/Computer Lab and associated user space (600 sq ft); two climate controlled chambers (150 sq ft) capable of maintaining -2°C (one suitable for primary productivity measurements); and freezer space (150 sq ft).

- Labs should be located so that none serve as general passageways. Access between labs should be convenient with wide doors and passageways.

- Labs to be fabricated using uncontaminated and "clean" materials and contracted to be maintained as such. Furnishings, HVAC, doors, hatches, cable runs and fitting to be planned for maximum lab cleanliness.

- Fume hoods to be installed permanently in the Main Lab and Analytical Lab. Wet Lab shall have provision for temporary installation of fume hoods.

- Provide routine dive locker with air handling equipment.

- Provide adequate lighting in labs and throughout the ship.

- Provide a space for ten 20-gallon aquariums.

- Provide a clean seawater scoop with a small lab nearby. Intake should be insulated.

- Provide an anteroom to the constant temperature lab.

- Cabinetry shall be high grade laboratory quality, including flexible through the use of unistruts on bulkheads, overheads and decks.

- Heating, ventilation and air conditioning (HVAC) as appropriate for laboratories, vans and other science spaces served. Laboratories must maintain temperature of 60-75°F, 50% relative humidity and 9-11 air exchanges per hour. Ventilation noise levels should be low in the labs and staterooms. Filtered air to be provided to Analytical Lab. Labs to be furnished with 110v and 220v AC electrical power with about 10-volt amperes per square foot of lab deck area. Total estimated laboratory power demand is 100 KVA, of which 15 KVA is to be uninterrupted clean power. Each lab area is to have uninterrupted clean power on a separate circuit. Uncontaminated sea water supply to most laboratories, vans and several key deck areas. Compressed air supply to be clean and oil free.

- All labs are to be on the main deck.

- Provide for a dark room (75 sq ft).

- Two locations are required for the meteorological equipment; one well forward of the mast for the IMET installation and one on top of the wheelhouse.

- Provide a staging area with an aft facing door. This is to be suitable for housing ROVs, SeaMark and others.

- Provide a partially protected open working deck area for formalin.

- Public heads are to be provided in the vicinity of the labs.
- All accesses to labs from the working deck are to have removable or dropdown sills. The central passageway between the labs is to access the aft working deck area.
- Provide a HAZMAT storage area on the main deck.
- Provide an explosives locker (1500 cu ft).
- Provide a gravimeter room.

Vans

- To carry up to four standardized 8 ft x 20 ft portable deck vans which may be laboratory, storage or other specialized use. Hook-up provision for power, HVAC, fresh water, uncontaminated seawater, compressed air, drains, communications, data and shipboard monitoring systems. Vans much have heated water and sewage lines. Vans should have direct access to ship interior but located in wave sheltered spaces. Arrangements should allow two vans to be linked together. Vans should be capable of withstanding Arctic climate.
- Capability to carry additional portable non-standard vans (200 sq ft) on super structure and working decks. Supporting connections at several locations around the ship including the foredeck.

Workboats

- At least one 21 ft inflatable (or semi-rigid) boat located for ease of launching and recovery. A 20 ft Norwegian style ice boat should be included.
- Room should be allowed for a 25-30 ft workboat as optional equipment in place of a van.

Helicopter

- Provision for the landing, fueling and general servicing of a small helicopter such as an MBB BO 105 should be included. This should require a fuel storage of 9,000-12,000 gallons of fuel. The accommodations for the pilot and mechanic will come out of the science complement.

Science Storage

- Total of 20,000 cu ft of scientific storage accessible to labs by interior and weatherdeck hatches and elevators. Half to include suitable shelving, ranks and tie-downs; remainder to be open hold space. The open hold should be equipped with heavy duty hold-downs on 2 ft centers.

Acoustical Systems

- Ship should be acoustically quiet as practicable in the choice of all shipboard systems and their location and installation. Design target is underway conventional echo sounding in Sea State 4 and acoustical dynamic positioning through Sea State 5.
- Ship to have conventional 12 kHz and 3.5 kHz echo sounding systems.

- Provide for an Acoustic Doppler Current Profiling (ADCP) broad band system with two hull mounted transducers for redundancy.

- Provide two 20" transducer wells, one forward and one aft. The forward transducer well will contain one 3.5 kHz, one 12 kHz and two ADCP transducers.

- The aft transducer well will contain one 3.5 kHz and one 12 kHz transducer and space for two spares.

- Provide a large pressurized sea chest (4 ft x 8 ft) to be located at an optimum acoustic location for at sea installation and servicing of transponders and transducers.

- Provide pressurized instrument wells forward and aft.

- Provide space in the machinery room for two air compressors capable of generating 1000 scfm for single channel seismic work.

- Provide multibeam echo sounding capability.

- Provide a Doppler speed log.

Navigation/Communications

- Global Positioning System (GPS) with appropriate interfaces to data systems and ship control processors.

Internal Communications

- Internal communication system providing high quality voice communications throughout all science spaces and working areas.

- Data transmissions, monitoring and recording system available throughout science spaces including vans and key working areas.

- Closed circuit television monitoring of working areas.

- Monitors for all ship control, environmental parameters, science and overside equipment performance to be available in selected science spaces.

External Communications

- Reliable voice channel for continuous communications to shore stations (including home laboratories), other ships, boats and aircraft. This includes satellite, VHF, and UHF. Particular attention should be paid to the problems of access to communication satellites at high latitudes.
- Facsimile communications to transmit high speed graphics and hard copy text on regular schedules.

- High speed data communications (via satellite) links to shore labs and other ships on a continuous basis.

Satellite Monitoring

- Carry transponding and receiving equipment including antenna to interrogate and receive satellite readouts of environmental remote sensing data.

Discharge

- All discharges will be on the port side with their holding tanks capable of holding for a minimum of 24 hours. Overboard discharges must meet all international and state requirements.

Ship Control

- Maximum visibility of deck work areas during science operations and especially during deployment and retrieval of equipment. This could be supplemented with television monitors as well as direct, unobstructed stern visibility. Portable hand-held units could also be used at various after deck locations during overside equipment handling.

- The functions, communications and layout of the ship control stations should be carefully designed to enhance the interaction of ship and science operations. For example, ship course, speed, attitude and positioning will often be integrated with scientific operations assisted by computer control from a laboratory or working deck area.

- Provide conning ability aloft with heat and an enclosed access.

APPENDIX VI

Scientific Research Priorities for an Arctic Research Vessel, October 5, 1992 (Draft)

The History of the Recent Development of the Arctic Research Vessel Design

The lack of a dedicated Arctic Research Vessel (ARV) has long been identified as a major deficiency in the US ability to conduct research in northern seas. An arctic ice capable vessel was established among the highest acquisition priorities for the academic fleet, and as a result the Fleet Improvement Committee of the University National Oceanographic Laboratory System (UNOLS) has developed the Scientific Mission Requirements (SMR) for an Arctic Research Vessel. Several iterations of the requirements have been produced in response to input from the Arctic research community and others. Earlier comments focused on the limited ice capability and small number of scientists that could be accommodated. The latest SMR has been distributed to more than 400 arctic scientists and has been reviewed favorably. The new design was received more favorably by the community. This latest SMR calls for an ABS A3 ice classification, roughly equivalent to breaking 3.5–4' of continuous ice cover at 3 knots, able to carry 36 scientists for up to 90 days. It will require a ship of about 320' with about 18,000 hp. This capability reflects the scientific support needs identified by the US arctic marine scientists. A conceptual design for the vessel based on these Science Mission Requirements is now in preparation.

Sea ice determines the environmental and navigational characteristics of polar seas, and yet it is one of the more variable of the physical features of the earth's surface. Within the Arctic Ocean, sea ice is primarily of multi-year origin. It averages 2–3 meters in thickness, and is often rafted into pressure ridges and hummocks. Navigation in winter is not feasible, but summer access is possible, as demonstrated by Soviet icebreaker cruises to the North Pole in 1977 and 1987. Extensive sea ice forms seasonally around the boundaries of the Arctic Basin and extends into the Chukchi and Bering Seas, the Canadian Archipelago, Hudson Bay, and the Barents and Greenland Seas. Maximum ice extent is reached in March or early April. The characteristics of this peripheral ice vary with geographic region. Bering Sea ice is seasonal and seldom exceeds 1 meter in thickness. Greenland Sea ice, in contrast, originates in the Arctic Ocean and is 2–4 meters thick. Springtime retreat starts first in Davis Strait and the northern Atlantic, and then in the Bering Sea and Hudson Bay. At minimum, the ice is confined to the central Arctic Ocean and portions of the Greenland Sea, Kara Sea and Canadian Archipelago. The Bering Sea, Hudson Bay, Sea of Okhotsk and Baffin Bay/Davis Strait are free of ice during the summer months.

Scientific Programs and Support Requirements in the Arctic

In preparing its report, "Priorities in Arctic Marine Science" (1988), the Committee on Arctic Marine Science of the Polar Research Board (PRB), National Research Council, conducted a poll among users of research vessels in the Arctic. The responses showed three primary areas of interest: the Bering/Chukchi Seas, the Arctic Ocean Basin, and its marginal seas and the Greenland Sea/Fram Strait/Norwegian Sea/Barents Sea areas. Scientific plans included, among others, such activities as box coring in the Norwegian Sea, marine geology/geophysics in Baffin Bay, radiotracer studies in the Barents and Beaufort Seas and Fram Strait, and winter work in the Greenland Sea, all requiring significant ice breaking capability. Many individual respondents planned to work in multiple regions, such as the Barents, Greenland and Chukchi or Beaufort Seas – spanning both eastern and western arctic regions, others needed access to the Central Arctic Ocean Basin. A significant number planned to work in the eastern Arctic, which requires a platform with ice breaking capability. In compiling this information, it became evident that much work was simply not getting done due to the lack of a suitable US vessel. Although the initial SMR was based on the assumption that the new vessel was to be a replacement for the *Alpha Helix*, with improved size and capability but without substantial ice breaking ability, this did not appear to meet the requirements of the scientists. The revised Scientific Mission Requirements addresses these needs.

The timeliness and importance of the work identified in the PRB survey has increased, with high priority issues driving the development of arctic national research initiatives, for example global change and arctic pollution. The National Science Foundation has initiated the ten-year Arctic System Science program, with a multidisciplinary study of the Northeast Water polynya in the Greenland Sea among the first marine projects funded under this umbrella. However, the capability to support this program at sea is inadequate. This region is extremely important from the global point of view, since it is a dynamic region with exchange of water between the Atlantic and the Arctic Ocean, exhibiting strong fluxes of heat between the ocean and atmosphere, and also is active in the formation of subsurface water layers which affect large areas of the world oceans. On a regional basis, the polynya is important to the marine ecosystem.

Access is difficult because the area is surrounded by heavy ice that moves southward from the Arctic Ocean via the East Greenland Current. The lack of a US dedicated research vessel strongly impacts our ability to understand the influences of these phenomena. this and other east arctic research efforts. In the western Arctic there is a need for research that spans the national boundaries between Russia and the US and the US and Canada. The most important processes might occur during the ice-covered season.

Some specific research needs will be addressed briefly:

Geological and geophysical studies of the Arctic Ocean Basin are needed in if we are to fully understand climatic change. For example, nothing is known about the state of the polar oceans in Cretaceous times, a time of extraordinarily equable climate. There are inadequate numbers of sediment cores from the Arctic Ocean which penetrate the Cretaceous, and for those that do exist, context and correlation potential are unknown, as their sites are unsurveyed. Site survey for any future Arctic Ocean drilling program will be very demanding in time and effort, since there is no background or data base for geophysical studies in the region. This will require extensive ship time on a vessel suitable for arctic ice operations. Other geological/geophysical study needs include work on sedimentary processes in the Arctic Basin and at the continental margins, tectonics of the Arctic, and the interaction of the North American and Eurasian Plates. Finally, the opening of the western Arctic Ocean is a matter which remains unsettled along with continuing questions about the projection of the Mid-Atlantic Ridge into the Arctic Ocean east and west of Greenland.

Physical Oceanographic studies in ice-covered waters are essential, since the permanent, dynamic ice cover significantly impacts the Arctic Ocean on a number of scales. In particular, the Arctic Ocean plays a major role in the formation of cold, saline water layers overlain by low-salinity, low-density surface waters. Studies of large scale processes in the Arctic Ocean, including mixing, and generation of cold saline water, require access to regions of heavy ice, as does work on shelf/basin dynamics and structure. The Arctic Ocean is one of the few areas in which there is deep convection, ventilation of the deep ocean and production of the intermediate and deep water masses of the global ocean. These studies must take place at times of the year with active ice formation and in locations that require a very ice capable research vessel.

There is a great deal of concern about the increasing **pollution of the Arctic** in general, most recently specifically with respect to radionuclides which have been introduced into high latitude Russian waters. Monitoring programs planned to address this problem and its broad effects will need to include physical oceanographic/circulation studies, sediment sampling as well as ecological work. This will be in addition to research underway or planned AMAP (Arctic Monitoring and Assessment Program) work.

Studies of **sea ice properties and ground truth measurements** in conjunction with satellite remote sensing using Synthetic Aperture Radar and other sensors, including the upcoming SeaWiFS, require access to ice covered regions.

Marine ecological work requires access to ice-covered regions, especially at the higher latitudes, where ice-related biological production and food chains become dominant. We currently lack information on the basis for the relatively high productivity of arctic waters, and therefore cannot estimate the impact of climate change on these systems. The long ice-covered season in polar seas does not necessarily result in biological dormancy, and critical biological activity may take place in extremely brief time periods early in the spring. Currently, lack of access beyond the marginal ice zone has precluded efforts to address this problem. Knowledge of the biological role of sea ice is particularly needed to allow prediction of the effects of variability in ice extent on marine species, including those fish and marine mammal species which are commercially-exploited or subject to subsistence utilization. Sampling must be expanded to earlier and later dates in the season than presently is possible.

Current Research Planning and the Evolution of the ARV

Perhaps the most important events in the chronology of the development of the arctic research vessel have been meetings of arctic scientists convened to define the outstanding research questions for the Arctic, with special reference to global change. One meeting, the Workshop on Arctic System Science (Moritz *et al.*, 1990), identified a number of research problems related to interactions among the ocean, atmosphere and ice of the arctic region, while another meeting, a workshop on The Arctic Ocean Record: Key to Global Change (Thiede *et al.*, 1992), identified a series of investigations needed to understand climate history and evolution of the basins and shelves of the Arctic Ocean. Fundamental to any scientific discussion of the Arctic Ocean and its marginal and adjacent seas, its atmosphere and seabed, is the suggestion in presently available global climate models that the Arctic contains many powerful processes and feed-back mechanisms that distribute its climatic influence world-wide and that the Arctic will be dramatically affected by the predicted climate change. Since our knowledge of past climate change in the Arctic is practically nil (Thiede *et al.*, 1992), and our understanding of critical state variables of the system is similarly quite small (Moritz *et al.*, 1990), it is clear that a wide variety of observational information is needed immediately. The realization in the scientific community that our understanding cannot improve without the platforms to investigate the Arctic has led to a unified and determined effort to obtain the appropriate research vessel needed for the wide variety of investigations that have been identified as necessary to achieve adequate understanding.

The workshop on Arctic System Science (Mortiz *et al.*, 1990) identified urgent scientific needs in two broad categories: climate change/models and first order features. The topics of highest priority in the first category were deep water formation, ice retreat, warming, atmospheric radiation, clouds, surface energy budgets, and albedo. In the second category, research on circulation, seasonal biological cycles, stratification, riverine influences, seasonal chemical cycles , and brine formation were viewed as urgently needed. Most topics in both categories require not just a single investigation but rather a detailed climatology that allows accurate assessment of variability.

Many topics are intertwined in their expression in the Arctic and in their effect on the global climate system. Consensus on broad research needs includes (Moritz *et al.*, 1990):

"1) Despite its relatively small size, the Arctic Ocean and adjacent seas exert a strong influence on the earth's climatic state. Deep water production in this region is a major driver of the global thermohaline circulation, and the ice-cover has an important effect on the planetary albedo.....2) Simulations with global climate models portray an arctic marine environment in which global warming would be amplified, due to a combination of effects including sea ice retreat and the stable atmospheric stratification. This potential polar amplification of global change singles out the Arctic as a sensitive and vulnerable region. In view of the important and inadequate parameterization of key arctic processes and variables in global climate models, it is essential to accelerate research on arctic clouds and radiation.....3) For several arctic processes, there are large gaps between state-of-the-art formulations and their treatment (or even inclusion) in global climate models.....Models of the global cycles of nutrients and carbon typically omit the Arctic Ocean altogether.....4) Important first-order features of the arctic marine environment have not been adequately described, including seasonal biological cycles in any regions, the circulation and stratification of major water masses, and the sedimentary record.....5) The present state of the Arctic Ocean depends on the large riverine input, equivalent to about 10% of the total global runoff. This input contributes to the strong stratification of the upper layer and encourages ice formation. The ice cover and stratification control many biological processes. The fresh water transported out of the Arctic through Fram Strait (mainly as ice) influences the global thermohaline circulation. Important quantities of chemically reactive and biogenic material may be transported by the rivers.....6) Arctic ecosystems are likely to be sensitive to the amplified signals of global warming, but in some cases we do not know enough to predict even the sign of the possible changes. ....The dearth of knowledge is encapsulated in the wide range and frequent revision of estimates of primary production in the Arctic Ocean and its adjacent seas.....7) The vast continental shelves of the arctic marginal and adjacent seas (more than 25% of the global total) and their continental slopes exert important effects on the biology, chemistry and physics of the ocean.....These regions may be significant sinks for combined nitrogen, organic carbon, and biogenic silica. The brine formation that occurs over portions of these shelves during winter freezing plays a major role in the formation of the arctic halocline and has important effects on chemical distributions. Few measurements exist from the outer portions of these shelves during periods of brine formation. There are few measurements of chemical cycling and deposition within these sediments and no studies yield insight into the seasonal cycle of biologically mediated chemical transformations here.....11) Because flows into and out of the Arctic Ocean are largely confined to narrow straits and because of continuing improvements in monitoring techniques, the Arctic Ocean lends itself well to the determination of energy and mass budgets. Such budgets serve as important constraints for models and process-oriented studies."

The Arctic Ocean Record: Key to Global Change (Thiede *et al*.., 1992) discusses a wide variety of scientific issues also; all relate to tectonic history, sedimentation, ice cover and evolution of the Arctic Ocean. The main thrust of the arguments in this document is that very few cores exist which allow development of useful chronologies, and in fact no agreement upon chronology exists presently for the region. Present day sedimentary processes are so poorly understood that a variety of competing hypotheses exist (i.e., sediment entrained by ice contacting the seabed, sediment incorporated in ice from storm resuspension during winter ice formation, sediments largely delivered by rivers, and so forth), with sedimentation rates generally unknown but thought to vary among areas around the Arctic Ocean. Sediment entrained in ice is moved around the Arctic Ocean with the ice until it melts, and therefore information on ice movement and sites and rates of melting sediment release is needed. These processes need quantitative evaluation. The evolution of the basins of the Arctic Ocean is complicated and not understood; the main outlet of the Arctic Ocean via Fram Strait may have opened fairly recently but the timing and nature of such expansion has not been investigated. Since Fram Strait plays a pivotal role in the global thermohaline circulation of the ocean, knowledge about its geological and tectonic history will inform us about potentially major climate change in the past associated with the establishment of Fram Strait. Ice cover of the region is thought to change rapidly, on the order of decades perhaps; whether this is true historically must be understood in order to evaluate possible future climate change and its temporal scales. The arctic ice cover is probably the single most important feature which exerts a controlling influence on climate, regionally and globally.

The justification for the studies of tectonic history and the sedimentary record is expressed at the outset of The Arctic Ocean Record: Key to Global Change (Thiede et al., 1992):

"One of the major unsolved questions in earth science is the paleooceanographic and paleoclimatic evolution of the Arctic deep-sea basins. Identifying the greenhouse warming within historical records requires quantifying the magnitudes, frequencies and rates of natural climatic change. Of hundreds of samples collected in the arctic Ocean only seven contain sediments that predate the onset of cold climatic conditions. There are no arctic deep-sea data covering the time span 5–40 Ma when the climate cooled, and thus there is no information available to decipher the forcing functions or time of onset of Cenozoic glacial conditions in the Arctic. Today, dense, cold arctic surface waters sink and flow southward filling the deep-sea basins of the Atlantic and Pacific Oceans with consequent major climatic implications..... Prioritized program objectives are complete paleoenvironmental record, paleooceanography, structure of major arctic features and margins, nature and age of arctic basement, former productivity levels, former extent and composition of sea ice and ice bergs, and windflux....."

The simple conclusion of both these community-wide statements of scientific needs and compelling scientific issues in the Arctic is that there is a vast amount of knowledge required in the very near future, but this knowledge simply will not be obtained without a new, substantial, ice-breaking research vessel in the US UNOLS fleet. The need for such a vessel is immediate and urgent.

In spring of 1991, the second revision of the US Arctic Research Plan was published (Interagency Arctic Policy Committee, 1991, Arctic Research 5: 2-89). It contains three research mission components which require immediate improvement in our ability to conduct observational programs in the Arctic, specifically requiring an ice breaking research vessel. These components are 1) Ice Dynamics and Oceanography, 2) Ocean and Coastal Ecosystems and Living Resources, and 3) Marine Geology and Geophysics. The topics identified as highest priority under the first component are: determination of processes, dynamics and mechanisms of ice production, deformation, advection and decay; determination of processes of renewal and mixing of arctic and subarctic water masses from large to small scales; determination of large-scale circulation of the Arctic Ocean, its variability and its dynamics including the role of shelf seas, boundary currents and exchange with adjoining seas; and determination of mean and variability of current and hydrographic features in the nearshore region of the Bering, Chukchi and eastern US Beaufort Seas. In the second component, the objectives are: determination of the magnitude and variation of marine productivity in arctic seas through studies of the structure, dynamics and natural variability of ecosystems; study of the influence of arctic marine productivity on the global cycling of biologically-active materials including carbon and nitrogen; and understanding the physical and biological processes that affect fisheries recruitment in the US waters of the Bering, Chukchi and Beaufort Seas. In marine geology and geophysics, the highest research priority is given to initiating arctic marine geological and geophysical studies to provide information on past and present climate change, support rational development of natural resources and addressing fundamental questions of global geological history and regional tectonic development; defining the geological framework, deep structure and tectonic history and development of the Bering Sea region; determination of modern sediment transport by sea ice, ice bergs and other processes;

characterizing the seafloor sediments by coring and reflection methods; establishing a well-dated stratigraphy; and development of new techniques for deployment of instruments in the harsh arctic environment.

The US Arctic Research Plan also contains climate and weather issues whose ocean, atmosphere, and ice components are similar to scientific needs identified in the Arctic System Science: Ocean-Atmosphere-Ice Interactions (Moritz *et al.*, 1990) justification. There are also considerable monitoring needs associated with potential pollution of the Arctic arising from Russian environmental practices over recent decades.

Through several years of the arctic research vessel design process it is clear that arctic marine scientists feel the need for a vessel that has the capability to support research under quite severe ice conditions in the Arctic Ocean. The United States currently has very limited capability to support shipborne science in the Arctic, apart from open water and ice margins, and the US scientific interests in the Arctic now clearly require such support. Without question, a vessel of A3 ice classification will greatly enhance our ability to operate in the Arctic, and will increase the number of users when compared with a smaller, less capable vessel. The evolution of the Scientific Mission Requirements has determined the proposed size and capability in accordance with their needs.

Design Considerations

The possibility of using the latest ice breaker hull technology to minimize the power required by the vessel and to optimize performance in ice breaking and open water is under consideration. Both the Thyssen/Waas design and a conventional wedge-shaped hull are being considered. A subcontract to a German marine architectural firm has been let to evaluate the various candidate hull forms on behalf of the FIC ARV subcommittee. This firm is one of the most experienced in the world with regard to ice breakers, having designed and conducted model and full scale tests on many Russian and other ice breakers.

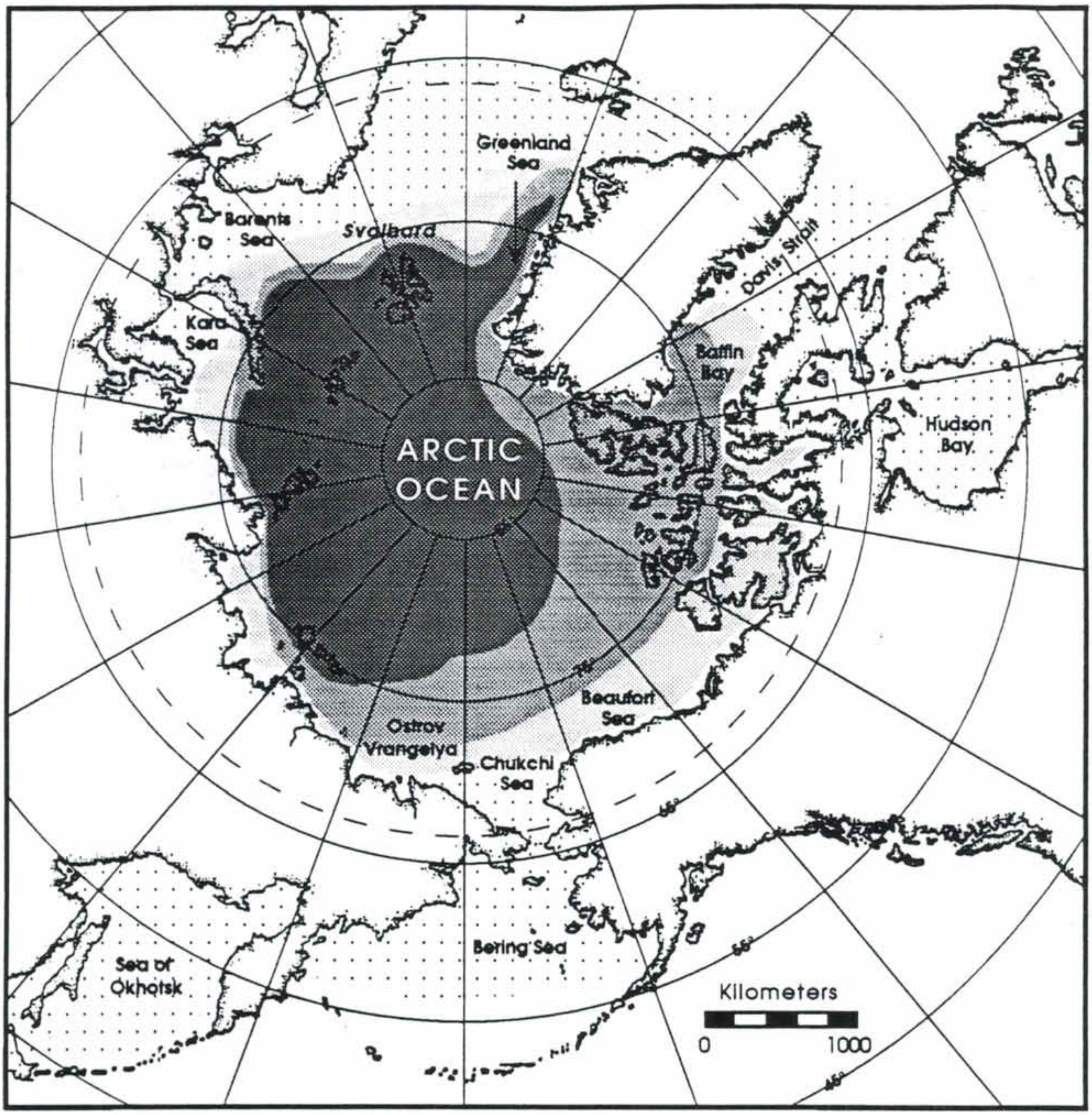
Why was an A3 capability selected rather than an A2 or even an A4? Why is the requirement for ice breaking capability growing, and will the increase ever stop? US arctic oceanographers have had to use various platforms (mainly foreign) on which they could obtain time to conduct their research. In using these platforms, they have been able to access regions far beyond the limitations of the R/V *Alpha Helix*. Science cruises on the German research vessel *Polarstern* and the Swedish icebreaker *Oden* in 1991 have given scientists new visions, hope and interest in Arctic Ocean work. The July–August 1992 cruise of the US Coast Guard icebreaker *Polar Sea* renewed the appetite of researchers to address new problems in the heavier ice pack in the Arctic. The response of the arctic science community for the vessel design progress to the A3 ice capability has been very positive. The A2 capability used in an earlier design was not acceptable to many in the Arctic community. An A4 capability would begin to conflict with the ice capability of US Coast Guard vessels, both existing and planned. The shift from an A2 to A3, however, doubles the time that the vessel can spend in the arctic offshore ice. An A3 ice capability will also allow this vessel to accompany a more ice capable vessel such as an A4 or A5 where such escort is needed, allowing the development of a partnership between the USCG and UNOLS in arctic operations. Such cooperation will continue to be very important to the success of the US arctic marine research program. An A5 can probably travel throughout the Central Arctic Basin depending on ice conditions of a given year. An A3 research vessel, though it can operate independently in much of the Arctic, will occasionally require an A4 or A5 escort (USCG).

Regions of Arctic Research Vessel Operation

Operating areas for an A3 research vessel alone and escorted are shown in Figure 1. The A3 classification would allow this vessel to operate independently in the Central Arctic Basin (multi-year ice) for short term, short distances from July through September and along the Arctic shelf from July through December. (see the map for operation areas).

Ice Operating Capability of A3 with and without Escort

Region	Independent A3 Operation	With A4 Escort	With A5 Escort
Central Arctic Basin	July to September	July to October	Year around
Sea of Okhotsk	Year around	Year around	Year around
Bering Sea	Year around	Year around	Year around
Hudson Bay	Year around	Year around?	Year around
Baffin Bay/Davis St.	Year around	Year around	Year around
Greenland Sea	Offshore shelf, July to December	Offshore shelf, Year around	Year around
		Central Arctic, July to November	Year around



Multi–year ice. Winter operation not possible.
Summer operation possible with icebreaker escort (A5 or better).

Operation possible July—December.

Extended operation possible June—December.
Some winter accessibility.

Seasonal sea ice. Year–round operation possible.

Kara and Barents Seas	July to October	Year around	Year around
Canadian Archipelago	July to December	Year around	Year around

Literature Cited

Thiede, J. *et al.* (1992). The Arctic Ocean Record: Key to Global Change. Polarforschung *61/1*: 1-102.

Interagency Arctic Policy Committee (1991). US Arctic Research Plan. Arctic Research *5*: 2-89.

Moritz, R. *et al.* (1990). Arctic Systems Science Ocean-Atmosphere-Ice Interactions. Joint Oceanographic Institutions Inc., Washington, DC, 132 pp.

Polar Research Board (1988). Priorities in Arctic Marine Sciences. National Academy Press, 73 pp.

APPENDIX VII

THE GLOSTEN ASSOCIATES, inc.
CONSULTING ENGINEERS SERVING THE MARINE COMMUNITY

600 Mutual Life Building • 605 First Avenue
Seattle, Washington 98104-2224

Facsimile: 206 682-9117
Phone: 206-624-7850

28 September 1992
File No. 9243
Serial No. 0026

(PLUS 5 ENCLOSURES)

VIA FACSIMILE

Dr. Thomas C. Royer
Institute of Marine Science
University of Alaska Fairbanks
Fairbanks, Alaska 99775-1080

Dear Tom:

At the request of the subcommittee we have developed rough estimates of construction and operating costs of the ARV. The subcommittee should bear in mind when reviewing these estimates that at this point in the design cycle the estimates will contain a rather large margin of uncertainty.

The construction cost estimates have been developed primarily by ratiocination using cost data for similar vessels adjusted to 1992 dollars and, where applicable, adjusted for differences in shipbuilding efficiencies between foreign and U.S. shipyards.

1. Construction Cost Estimate

The range of construction costs is shown on Figures 1 and 2. Figure 1 shows a regression line, with 90% confidence bands, based on a regression set that includes 6 of the vessels in Table 1 whose costs have been determined from various sources. The mean line indicates a construction cost for the ARV of approximately $119 million, with a range of plus or minus $20 million within the bounds of the 90% confidence bands.

The cost figures on the *Palmer* are somewhat speculative and in my opinion the estimated cost seems unrealistically low even when adjusted for shipyard profit. If the estimated cost of the *Palmer* is omitted from the regression set and the cost of the Canadian icebreaker *Henry Larsen* is arbitrarily reduced by 15% to account for differences between "military" ship procurement practices and "commercial" practice, the regression line of Figure 2 results. Note that while the estimated (mean) cost of the vessel in 1992 dollars is still $119 million, the 90% confidence bands are reduced to plus or minus $10 million.

Costs are plotted against an expression that is a function of horsepower and cubic number. This expression has three terms representing estimated cost influences of hull structure, outfit, and machinery. The weighting of the terms was verified against known weight and cost data from the *Thomas G. Thompson.*

2. Operating Costs

Average daily operating costs are estimated to be $32,800/day. This figure was derived assuming 250 days at sea (see Table 2). The subcommittee members may want to use a set of assumptions that are different from those shown on the table. We have based the projected 1992 operating costs of the ARV on data from the *Thompson* and *Ewing*.

3. Design Cycle

Completion of this cost estimate has provided us with additional data. These data will now be used to refine our estimate of lightship weight. These data will also allow us to cycle through the design spiral one more time checking displacement, deadweight, endurance, etc.

With best regards.

Yours very truly,

THE GLOSTEN ASSOCIATES, INC.

DIRK H. KRISTENSEN, P.E.

DHK:ld

Enclosure: Table 1 Vessel Characteristics
Table 2 Estimated Operating Costs
Fig. 1 Graph of Estimated Construction Cost
Fig. 2 Graph of Estimated Construction Cost (w/o *Palmer*)
Fig. 3 Graph of Estimated Lightship Weight

cc via facsimile:
Dr. Knut Aagaard, UW APL
Dr. Vera Alexander, UAF
Ms. E.R. Dieter, NSF
Capt. R.P. Dinsmore, WHOI
Dr. Robert Elsner, UAF
Dr. Marcus G. Langseth, LDGO
Dr. Sharon L. Smith, BNL
Mr. A. Sutherland, NSF DPP

If you have difficulty in receiving this transmission, call (206) 624-7850. Our FAX number is (206) 682-9117.

TABLE 2

Estimated 1992 Operating Costs
Costs in Thousands of Dollars

	R/V Thompson	R/V Ewing	ARV	Notes
1. Assumptions				
Crew size	22	22	26	
Propulsion BHP	6,000	3,250	16,000	
Operating days	277	314	275	
Days at sea	258	274	250	
Fuel, gal per day	?	?	11,560	1
2. Salaries & Wages				
Ship base salaries	770	861	964	2
Overtime & leave	613	822	848	2
Fringe benefits	258	383	379	2
Shore based administration	208	554	381	3
Total Payroll	**1,849**	**2,620**	**2,572**	
3. Repair, Maintenance & Overhaul	**397**	**480**	**1,059**	4
4. Other Expenses				
Fuel and lube oil	732	774	3,179	5
Food	296	151	300	4
Insurance	145	269	342	6
Stores, parts, etc.	120	194	320	4
Travel	112	208	189	2
Shore support & Miscellaneous	235	256	246	3
Total Other Expenses	**1,640**	**1,852**	**4,576**	
5. Indirect Costs	375	0	0	
6. Total Operating Costs	4,261	4,952	8,208	
7. Average Daily Cost	**15.4**	**15.8**	**32.8**	

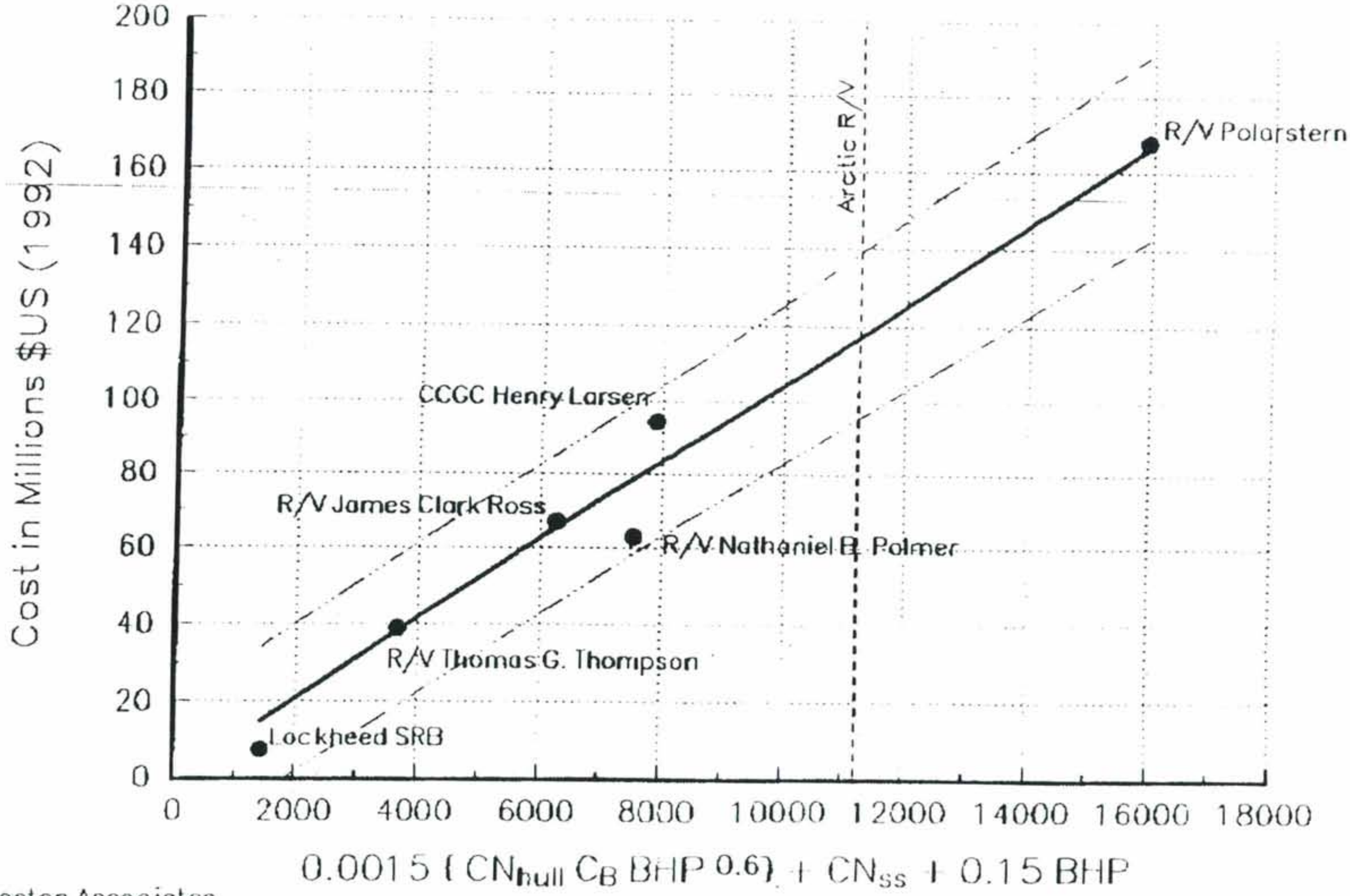
Notes:

1. Reference Glosten "Hull Characteristics Study" August 1992
2. Average of Thompson and Ewing increased by ratio of crew (i.e. 26/22)
3. Average of Thompson and Ewing
4. Thompson increased by ratio of horsepower (i.e. 16,000/6,000)
5. [Gallons per day] x [Days at sea] x [$1.00/gallon]
6. [Thompson Insurance] x [ARV Hull CN/Thompson Hull CN]

Figure 1

Arctic Research Vessel Construction Cost Estimate

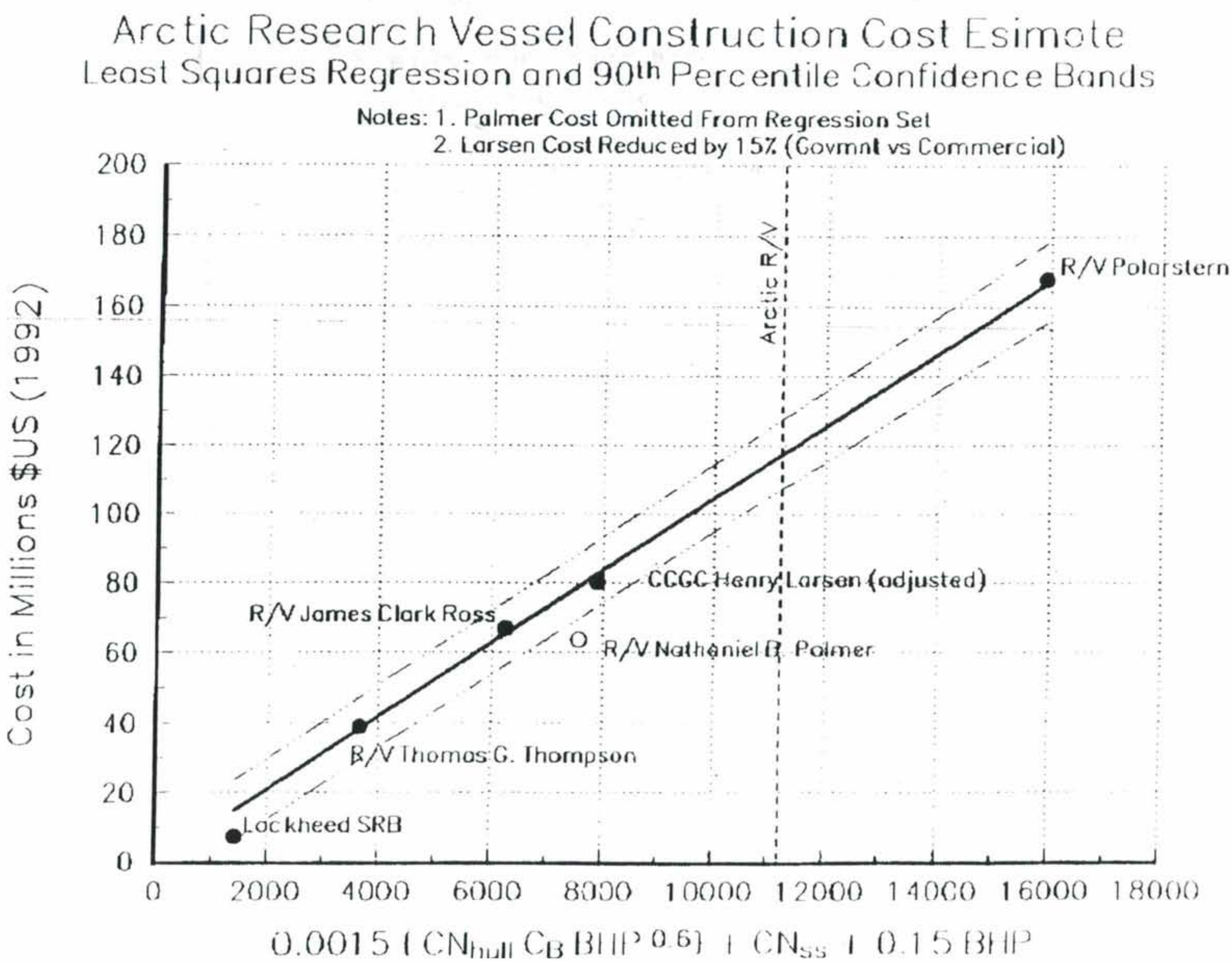
Least Squares Regression and 90th Percentile Confidence Bands



The Glosten Associates
File No. 9243, September, 1992

University of Alaska Arctic Research Vessel

Figure 2



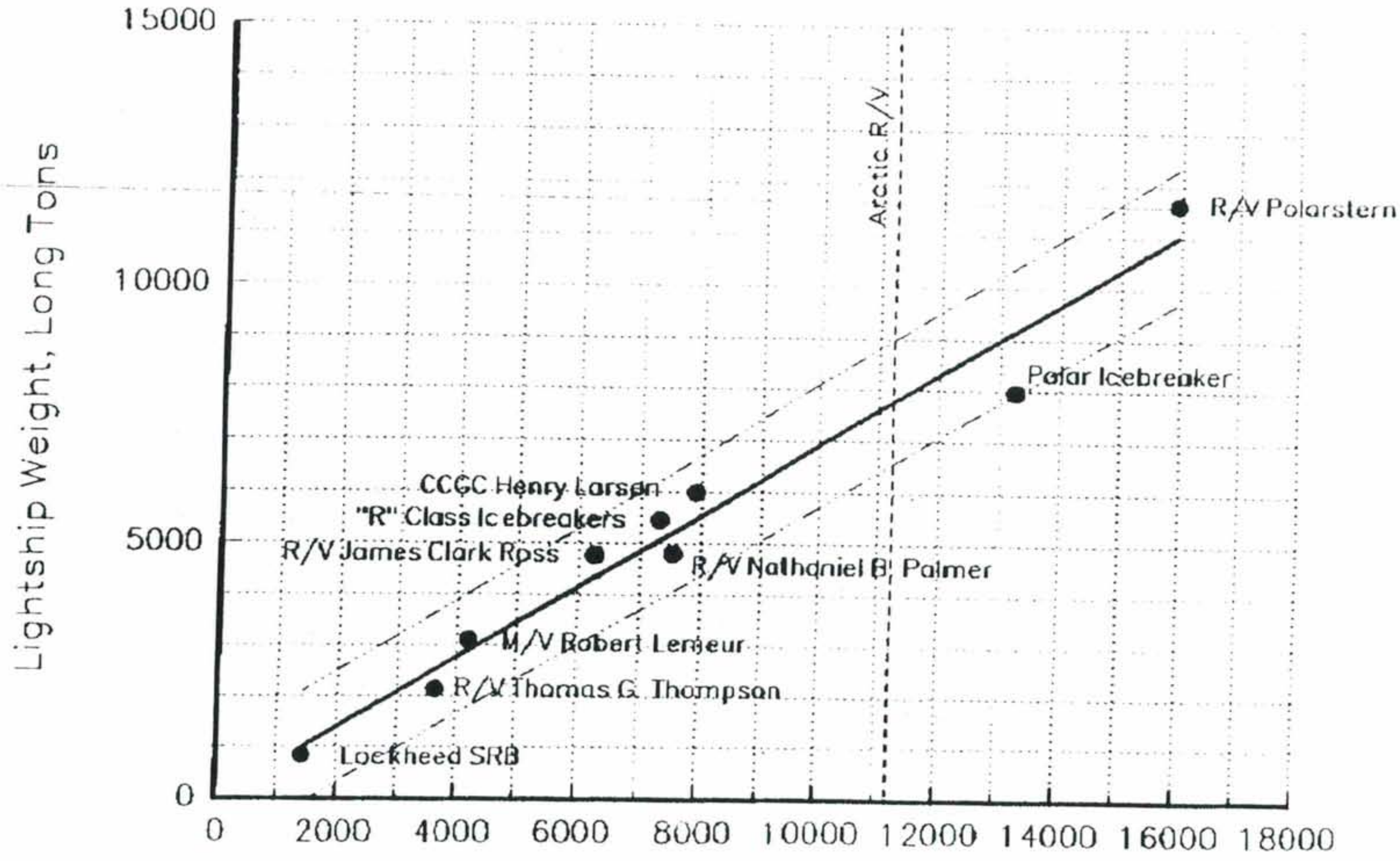
Arctic Research Vessel Construction Cost Esimate
Least Squares Regression and 90th Percentile Confidence Bands
Notes: 1. Palmer Cost Omitted From Regression Set
2. Larsen Cost Reduced by 15% (Govmnt vs Commercial)
200
180
160
140
120
100
80
60
40
20
0
Cost in Millions $US (1992)
Arctic R/V
R/V Polarstern
CCGC Henry Larsen (adjusted)
R/V James Clark Ross
R/V Nathaniel B. Palmer
R/V Thomas G. Thompson
Lockheed SRB
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
0.0015 (CNhull CB BHP 0.6) + CNss + 0.15 BHP

Figure 3

Arctic Research Vessel Lightship Weight Estimate

Least Squares Regression and 90th Percentile Confidence Bands

Note: 100 LT (Sci Outfit) added to Larsen, R - Class, & Polar Icebreaker



$0.0015(CN_{hull} C_B BHP^{0.6}) + CN_{ss} + 0.15 BHP$

The Glosten Associates
File No. 9243, September, 1992

University of Alaska Arctic Research Vessel

THE GLOSTEN ASSOCIATES, INC.
CONSULTING ENGINEERS SERVING THE MARINE COMMUNITY

2 October 1992
File No. 9243
Serial No. 0030

VIA COURIER

Dr. Thomas C. Royer
Institute of Marine Science
University of Alaska Fairbanks
Fairbanks, Alaska 99775-1080

Dear Tom:

Enclosed herewith are the revised graphs we discussed in our telephone conversation. We have also enclosed half-size reproductions of the lines plans received today from HSVA.

The graphs show estimated construction costs as follows:

Figure 1A, includes R/V Palmer and Larsen value undiscounted.

12,000 BHP	....	$88 M	± $20 M
8,000 BHP	ABS A2	$60 M	± $20 M

Figure 2A, R/V Palmer omitted and Larsen value reduced 15%

12,000 BHP	....	$88 M	± $10 M
8,000 BHP	ABS A2	$60 M	± $10 M

Tom, please let us know if there is anything else we can help you with for the upcoming FIC meeting.

With best regards.

Yours very truly,

THE GLOSTEN ASSOCIATES, INC.

DIRK H. KRISTENSEN, P.E.

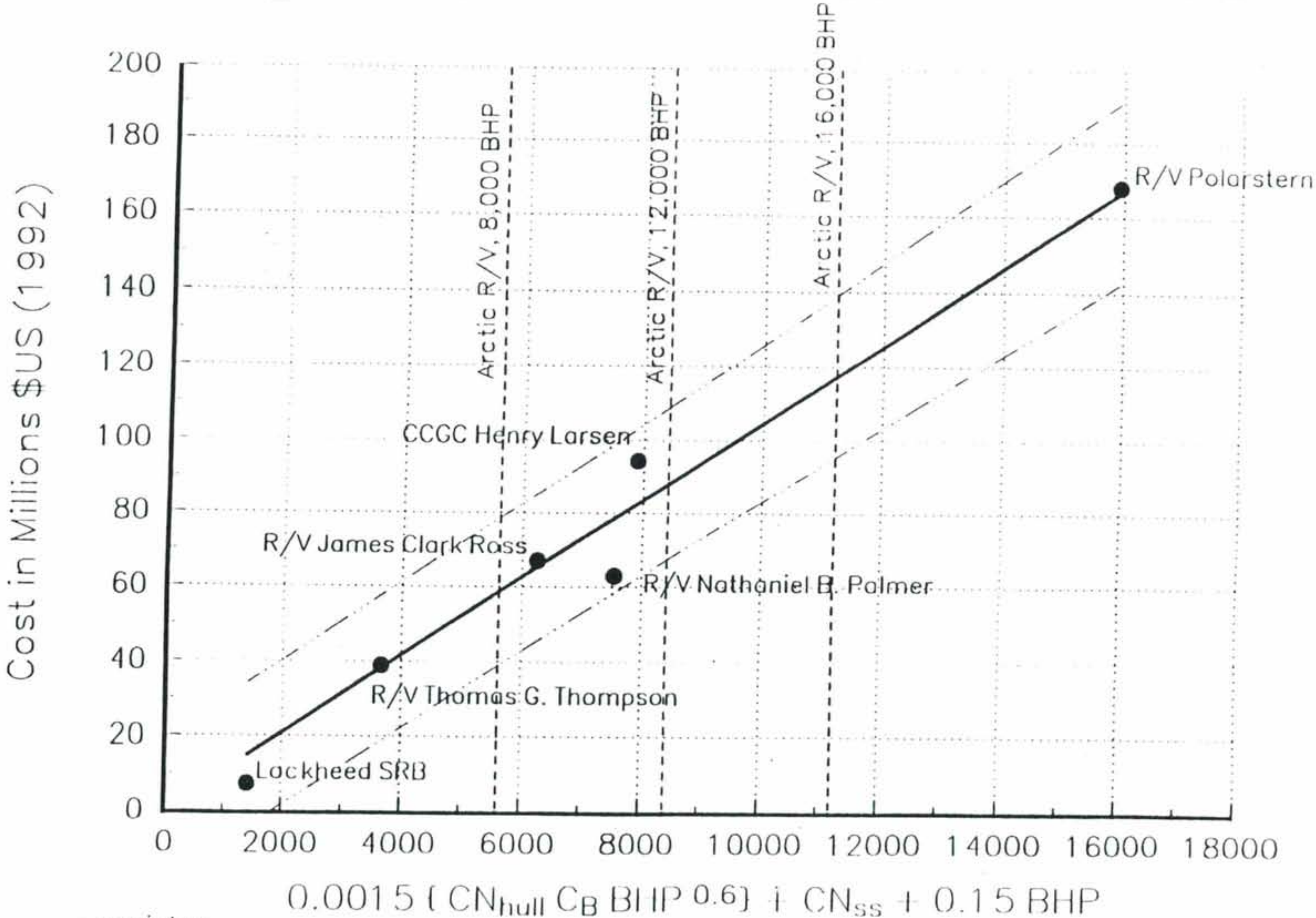
DHK:

Enclosure: Lines Plans (2) from HSVA
Fig. 1A Graph of Estimated Construction Cost
Fig. 2A Graph of Estimated Construction Cost (w/o *Palmer*)

Figure 1A

Arctic Research Vessel Construction Cost Estimate

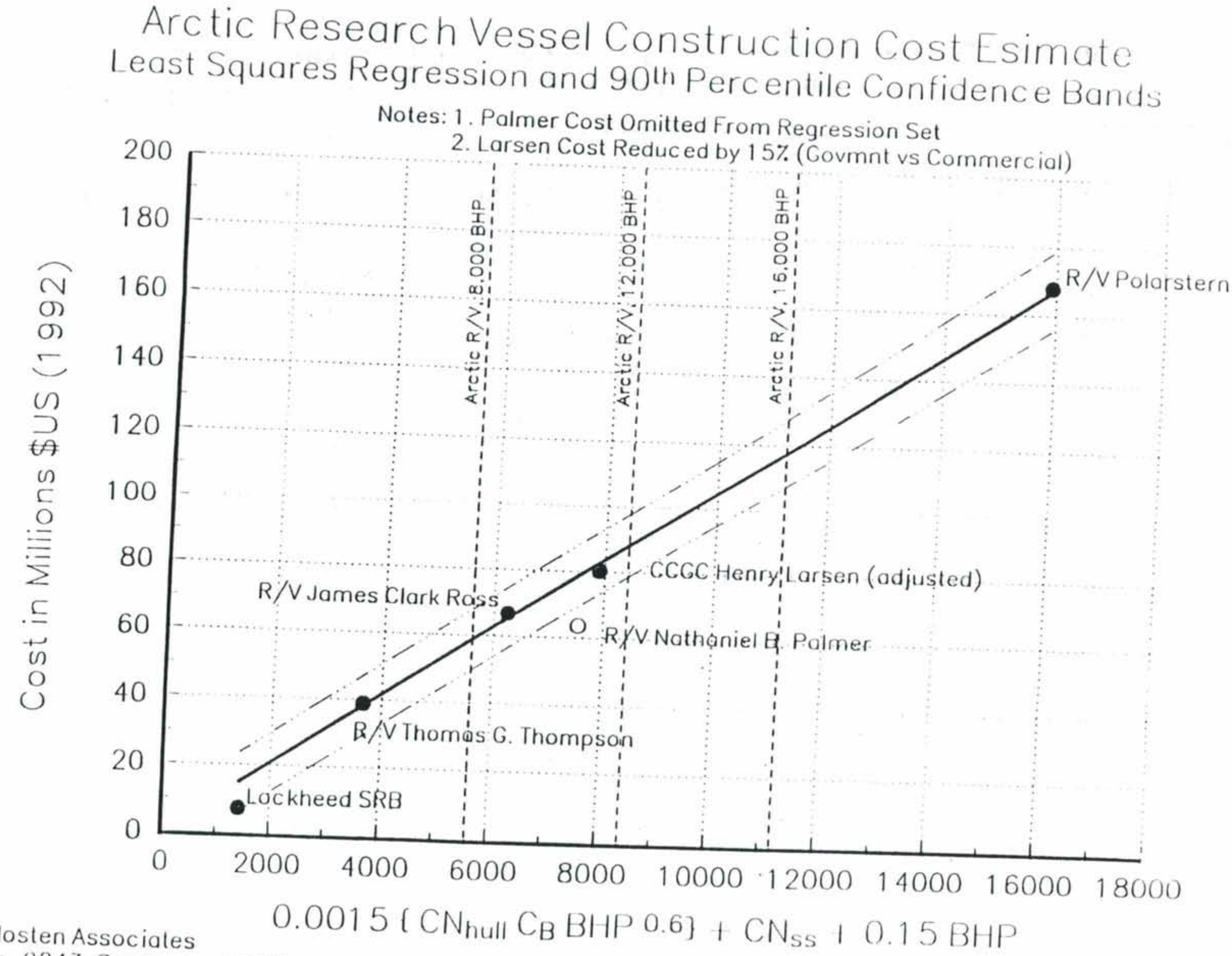
Least Squares Regression and 90th Percentile Confidence Bands



...ssociates
File No. 9243, September, 1992

University of Alaska Arctic Research Vessel

Figure 2A



The Glosten Associates
File No. 9243, September 1992

University of Alaska Arctic Research Vessel

TABLE 1

Vessel Name	L_{WL} (feet)	B_{max} (feet)	$D_{mn\ dk}$ (feet)	C_B	CN_{hull}	CN_{ss}	LSW (LT)	BHP	f	Est'd Cost (1992 USD)
1. Lockheed SRB	188.8	40.0	15.0	0.60	1,133	935	830	2,500	1,422	7.3
2. R/V Thomas G. Thompson	252.7	52.5	26.5	0.55	3,516	2,219	2,136	6,000	3,655	39.0
3. M/V Robert LeMeur	255.9	59.0	24.6	0.76	3,714	1,706	3,113	9,600	4,184	—
4. R/V James Clark Ross	311.7	61.8	32.2	0.64	6,203	3,550	4,773	8,800	6,255	67.0
5. R/V Nathaniel B. Palmer	279.8	60.0	31.0	0.62	5,204	4,119	4,800	13,200	7,535	63.0
6. 'R' Class Icebreaker	305.8	64.0	35.5	0.62	6,948	3,208	5,360	14,000	7,294	—
7. CCGC Henry Larsen	305.8	64.0	35.5	0.62	6,948	3,208	5,896	16,600	7,898	94.5
8. R/V Polarstern	357.6	82.0	44.6	0.53	13,078	8,973	11,633	20,000	15,931	168.0
9. ARV	295.0	78.0	36.0	0.56	8,284	6,501	—	16,000	11,218	—

Notes:
a) CN_{hull} = Hull Cubic Number = $(L_{WL} \bullet B_{max} \bullet D_{mn\ dk}) \div 100$
b) CN_{ss} = Superstructure Cubic Number = (Profile Area above Main Deck) $(B_{max}) \div 100$
c) LSW = Lightship Weight
d) BHP = Brake Horsepower, Propulsion Machinery
e) $f = \text{factor} = 0.0015\,[CN_{hull} \bullet C_B \bullet (BHP)^{0.6}] + CN_{ss} + 0.15\,[BHP]$

APPENDIX VIII

UNIVERSITY-NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

FLEET IMPROVEMENT COMMITTEE
Marcus G. Langseth, Chairman
Lamont-Doherty Geological Observatory
Palisades, NY 10964
Telephone 914 359-2900 X518 or 237
FAX 914 365-0718

Dear Colleague:

The UNOLS Fleet Improvement Committee (FIC) is carrying out an evaluation of accommodations and laboratories on UNOLS ship. The Ocean Sciences Division of the National Science Foundation asked FIC to undertake this assessment with the objective of improving the quality of accommodations and the effectiveness of labs on the ships in the UNOLS fleet. Our findings will be published in a report, which will be distributed to the agencies that support the UNOLS fleet and the oceanographic community.

An important outcome of this evaluation will be to identify those features that make a ship more commodious and effective as research platform. These features are often subtle things that are learned from first hand experience on a number of different ships. Thus, one way to discover these features would be to ask scientists who have used two or more ships in the recent past to compare their laboratories and accommodations. In particular we are interested in comparing UNOLS ships with non-UNOLS (i.e. research ships operated by a foreign country or another US agency).

UNOLS records show that you have been to sea as a Principal Investigator on at least two different research ships recently. You can help our effort by taking a few minutes to respond to the attached questionnaire. Remember that this effort is directed toward improving the accommodations, laboratories and equipment on UNOLS ships. The FIC will keep your responses confidential, and will not associate your name with any specific responses or opinions cited in our report.

If you have some questions about this questionnaire or the activity please do not hesitate to call me or the UNOLS Office.

Thank you for sharing your time and knowledge.

Marcus G. Langseth

Chairman
UNOLS Fleet Improvement Committee

BASIC INFORMATION:

Which research ships did you sail on?
If you sailed on a non-UNOLS ship please use that ship as one of the pair. If you sailed on more than one UNOLS or more than one non-UNOLS ship please provide information on the two ships that you judge to be the best over all.

Name of ship No. 1 ______________________________

The month and year of cruise __________________

Your research was in which of the following disciplines?

❑ Biological Oceanography ❑ Chemical Oceanography ❑ Geophysics
❑ Physical Oceanography ❑ Geology ❑ Geochemistry

Name of ship No. 2 ______________________________

The month and year of cruise __________________

Your research was in which of the following disciplines?

❑ Biological Oceanography ❑ Chemical Oceanography ❑ Geophysics
❑ Physical Oceanography ❑ Geology ❑ Geochemistry

****

COMPARISON OF ACCOMMODATIONS:

You found ship No. 1	**Superior**	**About equal**	**Inferior**
State rooms	❑	❑	❑
Steward service	❑	❑	❑
Mess area	❑	❑	❑
Food quality	❑	❑	❑
Lounge	❑	❑	❑
Library	❑	❑	❑
Other ________________	❑	❑	❑

What feature/s made the difference in above areas.

State Rooms and Steward Service ____

____

____

Food and Food Service ____

____

____

Lounge Library etc.____

COMPARISON OF LABORATORIES AND EQUIPMENT:

Which laboratory or laboratories were most important to your program?

____

You found ship No. 1	**Superior**	**About equal**	**Inferior**
Laboratory space	❑	❑	❑
Location (accessibility)	❑	❑	❑
Layout (flexibility)	❑	❑	❑
Utilities (power, gas, etc.)	❑	❑	❑
Environment (air cond., noise, etc)	❑	❑	❑
Technical support	❑	❑	❑
Communications (intraship)	❑	❑	❑
Communications (ship to shore)	❑	❑	❑
Computer capability (Off line availability)	❑	❑	❑
Realtime displays (navigation, meteorological)	❑	❑	❑
Data management (digital logging, accessibility)	❑	❑	❑

What feature/s made the difference.

Laboratories____

____

____

Technical support____

____

____

Computers, displays and data management____

____

____

Other ____________ ____

____

COMPARISON OF OTHER FACILITIES:

Some of the facilities below often depend on the size of the ship. If you are comparing two ships of about the same size your judgement about the following would be appreciated.

You found Ship No.1	**Superior**	**About the same**	**Inferior**	**Not Used**
Deck space	❑	❑	❑	❑
Storage space	❑	❑	❑	❑
Winches and wires	❑	❑	❑	❑
Cranes, frames and davits	❑	❑	❑	❑
Bridge/deck communications	❑	❑	❑	❑
Support for deck operations	❑	❑	❑	❑

What feature/s made the difference.

Deck and storage space ____

____

____

Over the side handling ____

____

____

Support of deck operations ____

____

____

Other ____

____

Other comments:

APPENDIX IX

Outline for UNOLS Fleet Plan 1992 - Nov. 92 version

I. Background:

A. Brief history of the UNOL Fleet.
B. Roles of UNOLS and FIC.
C. Fleet replacement plan and Fleet Improvement Plan
D. Motivation and purpose of the current update of a UNOLS Fleet Plan.

II. Elements of the UNOLS Fleet

A. Composition of the 1992 UNOLS fleet .
B. Projected composition of the 1997 UNOLS Fleet.
   1. Large ship construction-AGORS, ARV
C. Special (non-UNOLS) platforms-JOIDES RESOLUTION, FLIP, N.PALMER. Submersibles.
D. Major shipboard oceanographic systems. (SEABEAM, MCS, Jason-Argo, ROV's, AUV's).

III. What academic fleet is required in the next 20 years?

A. Current demand and ongoing oceanographic programs (RIDGE, WOCE, TOGA, JGOFS, Core Program, ONR, NOAA).
B. Coastal needs (possible impact on use of intermediates)
C. Arctic Research
D. Other facilities and high tech systems.

III. Funding the fleet:

A. Usage vs. availability a 5 year history
B. Current and projected costs of the maintaining the fleet. (An optimistic and pesimistic projection.
C. Sources of funding
   1. Traditional (NSF, ONR)
   2. New NOAA, other government labs.

IV. Recommendations:

A. Fleet size and composition for the year 2000.
B. Modes of operation (efficient use of resources.)
C. Methods for monitoring future ship needs and means to adapt the fleet to meet future needs and resources.

Reference documents:

1. A plan for Improved Capability of the University Oceanographic Research Fleet, UNOLS document prepared by the Fleet Replacement Committee, June 1986.

2. The Research Fleet, A brochure prepared by WHOI for NSF (1991)

3. Submersible Science Study for the 1990's, UNOLS document prepared by the Submersible Science Committee (Nov. 1990).

4. Report on the Federal Oceanogrphic Fleet Requirements, Prepared by FOFCC, (Aug. 1990).

5. UNOLS Fleet Imporvement Plan, Prepared by the UNOLS Fleet Improvement Committee (May 1990).

6. Academic Research Vessel, 1985-1990, Report prepared by the National Academy of Sciences, Ocean Science Board, 1982.

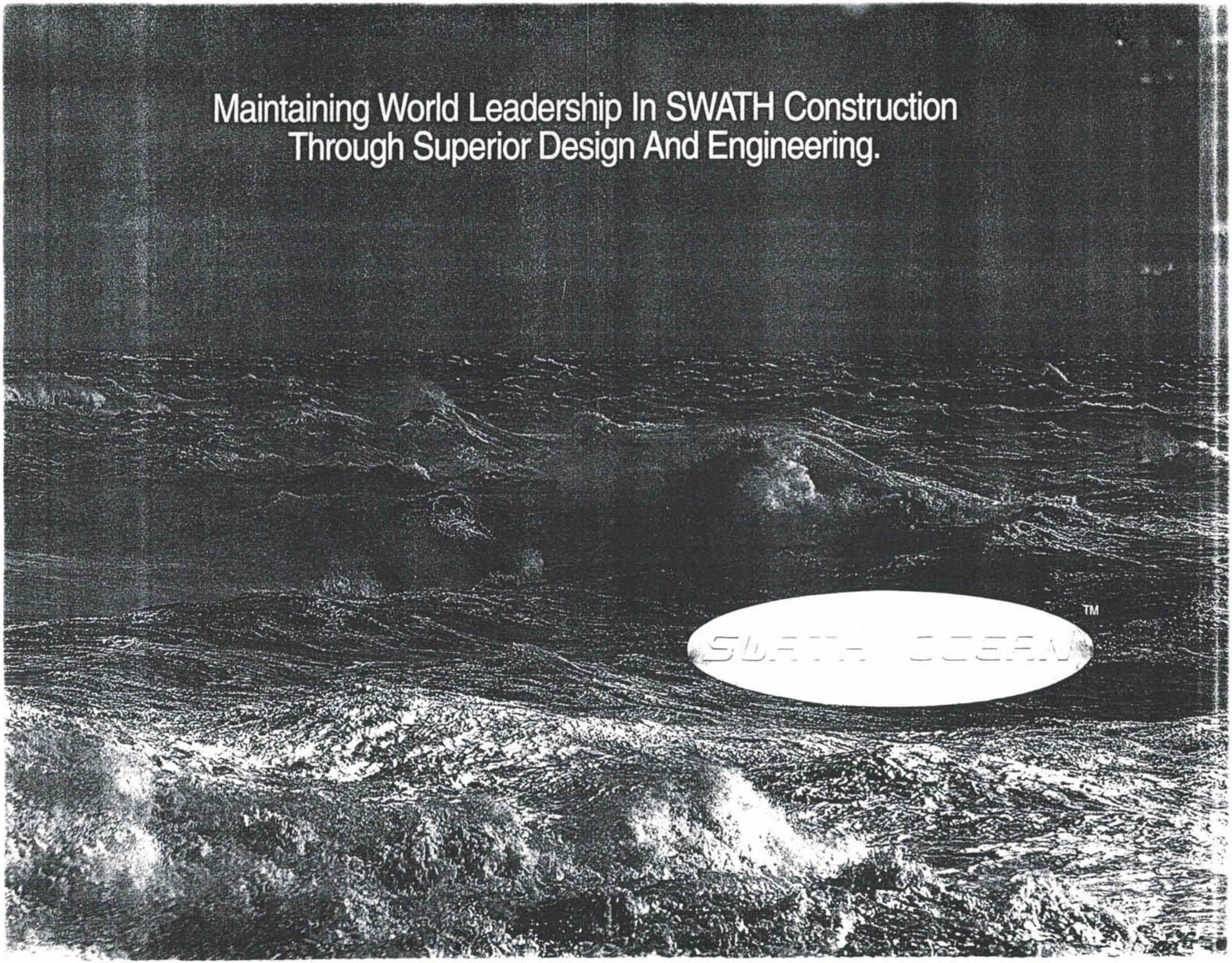
7. History of the U.S. Oceanographic Research Fleet and the Sources of Research Ships, Report of the UNOLS/FIC (Sept. 1988).

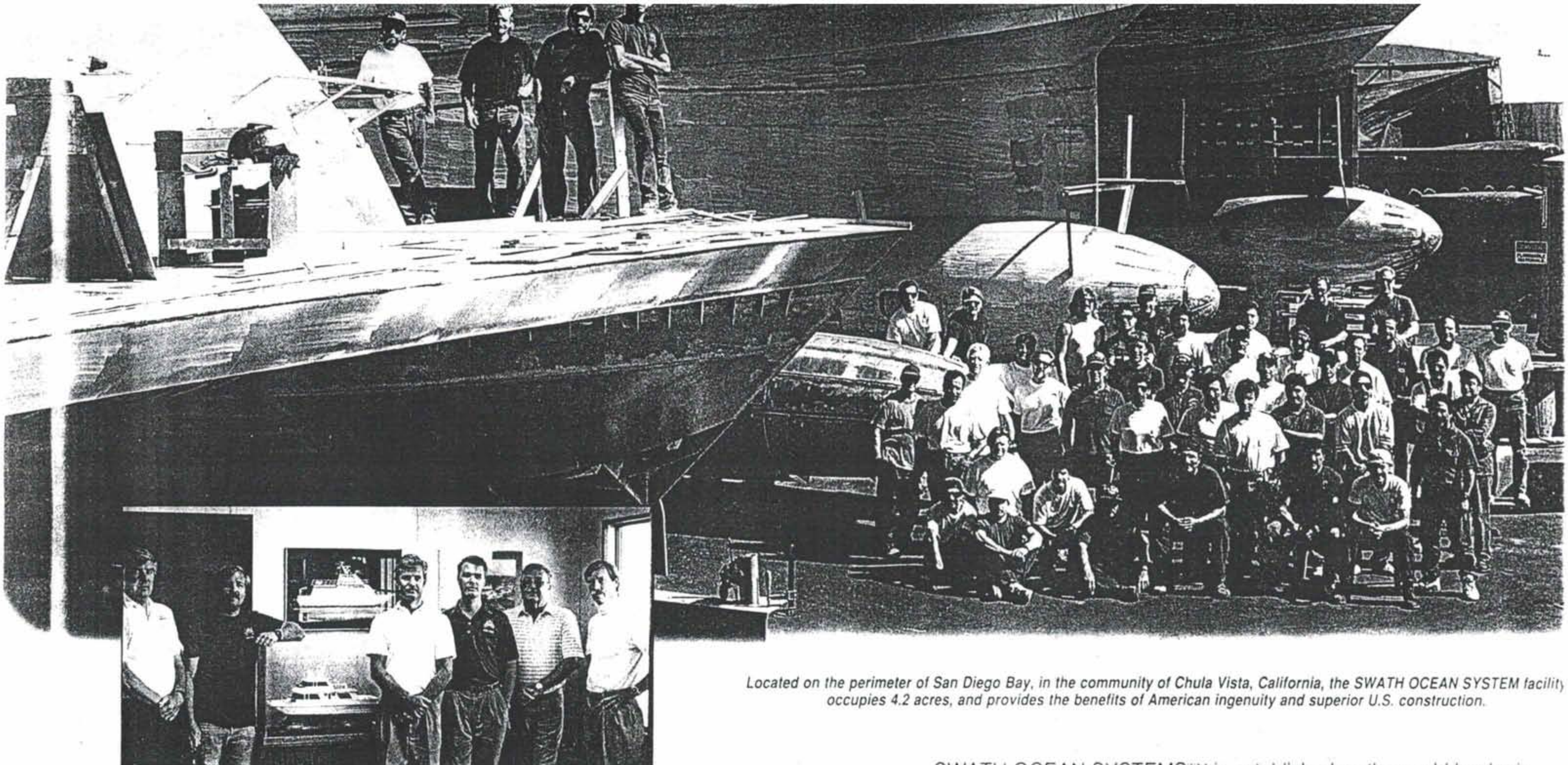
8. Scientific Mission Requirements for Oceanographic Research Vessels, Report of the UNOLS/FIC, (1989).

9. NOAA's Ocean Fleet Modernization Study, 3 part report prepared by NOAA (Sept. 1990).

10. Stable Research Platform Workshop, Report of Scripps Workshop, (April 1988).

APPENDIX X


Maintaining World Leadership In SWATH Construction
Through Superior Design And Engineering.
SWATH OCEAN™



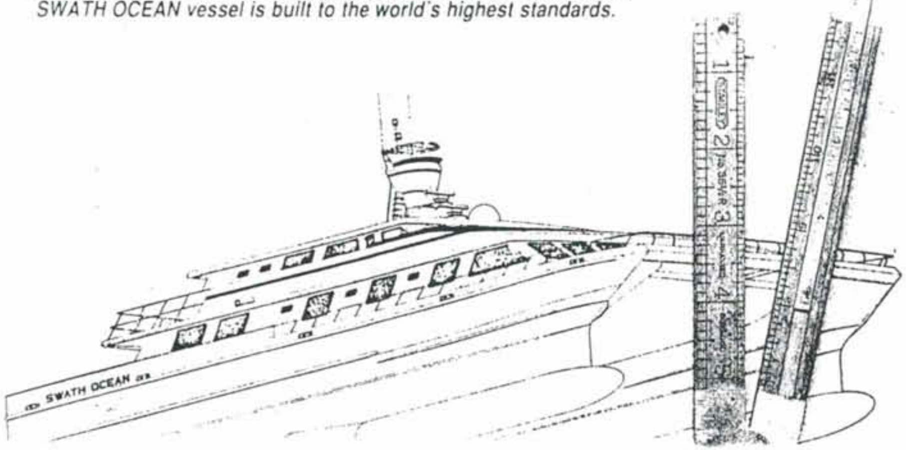
Our managerial staff (l. to r.): Kurt Schmidt, Architect; William Shaw, Yard Manager; Greg Smith, Construction Manager; Michael Dockter, Computer Designer; Nelson Hall, General Manager and Team Leader; and Robin Brackenbury, Director of Marketing. Together, they insure that every SWATH OCEAN vessel is built to the world's highest standards.

Located on the perimeter of San Diego Bay, in the community of Chula Vista, California, the SWATH OCEAN SYSTEM facility occupies 4.2 acres, and provides the benefits of American ingenuity and superior U.S. construction.

SWATH OCEAN SYSTEMS™ is established as the world leader in SWATH design, technology and construction. We've built more SWATH vessels than *any* other builder— and gained irreplacable experience throughout every project. This experience is the key to our design success.

Coordinating the many complexities of engineering, design and construction are a team of veteran builders that have pioneered SWATH (Small Water-plane Area Twin Hull) research and development over the last two decades.

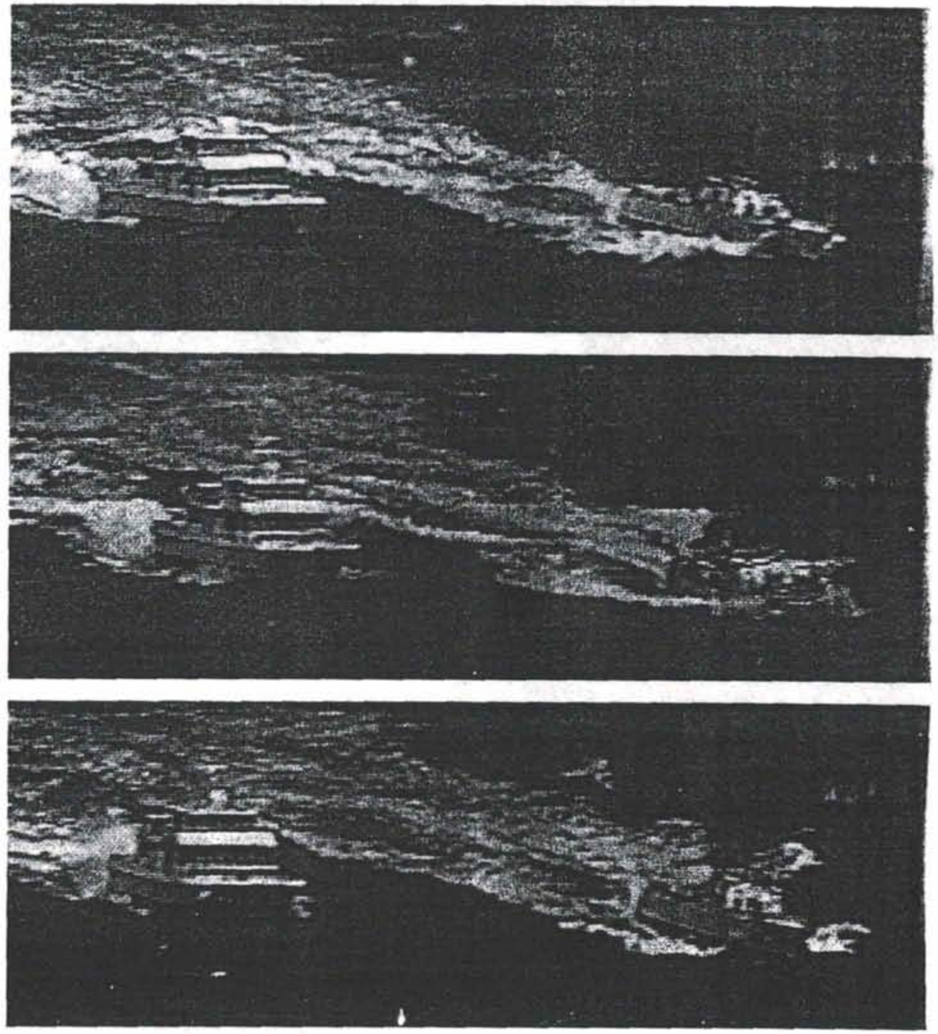
The SWATH OCEAN SYSTEMS™ commitment is to provide a vessel for sustained long-term performance, while utilizing the very latest in Swat technologies. The end result of this commitment is optimum owner/operat satisfaction, and a *superior* vessel that is launched on schedule.



Whether your actual vessel requirements are for the rigors of commercial operation in storm sea conditions, or a world class yacht standard— you can always depend on the proven performance of SWATH OCEAN SYSTEMS™.

When the sea state deteriorates and crew performance begins to suffer, the stability of SWATH OCEAN's vessels provide the platform for successful operation.

Actual video footage shot off the San Francisco bar on June 23, 1988.
Winds N.W. at 25 to 35 knots; sea state (5-6) 8 to 10 ft. swells. Video is available upon request.



SWATH vessel: "Chubasco"
built by SWATH OCEAN SYSTEMS
Stats: 72 ft. / 31 ft. beam / 70 tons

U.S.C.G. Cutter "Cape Romain"
Stats: 95 ft. / 20 ft. beam / 105 tons

Proven in the North Atlantic, and on the demanding bars of the North West Pacific, SWATH performance and stability is constantly setting new standards in sea-keeping ability.

SWATH OCEAN™


SWATH OCEAN
90 ft. Custom Long-Range Sportfisher
Now Under Construction.
65 ft. SWATH 2000 Class
"Houston" Pilot Vessel
Now Under Construction.
PILOT
SWATH OCEAN
90 ft. SWATH 3000 Class
High-Speed Ferry/300 Passenger.
"Chubasco" 72 ft.
Now operating—doing
research U.S.C.
47 ft. SWATH 1000 Class
OUTBOARD PROFILE
"Mbari" 115 ft. Custom Oceanographic
Research Vessel
Now Under Construction
SWATH OCEAN
"Pursuit" 35 ft. Custom Camera/Chase vessel
"Frederick G. Creed"
65 ft. SWATH 2000 Class
Operating: Canadian Dept. of Fisheries, Nova Scotia.
Maintaining World Leadership In SWATH Construction
Through Superior Design And Engineering.
Headquarters/Construction Facilities:
SWATH OCEAN SYSTEMS, INC.
979 "G" Street • Chula Vista, California 92011 (619) 426-2179 FAX: (619) 426-2196