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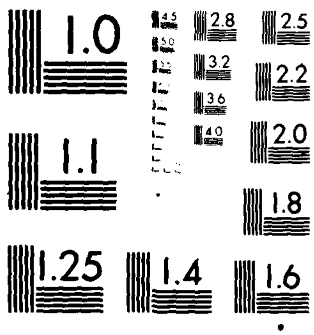
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report reviews the work completed on the project titled An Engineering Research and Development Project to Develop an Arctic Geological Core Sampling System which was funded by the Office of Naval Research under contract number N00014-75-C-0929. The primary objective of the report was to produce a lightweight aircraft deployable geological coring unit for obtaining sediment samples from throughout the arctic basin. The project initially consisted of two phases: a planning phase to establish mission requirements, as well as scientific and engineering specification and an advanced design study phase to-

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20. conduct a feasibility and development study of a new approach to coring in the arctic basin. The design study phase was divided into eight components:

1. Aircraft Deployment/Recovery System
2. Coring Unit Delivery System,
3. Sediment Coring Unit Subsystem,
4. Logistic and Field Personnel Support
5. Multiple Sensor Delivery Subsystem
6. Core Processing and Storage Subsystem,
7. System Integration,
8. Cost Analysis,

The advanced design study phase included examinations of all eight areas listed above. However, the follow-up research and development effort concentrated primarily on prototype design and field testing of the sediment coring unit. This work included a detailed system design, component research and development, and subsystem testing and evaluation. Those elements of the aircraft deployment and coring unit delivery subsystems which could be studied independent of a final corer design were also treated.

UNH ARCTIC RESEARCH PROJECT

FINAL REPORT

AN ENGINEERING RESEARCH AND DEVELOPMENT PROJECT TO DEVELOP AN ARCTIC GEOLOGICAL CORE SAMPLING SYSTEM

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Prepared for

Office of Naval Research

December 1981

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A. Arctic Flying Book

B. Cruise Report

FINAL REPORT

for

An Engineering Research and Development Project to

Develop an Arctic Geological Core Sampling System

I. INTRODUCTION

This report reviews the work completed on the project titled An Engineering Research and Development Project to Develop an Arctic Geological Core Sampling System which was funded by the Office of Naval Research under contract number N00014-75-C-0929. The primary objective of the report was to produce a light-weight aircraft deployable geological coring unit for obtaining sediment samples from throughout the arctic basin. The project initially consisted of two phases: a planning phase to establish mission requirements, as well as scientific and engineering specification and an advanced design study phase to conduct a feasibility and development study of a new approach to coring in the arctic basin. The design study phase was divided into eight components:

1. Aircraft Deployment/Recovery System
2. Coring Unit Delivery System
3. Sediment Coring Unit Subsystem
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The advanced design study phase included examinations of all eight areas listed above. However, the follow-up research and development effort concentrated primarily on prototype design and field testing of the sediment coring unit. This work included a detailed system design, component research and development, and subsystem testing and evaluation. Those elements of the aircraft deployment and coring unit delivery subsystems which could be studied independent of a final corer design were also treated.

II. PLANNING PHASE

The Planning Phase was aimed at establishing mission requirements and scientific and engineering specifications. This phase of the project included the following activities:

1. A review of literature holdings at library facilities of the Naval Arctic Research Laboratory, Point Barrow, Alaska, the U.S. Army Cold Regions Research and Engineering Laboratory, the Lamont Doherty Geological Observatory, and other institutions with information on seafloor coring and geology.

2. A thorough search of the references related to the project on file at the National Technical Information Service (NTIS) and at the Smithsonian Science Information Exchange.

3. Meetings with scientific and technical personnel with active programs and interest in arctic seafloor phenomenon. These interviews and meetings involved colleagues at the Naval Arctic Research Center, the U.S. Army Cold Regions Research and Engineering Laboratory, the Lamont-Doherty Geological Observatory, the Woods Hole Oceanographic Institution, the Naval Civil Engineering Laboratory, the University of Alaska, Arctic Institute of North America, the U.S. Geological Suvey, the University of Wisconsin, and several industries with research efforts in geological coring in the Arctic, such as the North Slope District of Atlantic Richfield Corp. (ARCO).

4. The formation of an ad hoc Scientific Advisory Committee. This committee, composed of members from the scientific community and the Office of Naval Research, helped to provide insight into the scientific requirements and to identify the regions in the arctic basin of greatest scientific and technical interest.

5. The following scientific and engineering specifications for the project were established.

A. The Scientific Specifications:

1. Provide sedimentary cores equivalent to those obtained with a standard Ewing Piston Corer.

2. A minimum inside core barrel diameter of 7 cm. (approximately 2 3/4 inches).

3. Utilization of standard core "catchers".

4. Core barrel penetration of up to 15 meters (approximately 50 feet) and recoveries of 80-100%.

5. Maintenance of the relative axial orientation from one section of core barrel to the next.

6. A system adaptable to both extrusion and core liner methods of coring.

7. Operate to water depths of 2500 fathoms (15,000 feet). The deepest known part of the arctic seafloor is located in the Pole Abyssal Plain at approximately 89° 20'N, 30°E.

8. Allow for on-site flow-in observations.

9. Cores shall be wrapped, marked and sealed in shipping tubes at the ice station. Labeling shall consist of the method specified by the core processing laboratory.

10. The core processing laboratory shall analyze the core, usually for the following data:

    a. General structure and stratigraphy
    b. Geomagnetic properties
    c. Composition and particle size distribution
    d. Dating, when appropriate

B. The Engineering Specifications:

1. Ambient temperature for operations. In air, -60°F to 100°F and in sea 28°F to 80°F.

2. A maximum system weight of approximately 2500 pounds. This includes the corer, winch, and recovery cable, but not the delivery vehicle.

3. Anti-frictional coatings shall not contaminate the core sample.

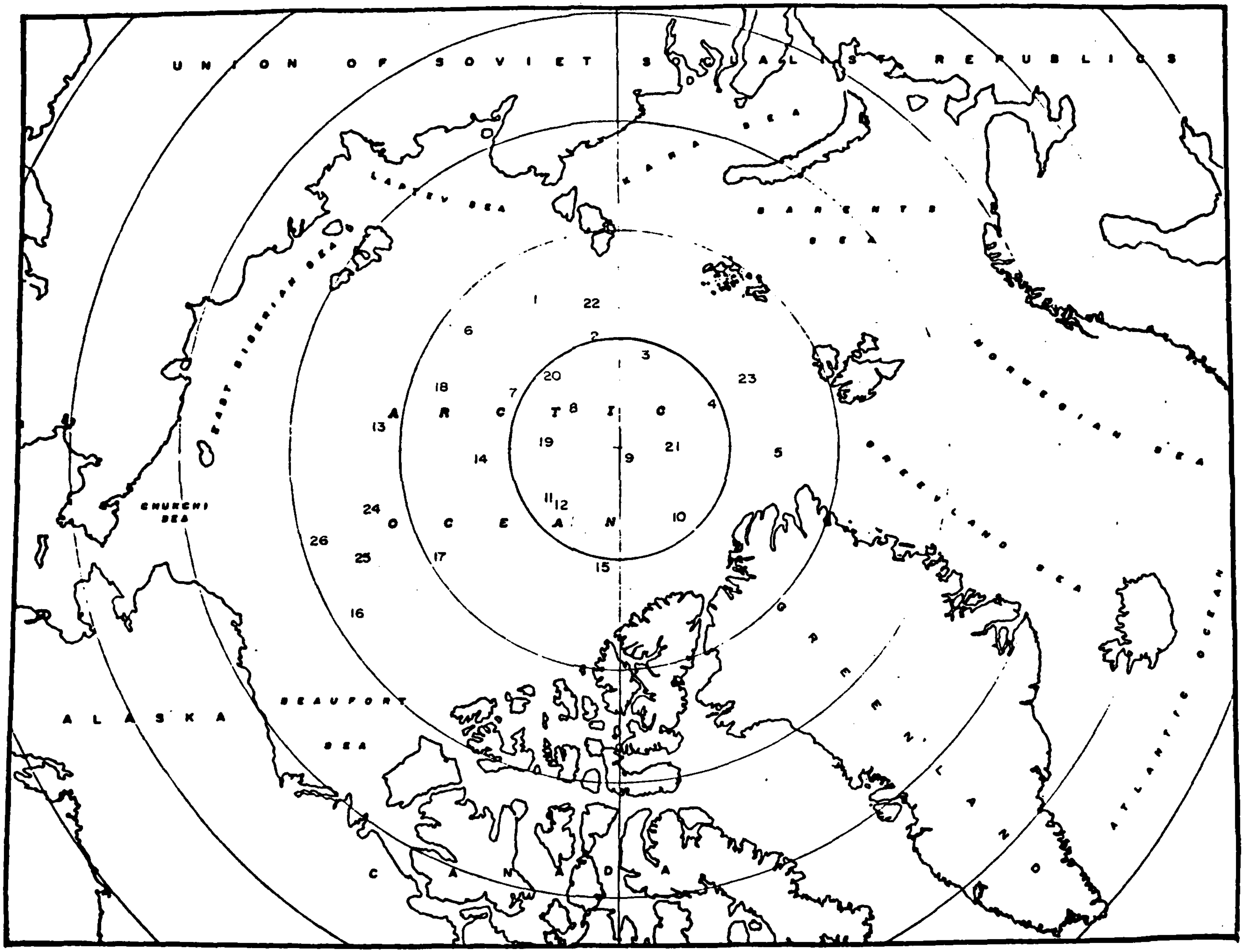
4. Core disturbence of a degree equal to or less than that obtained with standard piston core systems.

5. A system capable of recovering a core in approximately four hours or less, once an ice hole has been cut.

6. A core system capable of supporting other oceanographic data gathering instruments, multiple snesor capability for physical oceanographic and acoustic studies will be included in the final design.

7. A system that is corrision resistant.

8. A core system that can be operated by one man, if at all possible.



Priority listing twenty-six potential research sites for seafloor geological studies

9. Reliability of operation shall receive high priority.

10. The recovery aircraft will be protected from contamination by sea water drainage for system components.

11. A system that provides such associated operations as ice hole cutting, ice hole heating or circulation for maintenance of the ice hole, sea water wash for cleaning the core system on recovery, protection from the cold for operating personnel, and storage of empty and full core barrels (and/or liners).

12. Priority listings of twenty-six potential research sites in the arctic basin for seafloor geological field projects were identified. This list was generated by Kenneth Hunkins (Lamont-Doherty Geological Observatory) and David Clark (University of Wisconsin) and distributed to geologists with active research programs in the arctic for review. The sites are listed by priority in Table I and depicted in Figure 1.

Table I

A Rank Ordered List of Research Sites for Seafloor Coring in the Arctic

5 from Mid-Ocean Ridge (1-5)
5 from Lomonosov Ridge (6-10)
2 from area 85° 53'N - 124° 32'W to 85° 59'N - 129° 58'W (11-12)
3 from other parts of Alpha Cordilera (13-15)
2 from Canada Abyssal Plain (16-17)
2 from Fletcher Abyssal Plain (18-19)
2 from Pole Abyssal Plain (20-21)
2 from Barents Abyssal Plain (22-23)
3 from Chukchi Plateau and area (24-26)

III. DESIGN STUDY PHASE

This second phase was conducted as a feasibility and advanced design study. Its purpose was to produce a preliminary design for an air deliverable system for obtaining geologic cores from the arctic basin. This system was to comply with the engineering and scientific specifications established in the planning phase. Each of the eight components listed in the introduction was examined, with consideration given to alternatives from both new and existing technology. The following is a summary of the work completed during the Design Study Phase.

A. Aircraft Delivery/Recovery Subsystem

A report on the selection of aircraft to support scientific research in the central arctic basin was prepared. The report was reviewed by personnel at the Office of Naval Research, the Antarctic Development Squadron (VXE-6) and others knowledgeable in arctic aircraft operations. The report focuses on proven aircraft used in the central arctic basin since the early 1900's, focusing on aircraft which were used in the establishment of temporary scientific ice stations.

The report considers numerous aircraft as candidates for arctic operations, i.e. the USAF C-130, USN-LC-130F & 130R, Commercial C-130, Twin Otter, Caribou, Buffalo, and Helicopters UH-1B, UH-1N and the Lamma. Airships were considered but rejected after a review of the availability and demonstrated arctic capability. These aircraft were compared for performance, cost, demonstrated arctic capability, and numerous other factors affecting utility of the aircraft for supportung the deployment of a scientific party on the ice in the central arctic. In addition, 58 staging sites (airfields) throughout the North American Continent (U.S., Canada and Greenland) were analyzed. General conclusions from the aircraft study are summarized in the following paragraphs.

Four fixed winged aircraft (the Twin Otter, the Caribou, the Buffalo, and the C-130) were considered for an arctic research effort that comtemplates establishing ice stations over a broad expanse of the arctic basin. Based primarily upon cost effectiveness, range of operations, payload and proven experience with polar operations, the C-130 aircraft of the Antarctic S 'uadron Six (VXE-6) were recommended as the aircraft to be used for this program. The recommendation was based upon these factors:

a. The aircraft has the range to cover all the potential research sites being contemplated for a seafloor geological research effort.

b. The cost of operation for VXE-6 aircraft was lowest of all candidate aircraft on a cost per mile basis.

c. The VXE-6 Squadron had accumulated substantial operational and technical capability for conducting missions in polar regions.

d. The VXE-6 Squadron had established virgin field stations in the antarctic using a technique which could be translated to the arctic. It is clear to the writers that establishing virgin field stations is not a routine matter and the antarctic technique would require considerable adaptation to make it a more routine procedure in the anctic. However, the VXE-6 Squadron is the group with properly equipped aircraft and personnel capable of developing a more routine procedure for virgin ice station landings and for possibly conducting "hop scotch" missions.

e. The only other aircraft which met most of mission requirements is the Buffalo. However, the Buffalo is a military aircraft, used predominantly by the Canadian Armed Forces. Only one Buffalo could be found in the U.S., an aircraft operated by NOAA out of Boulder, Colorado. The Buffalo had not, as yet, been ski-equipped, so it had no arctic basin or polar ice/snow field experience. On these grounds, it was not considered a viable candidate.

f. The Caribou, with a reciprocating engine, was not considered as a candidate. Further, its cost of operation (roughly 100% more than the VXE-6 LC130's on a cost/mile basis) and its range, made it a less desired candidate.

g. The Twin Otter was an attractive candidate, particularly for near-coast operations. However, its range (which limits it to only about 25% of the research sites of current interest) and its small payload, made it undesirable as the main vehicle for this research program.

A final copy of this report was presented to the Office of Naval Research during the projects intial year. Further, the UNH team contributed two chapters in the ONR book entitled, Arctic Flying, both are attached, in Appendix A.

B. Delivery Subsystem for the Coring Unit

The delivery subsystem design encompassed all elements essential to transporting the coring unit from the aircraft to the ocean floor. These included a winch, a lightweight/high strength cable, an ice cutting apparatus and a support structure. The alternatives considered ranged from units installed and operated from the aircraft, to mobile laboratory units, such as sled vans or self powered snow vehicles, which could be unloaded onto the ice and removed at a later time. Initially, two approaches characterized the range of probabilities which were reviewed. They were:

a) A winch delivered conventional coring system which uses a lightweight winch with high strength to weight cable (like Fiber B) to lower and recover a conventional piston corer or similarly well-established coring system.

b) A free-fall/messenger line recovery coring system, utilizing a free-fall corer (of proven conventional design or new approach, such as the University of Miami's Niskin System) which pays out a messenger line during descent. On impact, the corer drives into the seafloor; after full penetration, the core barrel is released and guided to the surface on the messenger line. If desired, the messenger line can be used for other instrumentation purposes, provided the core recovery is delayed a sufficient time to permit other measurements to be made. The messenger line could be sacrificed, as that would eliminate the need for a winch. Since it is only a guidewire, it could be made of light-weight material and recovered on a small winch.

The final design selected for the sediment coring subsystem was from the winch delivered category.

To minimize the total weight of this system, a cable constructed from Kevlar was selected as a substitute for the conventional steel cable ordinarily used in the ocean. Kevlar with its low elongation and a strength to weight ratio thirty times greater than steel in water, was an attractive alternative. Existing test results with Kevlar had also demonstrated a cyclic bending fatigue strength at least comparable, and most often superior, to steel under normal environmental conditions and an increase in tensile strength at low temperatures. However, Kevlar had not been evaluated as a working cable at low temperatures and there existed legitimate concern about the effects of ice crystal formation on the self abrasive nature of Kevlar fibers. Before definately replacing steel with Kevlar, these concerns needed to be eliminated.

Contacts were made with twenty five reported users of Kevlar cable in ocean application and all manufacturers providing Kevlar cable products. Their experiences revealed that Kevlar had demonstrated some degradation as a working cable with conventional drum winches. However, the problem could be eliminated by using a traction winch. It was also apparent that very limited operational data existed on Kevlar in cold weather installations. There was a need for further testing to extend the limited cyclical test data on Kevlar, specifically in an Arctic-like environment. These tests, designed and conducted at the University of New Hampshire, have been completed and the final report is being prepared.

The traction winch for the system was also a non-trivial design problem. Weight constraints, working loads, environmental conditions, and the substitution of Kevlar prevented the utilization of a conventional drun winch. Thirty two winch companies were contacted regarding involvement in the development of a light weight, powerful traction winch for use in the Arctic. Eight of the companies responded positively and it was proposed that a joint effort be undertaken by the members of the project team and one of the following companies:

Reading Crane and Engineering Corporation
Potsdam, PA

Ocean Systems Incorporated
Boston, MA

Silent Hoist and Crane
Brooklyn, NY

The funding for such an endeavor, however, was not available.

C. Sediment Coring Unit Subsystem

The sediment coring unit subsystem was the key component in the system and, consequently, received the most attention throughout the project. Initially, a thorough review of available coring systems was conducted and thirty two different units were analyzed and compared. Sampler performances were evaluated based upon the engineering and scientific specifications established during the planning phase. Upon completing the comparisons, it was decided to utilize one of the piston corer type and to direct the project's energies at examining techniques for increasing the amount of penetration and the ratio of recovery to penetration.

Antifriction coatings were investigated as a means of increasing penetration and recovery rates. A prior laboratory study with flat plates, conducted by Ronald Erchiel at the Naval Post Graduate School, indicated potential increases in penetration due to antifriction coatings of up to 45%. In an attempt to reproduce these results in the field, a pilot project was conducted by the University of New Hampshire with gravity corers in coastal waters. The increases in penetration due to the lubricants were in the 15-20% range, somewhat less substantial than Erchul's laboratory data. However, the formulation of any definite conclusions would require a more extensive follow-up field study.

Next, an examination of the effects of variations in corer weight and impact velocity on the penetration depth of a free fall corer was conducted. Technically, the most desirable method for performing this analysis was to use finite difference or finite element techniques to solve the equations of motion for a corer penetrating the seafloor. However, this proved too costly because of the required computer time. Instead, several empirical methods of predicting seafloor penetration were reviewed and these experimentally verified methods were found to be more realistic as a design tool.

A method developed by David G. True and reported in a paper titled, "Rapid Penetration into Seafloor Soils", provided a reliable means of predicting corer penetration depths. The equation used to describe the corer motion was a modified version of the Poncelet equation and represented the total resistance as the sum of contributions due to bearing pressure, side adhesion, and fluid inertial drag. The equations reliability was verified with gravity corer data obtained from Woods Hole Oceanographic Institute. The computer simulation, utilizing this equation, produced penetration depths similar to those obtained in the ocean with the gravity corer. Although this analysis never provided a clearer understanding of the physical interaction between corer and seafloor, it did produce data establishing weight as a far more dominant variable than impact velocity in determining penetration depths. The equation also proved to be a valuable tool for predicting maximum work loads for tests with the prototype corer.

The design concept selected for the prototype corer was based upon the "bootstrap" corer proposed by John Isaacs and Daniel True at Scripps Institute of Oceanography. The "bootstrap" design possessed a number of attractive quality such as lightness, ease of withdrawal, and the potential for obtaining long cores. It did, however, produce samples that distorted considerably. The "bootstrap" initially acts similar to a piston corer and then is drawn deeper into the seafloor by an internal system of sheaves, utilizing the piston as an anchor. The prototype arctic corer was essentially a "bootstrap", modified to act as a driving mechanism,, carrying two externally attached sampling tubes which could retrieve distortion free cores. A twenty foot prototype, called the Arctic Corer, was constructed and tested. (This design is discussed in the cruise report enclosed in Appendix B).

Test data produced with the prototype was highly inconclusive. After several minor excursions to eliminate the basic design complications, three major cruises with the twenty foot prototype were conducted. The first cruise, situated out of Miami, Florida, included four unsuccessful drops with the fully assembled Arctic Corer. The lack of initial penetration experienced on these drops, with a maximum free fall distance of fourteen feet, was attributed to a highly consolidated seafloor. To determine the most suitable coring sites, a thorough survey had been conducted prior to the cruise by reviewing the literature and contacting principle investigators associated with previous coring expenditions in the area. However, an extensive acoustic survey never uncovered these pockets of soft layered sediment during the cruise.

The second cruise included four lowerings with the Arctic Corer. The first two attempts were aborted because of malfunctions with the triggering mechanisms and the final two resulted in four and six feet of penetration with negligible traces of sediment retained within the sampling tubes. Several additional tests were also conducted with the original "bootstrap" design. Removing the extraneous hardware improved penetration and a ten foot core sample was retrieved. The recovery ratio (core length/penetration depth) of 68% compared favorably with the 70% reported in the publication of Isaacs.

The third cruise included sixteen coring attempts with the original "bootstrap" design. The operational plan for this cruise had been restructured to begin with the most basic system and proceed in stages to the fully assembled Arctic Corer. This allowed for careful evaluation of each component as it was introduced into the system. However, the testing never advanced beyond the initial stage. The sixteen lowerings completed with the "bootstrap" corer provided minimal evidence of any additional penetration following the initial surge at impact. The methods used to measure penetration depth, exterior mud marks retained on the outer surface of the corer and the acoustic records, both indicated the same phenomenon.

IV. SUMMARY OF ACCOMPLISHMENTS

The objectives set forth in this multiyear research and development program were met. The major accomplishments were:

(1) The scientific mission requirements of the Geological Science Community were identified and served as the scientific requirements for this program.

(2) A thorough review of aircraft systems (aircraft, logistic support, etc.) identified aircraft fully capable of supporting the scientific missions. Two major arctic aircraft reports/book were prepared.

(3) Kevlar Cable was tested under arctic conditions and found to be fully adequate for the arctic science missions.

(4) Three commercial winch manufacturers, out of thirty-two companies contacted, indicated willingness to participate in a join ONR/UNH traction winch development program for arctic applications.

(5) A computer model of the coring process was developed and validated with field data. The model predicts the fact that corer weight is a far more dominant variable in penetration than is impact velocity. The model appears to be a reliable predictor of the coring process.

(6) Antifriction coatings were field tested, and were found to improve penetration by 15-20%, but did not improve the penetration by 45% as predicted by laboratory tests.

(7) Three prototype Arctic Corers were designed and field tested. The "boot strap" concept, while attractive did not develop the thrust necessary to provide design length cores. Further engineering design and testing would be required to fully evaluate the concept. The UNH project team suggested the program be terminated primarily because the cost of further development could not be justified based on the field data obtained in the cruise of December 3-10, 1977.

APPENDIX A

Two chapters of the enclosed book entitled Arctic Flying, were prepared by Robert Corell. This book was prepared as a result of needs expressed by the U.S. Navy, and its preparation was supported, in part, by the Office of Naval Research, Arctic Programs, and by this contract.

APPENDIX B

An Engineering Research and Development Project
to Develop an Arctic Geological Sampling System

Cruise Report for Period
December 3 - December 10, 1977

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