TRANSPORTING ICE CORE: METHODS AND COST ANALYSIS

by Harm De Boer

PICO
OR-91-4

PICO is operated by the University of Alaska Fairbanks under contract to the National Science Foundation, Division of Polar Programs

TRANSPORTING ICE CORE: METHODS AND COST ANALYSIS

by Harm De Boer

PICO
OR-91-4

PICO is operated by the University of Alaska Fairbanks under contract to the National Science Foundation, Division of Polar Programs

TABLE OF CONTENTS

PREFACE

The purpose of this report is to respond to a request from the GISP Science Management Office to determine a safe, cost-effective method of transporting ice core from the Greenland coring site (GISP II) to the ice core repository in Denver, Colorado where the ice core is further processed and stored.

Several different containers were considered for temporarily storing ice core and shipping it. In addition to air transportation, transport by land and sea was investigated for segments of the journey where a choice existed. A combination of all three modes of transportation appears to offer a safe and cost-effective option.

ACKNOWLEDGMENTS

I am indebted to my colleagues at PICO for their help in peparing this paper. Valuable input was received from Catherine Melville, Steven Peterzen, Mark Wumkes, Jay Klinck and Dr. John Kelley. Also, thanks to the PICO office staff for typing and proofreading. Special thanks to Mrs. Helen Stockholm, Publications Supervisor, Institute of Marine Science, and her capable staff for editing and final preparation of the paper. All this generous help is gratefully acknowledged.

ABSTRACT

After considering numerous shipping containers and different modes of transportation, transporting the ice core in leased, 20-foot marine freezer containers aboard the U.S. Navy ship *Green Wave* from Greenland to Bayonne, N.J., appears to be the safest and most economical way. Trucking the ice core inside a frozen van on a trailer with air ride suspension from Bayonne, N.J., to Denver seems to be the best transportation method for this leg of the journey. The equipment used is readily available, proven reliable, and can be leased for a competitive price.

INTRODUCTION

This report consists of three parts. Part I, entitled "Comparison of Methods of Ice Core Shipment", has eight different options, each of which briefly describes one method of shipping the ice core, the equipment required when using this method (containers, refrigeration, etc.), estimated cost of the equipment, and the advantages and disadvantages of that particular shipping option.

Part II, entitled "Ice Core Shipping Costs Considering Eight Options", details the shipping costs for each of the eight options over the period of one season. Starting at Schenectady, N.Y., McGuire AFB or Bayonne, N.J., expenses are estimated for each major operation or movement which the ice core and related shipping equipment undergoes. Estimated shipping costs are totaled for each option.

Part III, "Assumptions", is a list of some of the assumptions which were made in preparing the estimates listed in Part II. Trucking and air freight rates, labor costs, and weights of some of the associated equipment are found in this section.

Part I

1991 COMPARISON OF METHODS OF ICE CORE SHIPMENT

OPTION #1

Equipment Required	Total Estimated Cost
Four refrigerated containers at $33,500 ea	$134,000

This system would utilize four self-contained refrigerated containers mounted on a forkliftable aircraft pallet. Refrigeration unit operates on 50/60 cycle AC power or on an integral diesel unit. Approximately 160 core tubes per unit would be loaded into the refrigerated container at GISP II site.

Contents of container would be cooled down to -37 degrees Celsius before container is loaded on aircraft. The refrigeration unit would be plugged in to re-chill contents when the aircraft is refueling/reloading at Søndrestrøm AFB and again in Schenectady. The refrigerated container would be loaded on a flatbed truck and hauled to the Denver area with the self-contained diesel engine providing power to the refrigeration system while enroute. After unloading the contents of the refrigerated container, the 3,560 lb empty container would be trucked back to Schenectady before being airlifted back to Søndrestrøm AFB and GISP II for re-use.

Advantages:

1. Ice cores would be well protected against high temperatures during transport.
2. Ice cores would require no reloading from refrigerated containers between GISP II and Denver.
3. Refrigerated containers are readily available.

Disadvantages:

1. High cost of refrigerated containers.
2. High cost of shipping heavy (3,560 lb ea) empty container from Denver to GISP II. ($4,172 to ship container from Denver to Schenectady).

OPTION #2

Equipment Required	Total Estimated Cost
Four Wumkes design collapsible, insulated containers at $5,750 ea	$23,000
Three auxiliary mobile refrigeration units at $8,000 ea	24,000
	$47,000

This option would utilize collapsible type insulated containers and skid mounted auxiliary mobile refrigeration units powered by AC electricity. The ice core tubes would be loaded into the insulated containers at GISP II. The skid mounted refrigeration unit would pump cold air to the insulated container via two lengths of 10" or 12" diameter flexible duct inserted through holes in the container walls. After reaching the desired temperature, the refrigeration unit would be disconnected from insulated container and stored at GISP II while the container would be shipped to Søndrestrøm AFB. Another auxiliary mobile refrigeration unit would be permanently located at Søndrestrøm AFB and be used to re-chill the insulated container as soon as it arrived and until the aircraft departed for New York. The

third refrigeration unit would be located at the Schenectady air base and would be used if the container could not be loaded directly from the aircraft to the frozen van bound for Denver.

Advantages:

1. Relatively low total investment.
2. Relatively inexpensive shipping costs since no heavy refrigeration equipment is being transported and the shipping containers are of the collapsible type.
3. Very little time given to handling of core tubes as they remain in the same container from GISP II to its final destination.

Disadvantages:

1. Potential problem with getting proper air diffusion and cooling with core tubes tightly stacked in container.
2. Additional labor required to disassemble and reassemble insulated containers.
3. It would take a considerable amount of work and time to cool down each container when the containers are shipped 3 or 4 per aircraft since we would have only one refrigeration unit on the ground at each landing site.

OPTION #3

Equipment Required	Total Estimated Cost
Four insulated blankets at $1,000 ea	$4,000

Under this proposal we would use existing, on site, insulated core boxes placed on an aircraft pallet and then covered with an insulated blanket. After arriving in Søndrestrøm the pallets of ice core would be placed in a freezer at the air base until loaded aboard an aircraft for New York. After arriving at Schenectady the pallets would be placed inside a frozen van unit and trucked to their final destination whereupon the blankets would be shipped back to GISP II.

Advantages:

1. Very economical; purchasing and shipping costs are low with this plan.
2. Convenience in loading. Ice core boxes could be shipped in virtually any aircraft.
3. Simplicity; no mechanical breakdowns possible with this system.

Disadvantages:

1. Ice core is not quite as well protected from warm temperatures and physical damage.
2. Core handling labor is high as the pallets must be broken down in Søndrestrøm to get into and out of freezer units which have only a single door entrance.

OPTION #4

Equipment Required	Total Estimated Cost
Four Wumkes design collapsible, insulated containers at $5,750 ea	$23,000
Four auxiliary mobile refrigeration units at $8,000 ea	32,000
	$55,000

This option would use the same equipment as option #2, collapsible insulated containers and auxiliary mobile refrigeration units. However, under this option, the

auxiliary mobile refrigeration units would be shipped together with the insulated containers.

Advantages:

1. The big advantage with this option is, of course, the protection that it would offer to the ice core during any extended stop, anywhere along the route.
2. Relatively low total investment.
3. Very little time required to handle core tubes as they remain in the same container from GISP II to Denver.

Disadvantages:

1. Potential problem with getting proper air diffusion and cooling with core tubes tightly stacked in container.
2. Additional labor required to disassemble and reassemble insulated containers.

OPTION #5

Equipment Required	Total Estimated Cost
Four Wumkes design collapsible, insulated containers at $5,750 ea	$23,000
One 30' marine type freezer van	40,000
	$63,000

This option would utilize collapsible type insulated containers loaded inside a larger marine type freezer van. The core boxes would be loaded into the insulated containers at GISP II and the four loaded containers would then be placed inside the electric powered freezer van. After reaching the desired temperature, the entire freezer van and contents would be loaded onto the LC-130 and flown to Søndrestrøm and then on to Denver. The freezer van would be plugged in at any extended stop the aircraft made enroute to Denver - Søndrestrøm, at refueling stops, Schenectady, etc., and again immediately upon arrival at Denver.

Advantages:

1. Excellent protection for ice core.
2. The core boxes would only have to be handled once and the containers would not have to be opened until they reached their destination.
3. Relatively low investment.
4. Only one cooling unit would require attention.
5. Collapsible, insulated containers used to house the core tubes could possibly be replaced by the insulated boxes used in past years (insulated boxes placed inside freezer van).

Disadvantages:

1. The freezer van would be more awkward to load aboard aircraft.
2. The freezer van is bulky and would take up considerable space on back haul flights. However, with its large double doors it could be loaded with pallets of food, supplies, etc., on back hauls.

OPTION #6

Equipment Required	Total Estimated Cost
Four extra large Wumkes design collapsible, insulated containers at $8,000 ea	$32,000

This option would utilize four extra large Wumkes design, collapsible, insulated containers holding about 300 m per container. The ice core would be loaded into core tubes and placed into two of the large collapsible, insulated containers at GISP II, then loaded on an LC-130 bound for Søndrestrøm. The ice core tubes would be unloaded at Søndrestrøm and placed in a freezer. This operation would be repeated with two more containers of ice core, also stored in the Søndrestrøm freezer. When a Denver bound LC-130 was available all four large containers would be loaded with ice core tubes from the Søndrestrøm freezer and loaded on the aircraft. The aircraft would fly from Søndrestrøm to Duluth, refuel at Duluth, then fly on to Denver for a total flight time of about 11 hours. After unloading the ice core in Denver, the LC-130 would return to Schenectady.

Advantages:

1. Large amount of ice core being shipped per load (300 m/container x 4 containers = 1,200 m) would require only two shipments for entire season.
2. Relatively low investment in equipment.

Disadvantages:

1. Considerable labor involved in unloading the containers at Søndrestrøm, placing core tubes in freezer, then reloading core tubes in container for shipment to Denver.
2. Although the ice core would be inside an insulated container, the relatively long flight time (nearly 11 hours) plus refueling time at Duluth (give or take one hour) would leave the ice core without a means of being re-chilled for approximately 12 hours.

OPTION #7

Equipment Required	Total Estimated Cost
One 40' marine type freezer container, leased (6 month lease)	$ 5,160
One collapsible, insulated container	5,750
	$10,910

This option would utilize one leased 40' marine freezer container which would be stationed at Søndrestrøm AFB, from June until the ship *Green Wave* makes its last return trip from Søndrestrøm to Bayonne, expected to be in late August. The freezer container would be transported by the ship *Green Wave* in June. The ice core would be placed in core tubes and the core tubes would be loaded in an insulated container at GISP II for transport to Søndrestrøm. (The ice core could also be placed in insulated boxes and covered with insulated blankets for this trip.) At Søndrestrøm, the ice core would be placed in the freezer container. This operation would be repeated through the summer, storing most, if not the entire season's ice core in the freezer container. In August (the exact return sailing date for the *Green Wave* is not available as of this writing) the freezer container and contents would be loaded aboard a flatbed truck, trucked to dockside, and loaded aboard ship. The freezer container would be plugged into the ship's electrical system during transport to Bayonne, N.J. At Bayonne, the freezer container can be loaded aboard a flatbed truck with air ride suspension and

pulled to Denver. The tractor pulling the flatbed would be equipped with a diesel powered generator to run the refrigerator unit enroute to Denver. The ice core could also be unloaded from the freezer container in Bayonne, placed in a freezer van with air ride suspension, and trucked to Denver, thus avoiding the transportation charges of returning the leased freezer container to Avenel, N.J.

Advantages:

1. This option undoubtedly would be the least expensive of those considered since it involves no air transport of the ice core after it reaches Søndrestrøm.
2. Ice cores would be well protected against high temperatures during transport.
3. The freezer van is readily available and can be leased for the season.

Disadvantages:

1. The precise return sailing date of the ship *Green Wave* is not available as of this writing (3-1-91) so we don't know if all of the ice core could be processed in time for the sailing.

OPTION #8

Equipment Required	Total Estimated Cost
Two collapsible, insulated containers with integral cooling at $8,000 ea	$16,000
Two 20' marine freezer containers, leased. Three months lease: 2 x $2,640	5,280
	$21,280

This option would utilize two 20' marine freezer containers which would be leased for the season (90 days) and two pallet-sized, insulated containers with integral cooling. The smaller containers would be used to ship ice core from GISP II to Søndrestrøm AFB. The two 20' freezer containers would be shipped from Bayonne, N.J., to Søndrestrøm on the *Green Wave* and would be positioned at Søndrestrøm AFB and initially used for ice core storage. Sufficient ice core should be processed by August 18th (the approximate return sailing date for the *Green Wave*) to fill one 20' container and the container of ice core would be transported back to Bayonne, N.J., aboard the ship. From Bayonne, the ice core would be transferred to a frozen van with air ride suspension on trailer and trucked to Denver. Meanwhile, the second 20' freezer container would be used for ice core storage at Søndrestrøm. At the end of the season, the second freezer container of ice core would be loaded aboard a Schenectady-bound LC-130 and flown to New York. Again, the ice core would be reloaded onto a freezer van with air ride suspension on trailer and trucked to Denver.

Advantages:

1. Ice cores would be well protected against high temperatures during transport.
2. The 20' freezer containers are readily available and can be purchased or leased for the season. Leasing two of the containers for 90 days would cost only $5,280.
3. Use of the *Green Wave* to get both containers to Søndrestrøm and one container full of ice core back to the East coast will hold shipping costs to a minimum.

Disadvantages:

1. The ice core tubes would require more handling under this option. The core tubes would have to be reloaded from the smaller containers to the 20' container in Søndrestrøm, and again reloaded in Bayonne or Schenectady from the 20' containers into a frozen van.

Part II

1991 ICE CORE SHIPPING COSTS CONSIDERING EIGHT OPTIONS

OPTION #1

This cost projection itemizes the flight periods during which ice core and/or ice core containers are being transported.

This first projection considers Option #1 which uses three self-contained refrigerated units (refer to Methods of Ice Core Shipment document). Cost schedule begins in McGuire AFB, N.J.

Flight Period	Description of Transport	Total Extended Cost
June	Ship four empty refrigerated containers from McGuire to Søndrestrøm by air (6 hr x $4,862/hr) 4 ea x 3,560 lb/container Ship containers from Søndrestrøm to GISP II, space available	$29,172
July	Ship four refrigerated containers filled with ice core from GISP II to Søndrestrøm by air, space available 4 ea 3,560 lb + 3,450 lb/container Ship four full containers from Søndrestrøm to Schenectady (6 hr flight and 1 hr refueling stop) x $4862/hr	34,034
July	Ship four full refrigerated containers from Schenectady to Denver on flatbed	2,491
July	Truck four empty refrigerated containers from Denver to McGuire in van	1,840
August	Air freight four empty refrigerated containers from McGuire to Søndrestrøm. Ship containers, space available, to GISP II 4 ea x 3,560 lb/container	29,172
August	Ship four full refrigerated containers from GISP II. Søndrestrøm, space available. Ship four full containers from Søndrestrøm to Schenectady	34,034
August	Truck four full refrigerated containers from Schenectady to Denver on flatbed	2,491
August	Truck four empty refrigerated containers from Denver to McGuire in van	1,840
September	Ship empty refrigerated containers from McGuire to Søndrestrøm by air. Ship containers to GISP II, space available	29,172
September	Air freight four full refrigerated containers from GISP II to Søndrestrøm, space available. Ship full containers to Schenectady	34,034

September	Truck four full refrigerated containers from Schenectady to Denver on flatbed	$2,491
September	Truck four empty refrigerated containers from Denver to McGuire in van	1,840
September	Air freight four empty refrigerated containers from McGuire to Søndrestrøm for winter storage 4 ea x 3,560 lb/container @ $1.00/lb	14,240
	Estimated total seasonal shipping costs using four refrigerated containers	$216,851

OPTION #2

This projection considers Option #2, which uses the Wumkes design collapsible insulated containers (as detailed in Methods of Ice Core Shipment document). Cost schedule begins in McGuire, AFB, N.J.

Flight Period	Description of Transport	Total Extended Cost
June	Ship four empty insulated containers from McGuire to Søndrestrøm 4 ea x 1,000 lb/container @ $1.00/lb Ship containers Søndrestrøm to GISP II space available (no charge for reassembling containers at GISP II)	4,000
June	Ship one auxiliary mobile refrigeration unit from McGuire to Søndrestrøm 1,500 lb/unit @ $1.00/lb	1,500
June	Ship one auxiliary mobile refrigeration unit from McGuire to Søndrestrøm 1,500 lb/unit @ $1.00/lb Ship four full containers from GISP II to Søndrestrøm, space available	1,500
July	Ship four insulated containers filled with ice core from Søndrestrøm to Schenectady by air 4 ea 1,000 lb + 3,450 lb/container; 7 hr @ $4862/hr	34,034
July	Truck four full insulated containers from Schenectady to Denver in frozen van with air ride suspension on trailer In Denver, disassemble four insulated containers and secure to pallet 4 ea x 2 hr/container @ $25.00/hr	2,538 200
July	Truck four disassembled, palletized containers from Denver to McGuire 4 ea x 1,000 lb/container @ .4073/lb	1,629
August	Air freight four disassembled containers from McGuire to Søndrestrøm 4 ea x 1,000 lb/container @ $1.00/lb Ship containers to GISP II space available	$4,000

August	Reassemble insulated containers on aircraft pallet at GISP II, no charge for labor	
	Air freight four full, insulated containers from GISP II to Søndrestrøm, space available. Ship full containers from Søndrestrøm to Schenectady	34,034
August	Truck four full insulated containers from Schenectady to Denver in frozen van with air ride suspension on trailer	2,538
	Disassemble and palletize containers for return shipment	200
August	Truck four disassembled, palletized containers from Denver to McGuire	1,629
September	Air freight four disassembled, palletized containers from McGuire to Søndrestrøm	4,000
	Ship containers from Søndrestrøm to GISP II, space available	
September	Reassemble insulated containers on pallet at GISP II	No charge
	Air freight four full containers from GISP II to Søndrestrøm, space available	
	Ship full containers Søndrestrøm to Schenectady	34,034
September	Truck four full insulated containers from Schenectady to Denver in frozen van with air ride suspension	2,538
	Disassemble and palletize containers for return shipment	200
September	Truck four disassembled, palletized containers from Denver to McGuire	1,629
September	Air freight four disassembled, palletized containers from McGuire to Søndrestrøm for winter storage 4 ea x 1,000 lb/container @ $1.00/lb	4,000
September	Air freight one auxiliary mobile refrigeration unit from GISP II to Søndrestrøm for winter storage, space available flight	
	Air freight one auxiliary mobile refrigeration unit from Schenectady to Søndrestrøm for winter storage 1,500 lb/unit @ $1.00/lb	1,500
	Estimated total seasonal shipping costs using four Wumkes design collapsible, insulated containers and three auxiliary mobile refrigeration units	$135,703

OPTION #3

This projection considers Option #3 which uses the insulated pallet cover blanket (refer to Methods of Ice Core Shipment document). Cost schedule begins in Fairbanks, AK.

Flight Period	Description of Transport	Total Extended Cost
June	Ship four insulated blankets from Fairbanks to Søndrestrøm by charter 4 ea x 200 lb/blanket Ship blankets to GISP II, space available	
July	Ship four blanketed pallets of boxed ice core from GISP II to Søndrestrøm, space available	
	Ship four pallets ice core from Søndrestrøm to Schenectady, 7 hr x $4862/hr 4 ea (500 lb + 3,750 lb/pallet)	$34,034

(Boxes would be taken off pallet and stored in freezer in Søndrestrøm until aircraft was ready to depart for Schenectady. Although this involves a considerable amount of labor, no charge is made for the labor since it is performed by PICO employees in the course of a normal work day.)

July	Truck four pallets of boxed and covered ice core from Schenectady to Denver in frozen van with air ride suspension on trailer	2,538
July	Truck four empty aircraft pallets and four insulated blankets from Denver to McGuire 4 ea x 500 lb/blanketed pallet @ .4073/lb	815
August	Air freight four empty aircraft pallets and four insulated blankets from McGuire to Søndrestrøm 4 ea x 500 lb/blanketed pallet @ $1.00/lb Ship pallets and blankets from Søndrestrøm to GISP II, space available	2,000
August	Air freight four blanketed pallets of ice core from GISP II to Søndrestrøm. Unload and reload the pallets. Ship pallets of ice core to Schenectady	34,034
August	Truck four pallets of ice core from Schenectady to Denver in a frozen van with air ride suspension	2,538
August	Truck four empty pallets and four insulated blankets from Denver to McGuire	815
September	Air freight four empty aircraft pallets and four insulated blankets from McGuire to Søndrestrøm Ship pallets and blankets to GISP II, space available	2,000
September	Air freight four blanketed pallets of ice core from GISP II to Søndrestrøm. (Stop in Søndrestrøm for unloading and reloading.) Ship ice core to Schenectady	34,034

September	Truck four pallets of ice core from Schenectady to Denver inside frozen van with air ride suspension	2,538
September	Truck four empty pallets and four insulated blankets from Denver to McGuire	815
September	Air freight four empty aircraft pallets and four insulated blankets from McGuire to Søndrestrøm for winter storage 4 ea x 500 lb/blanketed pallet @ $1.00/lb	2,000
	Estimated total seasonal shipping costs using four insulated blankets to cover ice core packaged in insulated boxes stacked on and secured to aircraft pallet	$118,161

OPTION #4

This projection considers Option #4, which uses the Wumkes collapsible insulated containers (refer to Methods of Ice Core Shipment document) and auxiliary mobile refrigeration units air freighted together from GISP II to Denver. Cost schedule begins in Schenectady, N.Y.

Flight Period	Description of Transport	Total Extended Cost
June	Ship four empty insulated containers (disassembled and palletized) and four auxiliary mobile refrigeration units from McGuire to GISP II 4 ea (1,000 lb/container + 1,500 lb/unit) @ $1.00/lb Ship containers and refrigeration units to GISP II, space available	10,000
July	Ship four insulated containers filled with ice core and four mobile refrigeration units from GISP II to Søndrestrøm by air Ship four insulated containers filled with ice core and four mobile refrigeration units from GISP II to Søndrestrøm by air 4 ea (1,000 lb + 3,450 lb/container + 1,500 lb/unit) @ $.78/lb	34,034
July	Air freight four insulated containers filled with ice core and four mobile refrigeration units from Schenectady to Denver via commercial C-130	61,321
July	In Denver, disassemble four insulated containers and secure to pallet 4 ea x 2 hr/container @ $25/hr	200
July	Truck four disassembled, palletized containers and four mobile refrigeration units from Denver to McGuire 4 ea (1,000 lb/container + 1,500 lb/unit) @ $.4073/lb	4,073
August	Air freight four disassembled containers and four mobile refrigeration units from McGuire to GISP II. Ship containers and refrigeration units to GISP II, space available 4 ea (1,000 lb/container + 1,500 lb/unit) @ $1.00/lb	10,000

August	Reassemble insulated containers on aircraft pallet at GISP II, no charge for labor	
	Air freight four full, insulated containers and four mobile refrigeration units from GISP II to Søndrestrøm, space available	
	Ship four containers of ice core and refrigeration to units Schenectady	34,034
August	Air freight four full containers and four mobile refrigeration units from Schenectady to Denver via commercial C-130	$61,321
	Disassemble and palletize containers for return shipment	200
August	Truck four palletized containers and four mobile refrigeration units from Denver to McGuire	4,073
	Air freight four palletized containers and four mobile refrigeration units from McGuire to Søndrestrøm	10,000
September	Reassemble insulated containers at GISP II	No charge
	Air freight four full containers and four mobile refrigeration units from GISP II to Søndrestrøm, space available	
	Ship four containers of ice core and four refrigeration units to Schenectady	34,034
September	Air freight four full containers and four mobile refrigeration units from Schenectady to Denver via commercial C-130	61,321
	Disassemble and palletize containers for return shipment	200
September	Truck four palletized containers and four mobile refrigeration units from Denver to McGuire	4,073
September	Air freight four palletized containers and four mobile refrigeration units from McGuire to Søndrestrøm AFB for winter storage 4 ea (1,000 lb/container + 1,500 lb/unit) @ $1.00/lb	10,000
	Estimated total seasonal shipping costs using four Wumkes design collapsible, insulated containers, shipping four auxiliary mobile refrigeration units along with the containers, and air freighting the ice core all the way back to Denver	338,884

However, if we were able to truck the ice core using a frozen van with an air ride suspension trailer from Schenectady to Denver instead of air freighting it by commercial C-130, shipping costs could be reduced as follows (using same equipment - four insulated containers and four auxiliary mobile refrigeration units):

By Air			
Ice Core	3 loads	@ $61,321/load	$183,963
Back Haul	3 loads	@ $4,073/load	12,220
			$196,183
By Truck			
Ice Core	3 loads	@ $2,538/load	$7,614
Back Haul	3 loads	@ $1,629/load	4,888
			$12,502

Cost reduction for season $196,183 - $12,502 = $183,681

Then estimated total shipping cost for season would be ..... $338,884 - $183,681 = $155,203

OPTION #5

This projection considers Option #5, which uses the Wumkes collapsible insulated containers (refer to Methods of Ice Core Shipment document) shipped inside a marine type, 30 ft freezer container. The load of ice core would be air lifted the entire distance from GISP II to Denver. Cost schedule begins in McGuire AFB, N.J.

Flight Period	Description of Transport	Total Extended Cost
June	Ship four disassembled, palletized containers and one large freezer container from McGuire to Søndrestrøm 4 ea (1,000 lb/container) + 8,000 lb/freezer container @ $1.00/lb Ship four containers and one freezer container to GISP II, space available	$12,000
July	Ship four insulated containers (filled with ice core) inside one freezer container, by air, from GISP II to Søndrestrøm Ship four containers and one freezer container to Schenectady 4 ea (4,450 lb/container) + 8,000 lb/freezer container	34,034
July	Ship 30 ft freezer container and contents from Schenectady to Denver via commercial (non-military) C-130. 25,800 lb load @ $61,321	61,321
July	In Denver, disassemble four insulated containers and secure to pallet 4 ea x 2 hr/container @ $25/hr Truck four palletized containers and one freezer container from Denver to McGuire 4 ea (1,000 lb/container) + 8,000 lb/freezer	200 2,491
August	Air freight four disassembled containers and one freezer container from McGuire to Søndrestrøm	12,000

August	Reassemble insulated containers on pallet at GISP II. No charge for labor	
	Air freight four full, insulated containers inside one freezer container from GISP II to Søndrestrøm, space available	
	Ship freezer container and contents to Schenectady	34,034
August	Ship 30 ft freezer container and contents from Schenectady to Denver via commercial C-130	61,321
August	Disassemble four insulated containers and secure to pallet	200
	Truck empty freezer container and contents (insulated containers) from Denver to McGuire	2,491
September	Air freight empty freezer container and contents from McGuire to Søndrestrøm	12,000
	Ship freezer container and contents to GISP II, space available	
September	Reassemble insulated containers on pallet at GISP II	No charge
	Air freight four full insulated containers inside one freezer container from GISP II to Søndrestrøm	
	Ship freezer container and contents to Schenectady	$34,034
September	Air freight 30 ft freezer container and contents from Schenectady to Denver via commercial C-130	61,321
September	Disassemble four insulated containers and secure to pallet	200
	Truck empty freezer container and contents from Denver to McGuire	2,491
September	Air freight empty freezer container and contents from McGuire to Søndrestrøm AFB for winter storage 4 ea x 1,000 lb/container + 8,000 lb/freezer container @ $1.00/lb	12,000
	Estimated total seasonal shipping costs using four Wumkes design collapsible, insulated containers and one 30 ft freezer container, air freighting ice core from GISP II to Denver	342,138

However, if we were able to truck the ice core using a frozen van with air ride suspension trailer from Schenectady to Denver instead of air lifting it, shipping costs could be reduced as follows (using same equipment - four insulated containers and one 30 ft freezer container):

By Air			
Ice Core	3 loads	@ $61,321/load	$183,963
Back Haul	3 loads	@ $2,491/load	7,473
			$191,436
By Truck			
Ice Core	3 loads	@ $2,538/load	$7,614
Back Haul	3 loads	@ $1,222/load	4,887
			$12,501

Cost reduction for season	$191,436 - $12,501 = $178,935
Then estimated total, seasonal shipping cost would be	$342,138 - $178,935 = $163,203

OPTION #6

This projection considers Option #6 which uses four large Wumkes design, collapsible, insulated containers (as detailed in Methods of Ice Core Shipment document). Cost schedule begins in Schenectady, N.Y.

Flight Period	Description of Transport	Total Extended Cost
June	Ship four disassembled, palletized containers from McGuire to Søndrestrøm 4 ea x 1,200 lb/container @ $1.00/lb	4,800
	Ship four containers to GISP II, space available (no charge for reassembling containers at GISP II)	
July	Ship four insulated containers filled with ice core from GISP II to Søndrestrøm by air (two loads, space available) 4 ea (1,200 lb + 6,900 lb/container)	
	Unload core tubes from insulated containers and place in freezer	No charge
	Reload core tubes from freezer into four large containers and place containers aboard Denver bound LC-130	No charge
July	Air freight four large containers full of ice core from Søndrestrøm to Denver with a fuel stop in Duluth 10 hr 40 min flight time @ $4,862/hr	$51,861
	Reposition LC-130 to Schenectady 4.5 hr flight time @ $4,862/hr	21,879
July	In Denver, disassemble four insulated containers and secure to pallet 4 ea x 2 hr/container @ $25/hr	200
July	Truck four disassembled, palletized containers from Denver to McGuire 4 ea x 1,200 lb/container @ $.4073	1,955
September	Air freight four disassembled containers from McGuire to Søndrestrøm 4 ea x 1,200 lb/container @ $1.00/lb	4,800
	Ship containers to GISP II, space available	
September	Reassemble two insulated containers on pallet at GISP II	No charge
	Air freight two full containers from GISP II to Søndrestrøm	No charge
	Unload core tubes from containers and place in Søndrestrøm freezer	No charge

	Reload core tubes from freezer to containers and place two full containers on Denver bound LC-130	No charge
	Air freight two large containers full of ice core from Søndrestrøm to Denver with a fuel stop in Duluth 10 hr 40 min flight time @ $4,862/hr	51,861
	Reposition LC-130 to Schenectady 4.5 hr flight time @ $4,862/hr	21,879
September	In Denver, disassemble two insulated containers and secure to pallet 2 ea x 2 hr/container @ $25/hr	100
	Truck two disassembled, palletized containers from Denver to McGuire 2 ea x 1,200 lb/container @ $.4073	978
	Air freight two disassembled containers from McGuire to Søndrestrøm for winter storage 2 ea x 1,200 lb/container @ $1.00/lb	4,800
	Estimated total seasonal shipping costs using four large collapsible, insulated containers and air freighting the ice core all the way to Denver	$162,713

OPTION #7

This projection considers Option #7, which uses one collapsible insulated container and one leased, 40' marine freezer container. The freezer container would be transported to and from Søndrestrøm on the ship *Green Wave*. Cost schedule begins in Elizabeth, N.J., where we lease the freezer container.

Flight Period	Description of Transport	Total Extended Cost
June	Pick up leased container in Elizabeth, N.J., and transport it to dockside at Bayonne, N.J.; load aboard *Green Wave*	$200
June	Transport freezer container and one disassembled, palletized container from Bayonne to Søndrestrøm by ship	No charge
June	Unload freezer container in Søndrestrøm and truck from dockside to Søndrestrøm AFB	200
June	Ship disassembled, palletized container from Søndrestrøm to GISP II, space available	
July	Reassemble container	
July/August	Ship ice core from GISP II to Søndrestrøm, space available basis. Store ice core tubes in freezer container at Søndrestrøm. Repeat the above operations as ice core is processed	
August	Load full freezer container aboard truck and haul from Søndrestrøm AFB to dockside. Load aboard *Green Wave*. Plug in refrigerator unit	300

August	Transport freezer container with ice to Bayonne, N.J., aboard *Green Wave*	
August	Unload freezer container from ship and on to flat bed truck with air ride suspension	
	Haul freezer container to Denver (refrigeration unit plugged in to tractor-mounted diesel generator)	2,538
September	Unload ice core in Denver	
	Ship leased freezer container from Denver to Elizabeth, N.J.	1,840
	Estimated total seasonal shipping costs using one leased freezer container and one collapsible insulated container	$5,078

OPTION #8

This projection considers Option #8, which uses two leased 20' marine freezer containers and two collapsible, insulated containers with integral refrigeration which would be purchased. The two 20' freezer containers would be shipped to Søndrestrøm on the ship *Green Wave*. One of the containers would also return on the *Green Wave*, full of ice core, and the other one would be returned by air (LC-130) at the end of the season. Cost schedule begins in Elizabeth, N.J., where we lease the two 20' containers and also pick up the two disassembled, palletized containers with refrigeration units.

Flight Period	Description of Transport	Total Extended Cost
July	Pick up leased containers in Elizabeth, N.J.; transport them to dockside at Bayonne, N.J., and load aboard *Green Wave*	$200.00
July	Transport freezer containers containing the two disassembled smaller containers from Bayonne to Søndrestrøm by ship	No charge
July	Unload freezer containers and contents in Søndrestrøm and truck from dockside to Søndrestrøm AFB	200.00
July	Ship two disassembled, palletized containers from Søndrestrøm to GISP II, space available	
July	Reassemble containers. Ship ice core from GISP II to Søndrestrøm, space available basis. Store ice core tubes in the two 20' freezer containers at Søndrestrøm	
August	Disassemble smaller collapsible containers and return to GISP II, space available basis	
	Repeat the above operations as ice core is processed	
August	Load one 20' freezer container full of ice core aboard flatbed truck at Søndrestrøm AFB and truck to dockside. Load container full of ice aboard *Green Wave*. Plug in refrigerator unit	200.00

August	Transport freezer container with ice to Bayonne, N.J., aboard *Green Wave*	
August	Unload ice cores from 20' freezer container into freezer van with air ride suspension	300.00
August	Return leased 20' freezer container to Elizabeth, N.J.	200.00
August	Truck freezer van with ice core from Bayonne, N.J., to Denver	2,538
August	Meanwhile, ice core would be cored, processed, and shipped from GISP II to Søndrestrøm and stored in the second 20' freezer container	
September	At the end of the coring season the 20' freezer container should be nearly full and would be loaded aboard the LC-130 and shipped from Søndrestrøm to Schenectady	34,034
September	At Schenectady, unload ice core from 20' container into frozen 40' van with air ride suspension on trailer	300.00
September	Return leased 20' freezer container to Elizabeth, N.J.	300.00
September	Truck freezer van with ice core from Schenectady to Denver	2,538
	Estimated total seasonal shipping costs using two, 20' leased freezer containers and two collapsible, insulated containers with integral cooling	$40,810

Part III

ASSUMPTIONS

Highway Freight Rates

Schenectady to Denver, frozen 40' van, 4-day transit	$1,900
Schenectady to Denver, frozen 40' van load, air ride suspension on trailer	2,538
Denver to Schenectady, bulky items, 5-day transit: $1.1719/lb	
Denver to Schenectady, low bulk/weight items, 5-day transit @ .4073/lb	
Schenectady to Denver, 40' flatbed, 4-day transit	2,491
Denver to Schenectady, 40' van (for empty containers), 5 - 8 days transit	1,840

Air Freight Rates

McGuire to Søndrestrøm, MAC flight	1.00/lb
Søndrestrøm to GISP II, 109th TAG	1.00/lb
Søndrestrøm to Schenectady, 109th TAG	1.25/lb
Schenectady to Denver, commercial (non-military)	
C-130, 25,000 lb load of containers with ice core	61,321
LC-130 from the 109th TAG, Søndrestrøm - Duluth - Denver (with ice core) then empty back to Schenectady 15 hr 10 min x $4,862/hr	73,740

Coring, Shipping Schedule

1700 m core for season
150 m core/shipping container

Able to core and field process four containers (600 m) of ice in time for air transport from GISP II in July, August and September for a total of 12 containers.

Labor Costs, Etc.

Labor, Søndrestrøm	Supplied by Søndrestrøm personnel
Labor, GISP II	Supplied by GISP II personnel
Labor, Denver (estimated)	25.00/hr
Labor, Bayonne	25.00/hr

Weights

1 meter ice core weighs	20 lbs
1 core tube weighs	3 lbs

Self-contained refrigerated containers weigh 3,560 lbs; empty Wumkes design collapsible, insulated containers with pallet weigh 1,000 lbs. The extra-large collapsible, insulated containers with pallet weigh 1,500 lbs.

Auxiliary mobile refrigeration units (electric, 220V powered) weigh	1,500 lbs
Insulated blanket plus aircraft pallet weighs approximately	500 lbs
Insulated core boxes weigh 12 lbs each and hold 6 ea one meter length cores	
Core tubes weigh	3 lbs ea

Thus, "packaging" wt per 1 m core is
12 + 18 / 6 = 5 lb (used with insulated blanket)

Loaded with 150 m ice core, total weight (ice core, packaging, container, and pallet) for three options is as follows:

OPTION #1

Self- contained, refrigerated, insulated container	7,010 lbs

OPTION #2

Wumkes collapsible, insulated container	4,450 lbs

OPTION #3

Insulated pallet cover blanket with insulated core boxes	3,950 lbs

CONCLUSIONS AND RECOMMENDATIONS

Shipping ice core by air tends to be expensive and requires containers which are not readily available on the market. The shipping method used previously (1990 season) required bulky, insulated boxes which, although readily available, proved to be expensive to ship. The large amount of insulation around individual cores provided good protection from physical damage but also made for a high bulk-to-weight ratio. Aircraft were bulked out before weighting out. Also, this method required considerable handling since the cores had to be placed in a freezer in Søndrestrøm. Then the ice core was at considerable risk to high temperatures on the long aircraft ride from Søndrestrøm AFB to Schenectady, N.Y. Eventually, this shipping method was rejected for these reasons.

Originally it was felt that shipping the ice core by air all the way from the coring site at GISP II to Denver was the only practical way and provided the best ride for fragile ice core. It was also the most expensive and freezer vans were investigated for transporting the ice core in the continental U.S. More research led to freezer vans with air ride suspension on trailers to provide an air-cushioned ride for the fragile ice core. It was decided that this mode of transportation provided a safe alternative to expensive air freight.

Expensive air freight costs which would be encountered in shipping the ice core from Greenland to the continental U.S. also prompted investigation into a more economical transportation alternative for this long segment. The obvious solution was water transportation and the U.S. Navy ship *Green Wave* which makes two trips per season between Bayonne, N.J., and Søndrestrøm. Although the sailing schedule does not correspond precisely with our core shipping schedule (we may not have the entire amount of seasonal ice core processed by the last sailing date of the *Green Wave*), the large savings from using the ship made it a very attractive option. The containers can be shipped to and from Søndrestrøm on the *Green Wave* at no charge. After examining several different containers and the availability of these containers, it was felt that leasing two (possibly three) 20-foot freezer containers provided the safest and least expensive storage and shipping container for the ice core.

Thus, the shipping methods and containers which appear to be most attractive and cost-effective at this time are a combination of several of the options listed in Parts I and II. Budget restraints, coring progress, shipping schedules and numerous other variables could, of course, alter these plans.

At the present time, considering the funding available, we recommend leasing three 20-foot freezer containers, shipping the containers to and from Greenland on the *Green Wave* and using a highway freezer van to haul the ice core from Bayonne to Denver. The procedure would be as follows:

1. Placing the ice core in core tubes, then putting the core tubes in ISC boxes and placing the boxes on pallets for shipment from GISP II.
2. Shipping the ice core from GISP II to Søndrestrøm via LC-130.
3. Placing ISC boxes inside 20-foot freezer containers, removing core tubes from ISC boxes and stacking the core tubes of ice in containers on layers of bubble wrap.
4. Shipping the containers full of ice core, securely packaged, aboard the *Green Wave* from Søndrestrøm to Bayonne, N.J.
5. Unloading the core tubes from the 20-foot leased containers and into a 40-foot highway freezer van with air ride suspension on trailer.
6. Truck the freezer van full of ice core to Denver.