PICO
Polar Ice Coring Office

Logistical Support for Construction on the Greenland Ice Sheet

By:

K. Curtis
Department of Civil Engineering
and
J. Sonderup and
D. Dahl
Polar Ice Coring Office
University of Alaska Fairbanks
Fairbanks, Alaska 99775-1710

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LOGISTICAL SUPPORT FOR CONSTRUCTION ON THE GREENLAND ICE SHEET

K. Curtis[1], J. Sonderup[2], D. Dahl[3]

ABSTRACT: During the 1989 and 1990 summer field seasons, a scientific research camp will be constructed near the summit of the Greenland Ice Cap. The camp is located at 72° 34' N, 38° 31' W at an elevation of approximately 3,230 meters (10,600 feet). The facility will support a National Science Foundation (NSF) deep drilling project to retrieve an ice core roughly 3000 meters long extending from the summit through the ice cap to bedrock. Camp facilities sufficient to accommodate drilling operations, core processing, analytical research and living space for up to forty science and support personnel must be deployed during the limited work schedule dictated by summer weather at the summit. Construction logistics for remote camps supported entirely by air transportation differ, in many respects, from those employed in more traditional construction efforts. Expense and aircraft size limit not only the weight but also the volume of materials and equipment that may be used at a particular site. The expense of transporting manpower, materials and equipment to a remote site is significant and requires attention to every detail to maximize resource utilization.

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[1] Assistant Professor, Department of Civil Engineering, University of Alaska Fairbanks

[2] Assistant Director, Polar Ice Coring Office, University of Alaska Fairbanks

[3] Transportation Coordinator, Polar Ice Coring Office, University of Alaska Fairbanks

1. Introduction

The renewal of the Antarctic Treaty as well as the recent increased level of interest in paleoclimatology and the physical and chemical properties of snow and ice have resulted in intensive scientific research in circumpolar regions. At the same time, concern over the depletion of the ozone layer in the polar regions leads to a need for additional research facilities in both the Arctic and the Antarctic regions. Engineering and logistics support of such efforts continues to be hampered by a shortage of specialists with experience in polar operations. Logistics support efforts are further impeded by the lack of adequate documentation of reliable techniques suitable for such work.

The National Science Foundation (NSF) has been involved in glaciological research in Greenland, including the Greenland Ice Sheet, for a number of years. The first phase of the Greenland Ice Sheet Project (GISP1) was initiated in 1979 and just recently concluded. The site chosen for the second phase of the project, GISP2 (see Figure 1), is near the summit of the Greenland Ice Cap at 72° 34' N, 38° 31' W at an elevation of approximately 10,600 ft.

The Polar Ice Coring Office (PICO) provides drilling and ice coring services to scientists conducting research in Greenland. PICO, operating under contract to the National Science Foundation, Division of Polar Programs, is also charged with the establishment of facilities and transportation of personnel, equipment and supplies to the GISP2 site. The facilities must be sufficient to support the NSF deep drilling project (GISP2) and handle the roughly 3,000 meters of ice core that will be obtained over the life of the project, estimated at three years. Camp facilities sufficient to accommodate the drilling operations, core processing, analytical research and living space for up to forty science and support personnel must be deployed during the limited work schedule dictated by summer weather at the summit, approximately 4 months.

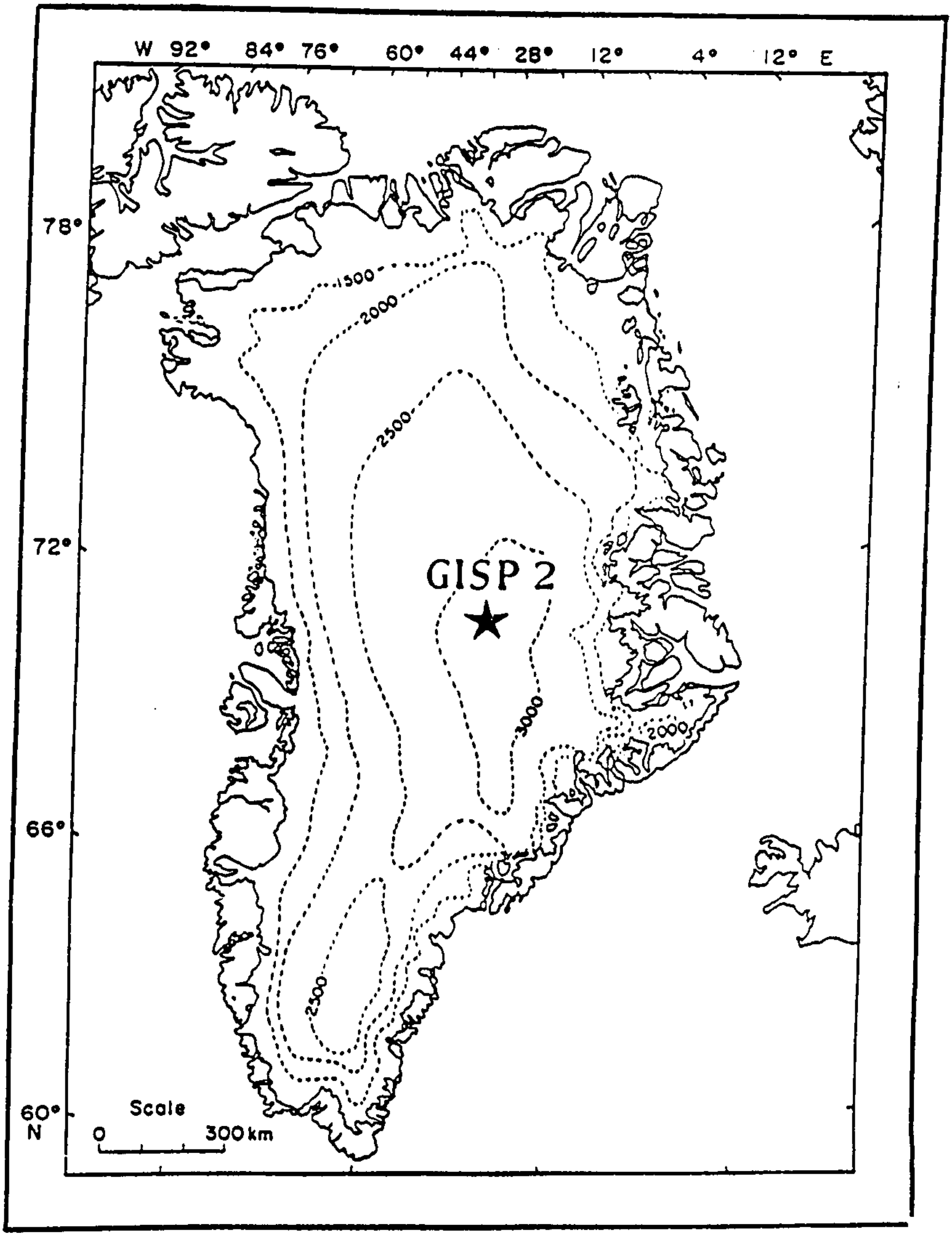

Figure 1. Location of the GISP2 site.

2. Logistics Criteria

When the sole feasible means of transportation to the site is by air, the costs associated with shipping materials and supplies to the site can overwhelm all other project costs. Logistics personnel must carefully balance a number of apparently conflicting requirements to minimize project costs associated with camp support.

- Shipping weight is a major factor in air supported logistics planning. Air transportation costs are largely based on the price per pound shipped. The GISP2 project pays $0.83 per pound to ship materials from the staging area on the East Coast of the United States to Sondrestrom Air Base in Greenland. Additionally, it costs the project approximately $1.00 per pound to ship the same materials from Sondrestrom to the GISP2 site on the ice sheet. These figures result, for example, in a diesel fuel price of approximately $8.50 per gallon delivered on site. Of the $8.50, transportation costs are responsible for $7.60, or 89% of the cost of the fuel delivered to the camp. Minimizing shipping weight through the use of more expensive, higher strength-to-weight ratio materials must be considered by logistics personnel on air supported operations. In addition to the shipping costs associated with the weight of materials there are pragmatic limitations on the weight of a loaded aircraft landing on a processed snow runway. When transporting extremely heavy equipment and materials only a portion of an aircraft's cargo space may be utilized due to the bearing capacity of the processed snow runway.

- In addition to weight, the shipping cube of all materials shipped to the site must be carefully considered when using aircraft for transportation to remote sites. There are structural systems and equipment that meet the requirements for remote camp operations but which cannnot be used because they simply will not fit in the aircraft.

o The consequences of not shipping certain supplies or a particular piece of equipment to a remote site range from unimportant at best to life threatening in the worst case. The successful operation of the camp, continued personnel safety and the long-term costs associated with the shipment of resupply items such as food and fuel must be factored into the total cost of a project. For equipment, previous performance data can be examined to determine the likelihood of its availability over the life of the project. This is a standard component of logistics scheduling. The remoteness and environmental severity associated with most circumpolar facilities dictates that an additional factor be considered in down-time estimates, that is, the importance of a given item to the life support system of the camp. A subjective importance factor greater than or equal to one must be associated with all supplies and equipment shipped to the site. In many cases, the only way to ensure that vital systems remain operational is to supply redundant systems and spare parts. Each of these back-ups result in direct costs to the project.

3. Logistics Decision Scheme

Figure 2 is a graphical representation of a decision-making scheme which may be helpful in selecting optimal equipment support systems and supplies for utilization in remote circumpolar camps.

The initial cost of an item is readily available from the supplier and includes shipping. This is the most deterministic aspect of the total cost approach to resource allocation.

Maintenance costs include all materials, spare parts and system components that must be shipped to the site for continuous operation. These costs include shipping charges associated with operation support such as food, fuel, surface protection systems for buildings and so forth. Historical records of past projects can be used to quantify, to some extent, these costs for given pieces of equipment, personnel levels, and so forth.

Expected costs of failure include all costs associated with restoration of a system subsequent to failure. These costs must include shipping charges associated with costly unscheduled flights and purchasing and shipping spare parts, as well as the importance factor outlined above. This aspect of the total cost will likely remain difficult to quantify.

The present government procurement and purchasing system that governs PICO's (and many government funded projects) transactions is not designed to account for this decision making scheme.

Government systems are generally based on low bid purchasing of items based on a written specification. This system concentrates only on the initial cost portion of Figure 2 and largely ignores the other cost components. While such items as quality and weight can be written into the specification, documentation of the level of quality and justification of weight restrictions must also be provided. In many cases this documentation is unavailable or difficult to provide. Many of the costs associated with the failure of a component or system are not known prior to the failure.

A recent example of the results of ignoring all but the initial cost component of an item illustrates this point. During the 1989 field season, GISP2 project personnel requisitioned a number of fuel bladders which are used to transport Arctic Diesel Fuel (DF-A) to the site. PICO had identified a particular manufacturer who supplied bladders with a suitable performance record to a number of previous projects. During the government bid process, a second company was selected on the basis of low bid--and provided assurances that their product was equal in quality to the fuel bladders that were used previously. Subsequent to purchase, the bladders were shipped to Sondrestrom, filled with fuel, and five of seven bladders developed varying degrees of leakage. Although field personnel patched the bladders, the military refused to ship them to the site due to the possibility of additional leakage and fire hazard. Costs of this failure included purchasing bladders from the original supplier, transporting the new bladders to the site at the above mentioned shipping rates and the down time associated with these operations.

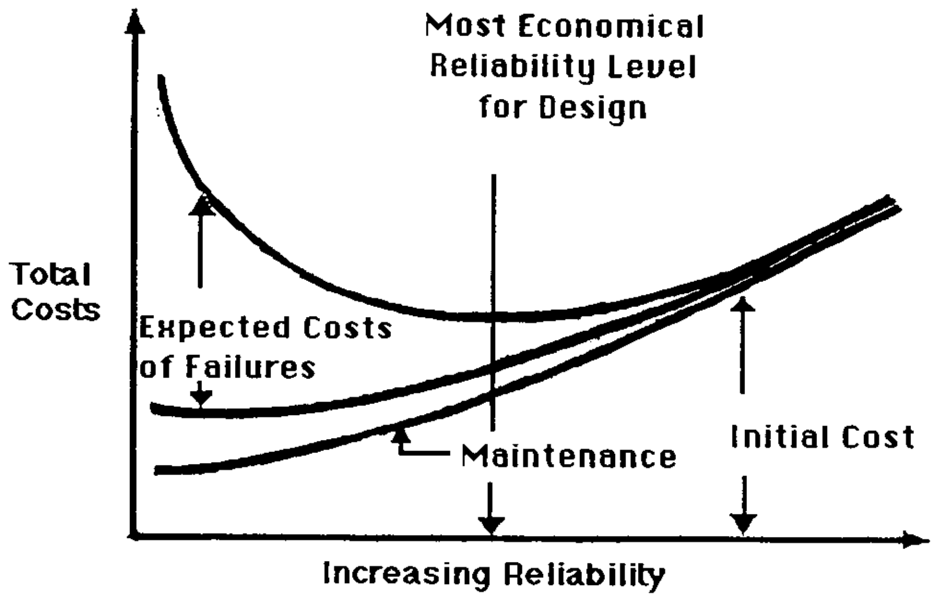

Figure 2. Logistics Decision Scheme

4. Logistics Considerations

In many cases, base camp facilities are located in areas remote from logistical support centers. All building materials and supplies not available at the site must be flown in at great expense to the project. Shipping weight and cube become essential to the selection of building systems and materials. Additionally, base camp facilities must be founded on whatever material is available at the chosen site. In many cases, the only available foundation material is snow. The efficient utilization of snow in the construction of base camp facilities greatly reduces the total weight and volume of building materials that must be shipped to the site.

One critical consideration in planning the systems to be used in severe environments is the serious impact the failure of engineered systems and structures would have on the personnel. The failure of elements of the engineered life support infrastructure in extremely cold environments can result in life threatening situations or even loss of life for these personnel. Inadequate preparati and allowance for cold environment operations can impose burdens on personnel which range from safety, health and sanitation deficiencies to overall station integrity.

In light of the increased number of scientific and engineering projects that are anticipated in circumpolar regions in the future, it is important that efforts be expended to augment or develop the planning and scheduling tools necessary to allow these efforts in remote facilities to proceed in a safe and effective fashion. Logistics scheduling operations for remote, circumpolar science facilities must include many factors.

i) The collection of adequate weather data is critical not only to structure and system design but also to logistics operations. The environmental influences that must be overcome by engineered systems and structures at the site of interest must be quantified to such a degree that logistics planning must provide the best combination of operating efficiency and personnel safety. The weather data must include temperature at several levels, wind magnitude and direction and annual snow accumulation.

ii) Snow stabilization procedures must also be considered during the facilities planning stages of a project. While the strength of the snow to be used in the foundation of structures can be increased greatly through proper handling, long-term creep deflections and the resulting potential for differential settlement remain a serious problem in the design of engineered structures. In order to use the snow at the site as an engineered foundation material, data must be available on the snow characteristics at the site. The selection of the correct handling and stabilization techniques is dependent on these characteristics. Early logistics operations must adequately reflect the type and strength of the snow on the site and make allowances for the varying foundation systems that will optimize foundation material shipped to the site.

iii) Techniques exist for the supply of clean water and the disposal of waste water in remote polar facilities. These concepts need to be incorporated into a systems approach to camp layout that adequately addresses sanitation safety considerations. Logistics planning personnel need to identify and plan for an adequate supply of potable water and waste disposal as early as possible in project conceptualization as this system impacts the majority of the facilities on site.

iv) Personal injury and fire damage to structures pose a serious threat to remote stations personnel. Traditional water-based fire protection schemes are generally not feasible for use in remote low-temperature facilities as energy requirements to melt and maintain an adequate water supply impose an unacceptable burden on camp power facilities. Halon fire protection systems have been successfully used in cold-regions structures but are expensive to operate and require recharging after use. Personal safety considerations dictate, however, that the issue of fire protection be incorporated into the original camp design. Fire protection system selection must be addressed in the early stages of planning to ensure that adequate logistics resources are allocated to the fire protection system.

v) Snow drift patterns at a site have a serious impact on the adequacy of a camp layout. Heavy drifting can also result in additional loads imposed on systems and structures. It is generally understood that certain structure types reduce local drifting and increase wind scour but not how multiple structures affect each other and the scour potential of the site. Research on snow drifting and drift reduction schemes must be correlated with the design criteria during the initial planning phases of a project. Information on this topic is inadequate at this time to correctly formulate such design criteria. Logistics operations must consider and allow for adequate manpower and equipment to ensure that drifting does not impact personnel safety or the efficiency of camp operations. Increased snow handling results in a greater volume of personnel and equipment on site which, in turn, results in an increase of food, fuel and shelter shipments.

vi) Depending on use, the design life of facilities required by science and engineering projects operating in circumpolar locations ranges from a single season to "permanent." The design life of many circumpolar projects extends far past original estimates as users adjust and revise original schedules and scopes of work. The project design life is an integral factor in the selection of the most cost and performance effective system for a particular camp. Camp layout, optimal structural foundation systems and sanitation facilities design are all dependent on the design life of the facility. Logistics operations personnel must identify a target design life early in the planning process which will not limit future uses of the facility but which will also not impose an undue burden on the project budget.

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Biographical Sketch

Kevin C. Curtis, Ph.D.
Assistant Professor
Civil Engineering Department
University of Alaska Fairbanks
Fairbanks, Alaska 99775
(907) 474-5118

An Assistant Professor of Civil Engineering at the University of Alaska Fairbanks, Dr. Kevin Curtis has conducted research on structures and construction in polar regions. He has extensive experience in construction logistics and worked for 10 years as a design engineer as construction manager in the nuclear power industry. Dr. Curtis came to the University of Alaska Fairbanks in 1988 and has been involved in the design and construction of the National Science Foundation (NSF) supported Greenland Ice Sheet Program (GISP2) through the NSF Polar Ice Coring Office (PICO).

Currently, Dr. Curtis' research is focused on the design of structures of polar ice camps and the trade offs of various designs and to the costs of transport to remote sites.

Biographical Sketch

Jay Sonderup
Assistant Director
Polar Ice Coring Office
University of Alaska Fairbanks
Fairbanks, Alaska 99775
(907) 474-5585

Mr. Sonderup, a Civil Engineer, serves as Assistant Director of the National Science Foundation Polar Ice Coring Office (PICO) at the University of Alaska Fairbanks. He has been associated with PICO for more than three years.

Mr. Sonderup's interests are in civil engineering and construction management with empahsis on the construction of structures in remote polar regions and the development of ice coring and drilling equipment. He has extensive field experience in both Greenland and Antarctica.

Biographical Sketch

Dorothy P. Dahl
Administrative Assistant
Polar Ice Coring Office
University of Alaska Fairbanks
Fairbanks, Alaska 99775
(907) 474-5585

An Administrative Assistant at the National Science Foundation Polar Ice Coring Office (PICO) at the University of Alaska Fairbanks, Ms. Dahl also serves as Transportation Coordinator for PICO. Ms. Dahl has been associated with the PICO program since its establishment at the University of Alaska in early 1989. She has worked in every area of responsibility associated with PICO's world-wide projects, in particularly those areas concerned with the movements of personnel and equipment through civilian and military services.

Ms. Dahl also edits all reports generated by the Polar Ice Coring Office and serves as the Technical Editor of the PICO Bulletin. A current project is the production of the Proceedings of the AAAS workshop on New Technological Developments in Support of Arctic Research.