NICL Summary of Field Test Results

The following report summarizes the processes and procedures performed by the National Ice Core Laboratory (NICL) during the Deep Ice Sheet Coring (DISC) drill test at Summit Station Greenland in summer 2006. Areas for improvement or modification to existing equipment or procedures are also presented. This report follows the format set forth in the NICL Greenland Field Test Plan, (with section numbers) which was submitted prior to deployment. Italicized text in this report is text abstracted from the Greenland Field Test Plan.

6.0 OBJECTIVES

6.1 ***Safety –*** *The health and safety of all personnel at Summit Camp is the first priority. Modifications to NICL equipment and procedures may be undertaken in the field to ensure the health and safety of all personnel at Summit Camp. In addition, changes that will result in improvements in safety will be identified throughout the testing of the NICL core handling system. The NICL Curator is responsible for ensuring that such improvements are thoroughly documented. In addition, NICL personnel will read and familiarize themselves with ICDS' DISC Drill Safety Plan (8505-0009) and develop a NICL safety plan prior to deploying to Greenland.*

During the Greenland field test, safety was of the utmost importance to the NICL. No major injuries occurred while at Summit. The following is a list of procedures and/or equipment that NICL felt would improve safety at WAIS (some of the following were not feasible for testing in Greenland.)

- We have installed two safety switches on the saw for on/off and emergency shutdown.
- The linear actuator added an element of safety because it allows the core handler to run the saw without having to manhandle the saw arm. Also, this keeps the core handler away from the blade while it is cutting.
- Sandpaper safety tape was good for the floors because they get slick with "sugar snow" from cuttings as well as IsoPar spills.
- Lifting the vacuum, saw, cores, etc. will require multiple personnel to ensure safety. A class or talk on safe lifting procedures should be administered each field season.
- Since the core handler area will be kept at -20º C, warming boxes, proper clothing, food, liquids, etc. must be provided. Each individual should also monitor the status of the other workers as well, to ensure that they are performing their station duties correctly.
- A procedure for lowering core into the basement safely using the gantry needs to be designed and executed.
- Standardized procedures for signals, commands, etc. for communication from the basement to the core handling area are needed.
- Rail guards for the basement floor openings are needed.

- A system is needed to check air quality in the basement before anyone descends into it.
- Procedures for ladder(s) entry into the basement (as well as a fall protection system.)
- Procedures and equipment for evacuation from the basement.
- Need clearly marked defibrillators, medical kits, fire extinguishers, etc.
- Procedures for fire escape and fire safety.
- Noticed that IsoPar was not as volatile as thought (could not really smell it, not noxious, etc.) But, NICL still needs a way to monitor vapor levels. NICL needs to speak with ICDS to find out what kind of volatile organic compound (VOC) detectors they have. None of the VOC detectors that NICL tested worked on IsoPar in the cold.
- Procedures for moving loaded carts (these may weigh in excess of ~900 lbs.)
- Procedures for moving ISC or HD containers (these may weigh in excess of ~100 lbs.)
- Procedures for carrying aluminum v-trays (may weigh in excess of ~90 lbs.)
- Anti-fatigue mats will be beneficial for standing long periods on sip panels.
- Absorbent material or rags for chemical spills are needed.
- Noise will be an issue at WAIS. Earplugs would probably not work well in the cold. Earmuffs with adjustable radio communication inside would work best. Also, because noise will be such an issue, safety is of the utmost importance.
- Wilderness First Responder may be good training for some of the line mangers, or at the very least CPR/AED/basic first aid training.
- Regular safety meetings should be scheduled, as well as one at the beginning of every field season.
- Inter-shift reports passed between core handlers should be mandatory
- All power tools should have emergency kill buttons (there should also be a master switch at every station in case the person in trouble cannot reach it)
- Visitor safety sheet: visitors should not be allowed to enter the core handling area without prior consent as well as a basic briefing on safety.

6.2 Assembly and Disassembly of all NICL core handling equipment

6.2.1 ***Purpose*** *– The purpose of these tests are to determine the amount of time and the resources required to unpack, assemble, disassemble, and pack those components of the NICL core handling system that are brought to Greenland.*

6.2.2 ***Data and Information Collected –*** *The amount of time, the number of people, and the tools required to unpack and assemble each component of the core handling system will be recorded as will the sequence of assembly. In addition, suggestions concerning improvements in methods of assembly/disassembly, suggestions concerning packing/unpacking, and suggestions for modification(s) to equipment facilitating assembly/disassembly/packing/unpacking will be recorded.*

NICL found that set-up of our equipment was governed by three major factors.

First, Our gear needed to be placed in an area such that it was accessible for unpack. To do this, NICL relied on the help of VECO Polar Services to move our pallets around (as they were too unwieldy and heavy to move ourselves.) NICL found that it was difficult to work out of boxes outside of the tent (i.e. moving gear into the tent piecemeal and then assembling it.)

Second, it was a definite asset to have detailed packing lists. Organization, and access to the correct tools/equipment affects the whole unpack/pack procedure.

Third, we needed a larger space in Greenland so that we could actually unpack (we worked out of boxes in the tent most of the time.)

Based on our experiences in Greenland and given that the following conditions are satisfied:

- Palletized NICL cargo is brought from the cargo line to the immediate proximity of the core processing area by RPSC
- Assistance is available to position the heaviest monolithic pieces in their final positions (e.g. the gantry)
- The space prepared for the core processing area is completed to agreed-upon specifications

we anticipate that it will take two people a full week to complete the unpacking, assembly and final set-up.

NICL found that the following systems worked well for shipment/packing:

- Joan's Blue Hardigg boxes worked extremely well because they incorporate a seal and a lock type lid which cinches it tight. The black boxes that NICL bought could be modified to this end, but it will take some doing.
- The saw boxes were very unwieldy, and would work better with some better structural stability.
- The large tower section box worked well, and was handy for stuffing with irregular sized items. Perhaps more boxes of this size and shape should be constructed for WAIS.
- Using uniform box sizes allows more efficient handling of cargo when building aircraft pallets.
- NICL would benefit from a stencil kit and paints that will not freeze in the field.
- Photos of every step of the pack up process would assist NICL in unpack and re-pack. This could also be done for assembly/disassembly of equipment.

Based on our recent field experiences, NICL will acquire or request the following additional items to help expedite the unpacking/assembly and disassembly/repacking operations:

- 2 cordless drills, 1 circular saw, 1 sawzall

- A toolbox and worktable
- Sawhorses, and more extension cords.
- Large power tools such as table saws, band saws, etc. would be very useful.
- Shared use of tools between NICL and ICDS proved to be beneficial.

6.3 Alignment of NICL 4m tray table with the ICDS core barrel

6.3.1 Purpose – *There is no alignment capability between the ICDS tower section and the NICL tower section. The two sets of tower sections bolt together and form one long (8m) strong back that supports the NICL 4m tray/FED table and the ICDS core barrel unit. The NICL 4m tray/FED table and the ICDS core barrel unit must be properly aligned to one another to ensure good core quality. Any vertical and/or horizontal offset between the two units will add stress to the core and potentially crack it.*

6.3.2 Actions – *The following items need to be determined prior to, and tested during, the Greenland Field Test:*

Determine if NICL can use ICDS' optical alignment system to align the 4m-tray/FED units to the core barrel unit. If NICL cannot use ICDS' optical alignment system, NICL will need to determine a standard operating procedure for aligning the NICL 4m tray/FED table to the ICDS core barrel unit

NICL found during the field season that with ICDS's alignment system, we could in fact align each portion of our FED, V-Tray, and tower section. In order to do this, Jay Johnson made a "jig" for the V-tray, which allowed ICDS to shoot a level. NICL will fabricate or purchase another "jig" for the same purpose that will be utilized with the new V-tray to be used at WDC.

Ascertain that the FED can properly align with the NICL 4m tray/tower section as well as with the ICDS core barrel unit.

NICL found that the FED needs adjustable, secure mounts in order to ensure that it can be aligned properly and maintain its alignment. Over the course of the field season the mounts constructed by NICL slowly slipped out of alignment. The gradual misalignment was due to differential expansion between the 4-meter aluminum receiving table and the stainless steel strong back it was mounted on. The table is held to the strong back at two points about 1.3 meters in from each end of the 4-meter aluminum table. Adjustments were initially done when the temperature of the core-handling tent was cold. As the temperature of the tent warmed up, the aluminum table would expand more than the stainless steel strong back. This caused the center of the table to bow down. Because of this, the FED would rise about 1/8 inch.

After discussion with Jay Johnson and Bill Mason of ICDS, NICL will re-mount the receiving tray to the stainless steel strong back using several mounts (four or five). These mounts will allow for the differential expansion. The FED will be mounted to the stainless steel strong back with vertical and side ways adjustability.

Ascertain that core can be pushed through the FED using the same plunger/pusher that ICDS uses to push the core out of the barrel.

The plunger/pusher that ICDS brought to Greenland was more than sufficient to push core through the core barrel and the FED.

Work with ICDS to establish a plan to ensure that the azimuth of the core is positioned the same way every time before passing through the FED.

Both NICL and ICDS worked briefly on azimuth alignment towards the end of the drilling season. ICDS found that azimuth alignment could be performed within +/- 10 degrees. ICDS felt that further modifications to their alignment system would allow azimuth alignment to within perhaps +/- 5 degrees.

Establish mutually agreed upon (ICDS and NICL) command procedures regarding measures that may be needed for extraction of the core out of the core barrel, through the FED and onto the NICL core tray*.*

The core barrel to FED transition is extremely smooth. NICL feels that communication with ICDS is of the utmost importance. Because there was no wall between the Drill tent and core handler tent, all parties were involved with core extraction/receiving. At WAIS, there will be a wall separating the two areas, so some form of digital or verbal communication would be extremely beneficial. This will be extremely important if core-handling members are away from the receiving table. At a minimum, knowing whether or not the drill is ascending or descending would allow core handlers to better allot their time.

6.4 Drilling Fluid Removal

6.4.1 Purpose – *The science requirements for the WAIS Divide project require that the majority of the drilling fluid be removed from the core. The purpose of this objective is to test whether the current system, consisting of the FED, physical absorption and drying booths, adequately dries the core in a reasonable amount of time.*

6.4.2 Actions – *The following items need to be determined/tested during the Greenland Field Test:*

Ascertain how thoroughly, and how consistently, the FED removes drilling fluid from the core. After the core has passed through the FED, NICL will use multiple methods to access how thoroughly the drilling fluid is removed from the core. These methods will include visual observations, "blotting" the core with Kim-Wipes, and potentially screening the core for fugitive volatile organic compound (VOC) vapors using a handheld FID and/or PID.

After the core had passed through the FED, NICL found it to be quite dry. Most of the fluid and chips had been removed from the surface of the core. NICL made specific comparisons between core that had passed through the FED, and core that had not been passed through the FED. By visual observation, it was apparent that the FED passed core was substantially drier, with no cloudiness or chips on the core surface. NICL also used brown paper towels (Kim Wipes were too translucent when wet) to blot test the effectiveness of the FED. When held on the core for 10 seconds, and compared with others held on a non-FED core for 10 seconds, it was apparent that the FED passed core was drier.

The handheld VOC detectors that NICL brought to Greenland were not sufficient to obtain readings from the cores. NICL tried various methods to obtain a vapor reading (using devices to increase the concentration of the IsoPar vapor above the core) but to no avail. IsoPar is not volatile enough to have sufficient vapor pressure at the temperatures experienced at the test site. NICL did obtain samples of core at various stages of the drying process to possibly be analyzed at a later date.

Experiment drying the core with cotton rags after coming out of the FED. When brittle and/or broken ice is encountered the FED may not sufficiently dry the core. In such cases, drying the core with a rag may prove to be more effective.

After the core had been removed from the FED, NICL used terry cloth towels to remove the remaining fluid from the cores. With the addition of the towels to the drying process, NICL feels that almost all drill fluid is removed from the core. However, addition of the towels to the drying process substantially increases handling of the core.

Experiment with drying cotton rags on clothesline to see effectiveness of removing fluid in polar atmosphere. The Summit Science Coordination Office has been consulted and we have their permission to dry the cotton rags on clotheslines located outside of the drilling tent.

NICL experimented with placing used terry cloth towels onto a clothesline located outside of the NICL tent for drying. The towels appear to dry overnight (~ 8 hours,) if only slightly dampened with IsoPar. NICL also placed towels which were extremely wet outside, and found them to not be dry when checked after ~ 26 hours.

Ascertaining the effectiveness of the drying booths in drying core. Drying times should be tested to determine the minimum amount of time that core needs to be stored in the drying booths. Ambient temperatures should also be recorded since the temperatures in Greenland are likely to be different than those in Antarctica

NICL constructed a drying booth within a ~ 12 foot deep basement dug by VECO Polar Services. This booth consisted of a pallet rack draped in canvas tarps. The drying system was comprised of a squirrel cage fan of 850 cfm connected to ducting allowing the fan to blow air into the booth on one end and draw air out from the other. The discharge side of the fan also had a small duct with an air valve incorporated so that 10 to 20% of the re-circulated air could be discharged to the outside. This allows the booth to have negative pressure, which prevents fumes from being blown into the working areas. This also allows a continuous influx of fresh cold air to be drawn in.

The discharge side of the fan was connected to a plenum with 7 diffusers. These diffusers were set such that the air was directed across the tops of the cores that are in a 7-shelf rack with 3 cores per shelf. Each of the seven shelves is covered with an HDPE plastic liner to ensure that there is no loss of flow between shelves.

The use of adjustable diffusers allows NICL to create a uniform flow rate for each of the shelves, and minimizes flow lost to eddies, vortexes, etc. The air flow is set for each diffuser using an anemometer to get a wind speed, and then multiplying that speed by a given cross sectional area to give flow rates.

NICL tested the booth on cores which had or had not been run through the FED, and/or dried with towels. NICL found that cores which had not been run through the FED dried in ~12-28 hours. Core which had been run through the FED dried in ~ 8 hours and cores which were run through the FED and then dried with terry cloth towels dried in ~ 4 hours. Core wetness was measured by touching brown paper towels to booth run core for ten seconds, and comparing them to the same test performed prior to placement (photographs taken). The temperature in the basement was ~ -20 degrees

6.5 Determination of Core Quality

6.5.1 Ductile Ice – *Once ICDS begins the 'Ductile Ice Coring Acceptance Test' (as outlined in the DISC Drill Field Test Plan, 8505-0005); all core that is produced during this acceptance test must be saved by NICL. NICL will evaluate the quality of the core based on the following characteristics:*

Three contiguous core segments, totaling approximately 12 meters in length should be recovered by ICDS.

Prior to this test, ICDS was producing on average, 2.47 meters of core per drill run. For the ductile ice test, ICDS drilled 2 meters of ice without the core dogs in place. ICDS would then retrieve the core barrel, replace the dogs, change the chip screens, and drill another 2 meters to remove a 4-meter section of ice. By doing this, ICDS was able to produce three continuous 4-meter sections of core. The core lengths that ICDS produced were: 4.165 meters, 3.98 meters, and 4.15 meters (giving a total of 12.295 meters)

Packed core should not have more than 12 pieces of ice per 10-meter section of core.

The three segments of core retrieved for the ductile ice acceptance test were contiguous and were cut into 10 one-meter lengths for a total of 12 pieces.

Ice pieces fit snugly together, without any gaps

All of the ice pieces fit together, without any gaps.

No micro cracks that provide a conduit for contamination into the core

All of the cores drilled by ICDS showed evidence of microcracks. Most were ~1-2 millimeters deep. Early cores had surface fractures that propagated at 45 degree angles to the “thread line” created by the cutter teeth. In later cores, ICDS changed the relief behind the cutter point on the core side of the teeth. This reduced the number of surface fractures, and alleviated the 45-degree angle cracks.

***6.5.2 Brittle Ice** – Once ICDS begins the ‘Brittle Ice Coring Acceptance Test’ (as outlined in the DISC Drill Field Test Plan, 8505-0005); all core that is produced during this acceptance test must be saved by NICL. NICL will evaluate the quality of the core based on the following characteristics:*

Three contiguous core segments, totaling at least 4.5 meters in length should be recovered by ICDS.

ICDS chose to perform two separate brittle ice tests (one early in the season and one later) due to the variation in expectations of the depth at which brittle ice occurs. For the first brittle ice test which ICDS performed, three contiguous cores of lengths 2.05 meter, 2.15 meter, and 2.01 meter (6.22 meter total) were drilled.
For the second brittle ice test, three contiguous cores of lengths 1.98 meter, 2.07 meter, and 2 meter (6.06 meter total) were drilled.

80% of the ice mass should be in pieces larger than 2 liters. A piece is defined as a single contiguous interval of core that is free of internal fractures.

Greater than 80% of the ice mass was found to be in pieces larger than two liters. (See Below)

Ice pieces fit together and retain stratigraphic order.

All of the ice received from ICDS fit together and retained stratigraphic order.

Fractures that occur after the ice is removed from the core barrel are not a function of drill design and will not be considered

NICL found that thermal shock was probably the biggest threat to the ice cores being received. Our tent was not cooled; it was open to ICDS’s drill area, which was always warmer (due to the nature of their equipment). NICL witnessed this shock as the core was removed from the core barrel. On average, the core was received at a temperature of -24 degrees Celsius. NICL’s tent temperature averaged -9 degrees Celsius. The Aluminum tray temp averaged -11 degrees Celsius. The core would “pop” and crack due to this large temperature difference. NICL tried to combat this by opening our tent door to allow colder air to enter. We also sometimes ran the exhaust fans from ICDS to draw colder air into the NICL area. Another technique was to line the Aluminum tray with HDPE or plastic layflat. This helped, but the ambient temperature was still too high. The layflat would “bunch” making it hard to push the core form the barrel. As well, the plastic acted as a reservoir for fluid to remain on the 4 meter tray. The best solution for avoiding thermal shock is to cool the core-handling tent to an acceptable temperature for the ice (-30 Celsius.) As well, it may be a good idea to cool the drill tent to ensure that the ice never reaches a point where thermal shock is a problem.

Separate the 4.5 m of core apart along the natural factures.

This was no problem because the core did not have many fractures.

Weigh each piece

All of the ice pieces had effective volume of greater than 2 liters except for two pieces on the second brittle ice test performed. The two pieces weighed 720 and 513 grams, respectively (2 liters of ice weighs 1,840 grams.)

Calculate the percentage of the total weight that is in pieces larger than 2 liters.
100% of the ice cores recovered by ICDS during the first brittle ice test were greater than 2 liters. For the second test, 98% of the ice mass was in pieces larger than 2 liters.

6.6 Handling of Brittle Ice

6.6.1 ***Purpose –*** *Brittle ice is expected to begin at approximately 500 meters below surface and extend to approximately 1300 meters below surface. During the GISP2 project ice below 710 meters was stored for one year to allow relaxation. The purpose of this objective is to demonstrate that the core handling procedures work as well with brittle ice as they do with ductile ice.*

6.6.2 ***Actions –*** *The following items need to be determined during the Greenland Field Test:*

Determine if brittle and/or broken (or chipped, spalled, etc) core can pass through the FED. If it cannot pass through the FED, modifications to the FED need to be made and/or a new method for drying the core as it comes out of the core barrel needs to be ascertained and tested.

Broken, chipped, spalled, etc. ice core cannot pass through the FED without a connector piece to bridge the ~8 centimeter section of the core barrel that has no liner. Without the bridge, broken ice that passes between the core barrel and the FED will drop down in the space between the core barrel liner and FED and become stuck. When this occurs, NICL opens the top of the FED and passes the core through (1/2 of the core is still dried this way.) Upon return, NICL will experiment with ways to allow a transition between the core barrel and FED using the connector bridge.
Another core drying method tested in the field was the use of a vacuum wand. The wand fits the radius of the core, and allows fluid to be removed from within cracks, or around odd shaped pieces. The wand worked quite well in Greenland.

Ascertain the best method(s) to "capture" brittle or broken core. The use of panty hose, fish net stockings, turkey netting, polycarb cotton, etc to surround the core as it is pushed out of the FED may be used.

NICL tested the use of both panty hose and wine netting to contain broken core. The panty hose was tested first, and was promptly found to be too small in diameter to contain the core. Because of this, the core caused the panty hose to become ripped, and run.

NICL found that by using turkey netting the core could be contained even when broken. Hitting a core, which had been placed in wine netting with a 4-pound hammer, tested this. The netting was chosen because it expands to fit around the core while still allowing it to dry. The netting does not hinder the receiving process. A device to hold the netting in place while the core is received from the drill barrel should be made.

Ascertain whether or not the ice undergoes thermal shock upon contact with the 4-meter aluminum tray. This is especially critical for brittle ice but also pertains to ductile ice. NICL should also have the means to test this using plastic liner in the trays to see if there is a difference in thermal response of the ice.

As mentioned above, NICL found that thermal shock was probably the biggest threat to the ice cores when being received. The problem in Greenland was that our tent was not cooled, and it was open to ICDS's warmer drill area. NICL witnessed cracking and breakage due to shock as the core was removed from the core barrel. On average, the core was received with a temperature of -24 degrees Celsius. NICL's tent temperature averaged -9 degrees Celsius. The Aluminum tray temp averaged -11 degrees Celsius. The core would "pop" and crack due to this large temperature difference. NICL tried to combat this by opening our tent door to allow colder air to enter. We also would sometimes run exhaust air from ICDS into the NICL area to draw in the colder air. Another technique was to line the Aluminum tray with HDPE or plastic layflat. This helped, but the ambient temperature was still too high. The layflat would "bunch" making it hard to push the core from the barrel. As well, the plastic acted as a reservoir for drill fluid. The HDPE allowed the core to be placed into the V-tray with a minimal amount of surface contact, while protecting it somewhat from thermal shock from the tray. With a tray liner, the core still underwent thermal shock. The best solution for avoiding thermal shock is to cool the core-handling tent to an acceptable temperature for the ice (-30 degrees Celsius.) As well, it may be a good idea to cool the drill tent (or just the receiving tray area?) to ensure that the ice never reaches a point where thermal shock is a problem.

Vibration and stress were second to thermal shock in destroying core. Both of these are due principally to the effects of vibration from the saw. The saw can translate vibration to the core while cutting through it, through the table, or through the V-tray. Stress can also be caused by misalignment of the core, tray, or saw blade. An unsupported core has large amounts of stress on it causing the core to break. NICL found that placing the V-tray flush with the saw blade, and having the one-meter tray and the 4-meter trays accurately aligned, greatly reduced this.

Determine the best method(s) for evaluating whether or not brittle ice pieces are at least 2 liters in volume.

By using some basic mathematical equations, NICL could ascertain whether or not the ice pieces were greater than 2 liters. Two calculations were done, one by mass, and the other by length. In the absence of extremely anomalous ice features, these methods gave NICL the means to measure the ice pieces.

6.7 Standardization of Core Handling Procedures

6.7.1 Purpose *– One fundamental goal of the Greenland Field Test is for NICL to develop standard operating procedures for all core-handling activities involved with the WAIS Divide project. NICL is responsible for preserving the quality of the core from the time it comes out of the core barrel until it is shipped out from WAIS Divide (and then again once it reaches the NICL facility in Denver, CO). It is anticipated that production drilling at WAIS Divide will take several years to complete and therefore there is the high possibility that from year to year different core handlers may be involved in the project. In order to maintain the highest core quality it is imperative to maintain as much consistency in core handling as possible. Consistency in core handling needs to be maintained between core handling personnel for a given year and from year to year. In order to achieve this, it is vital that NICL develop and formally write standard core handling procedures for the WAIS Divide project.*

6.7.2 Actions *– A continuous evaluation of all core handling equipment, subsystems, and procedures should be carried out throughout the Greenland Field Test. It is expected that when possible, improvements/modifications to equipment and procedures will be carried out while in Greenland. For those improvements/modifications that cannot be completed while in Greenland, thorough notes should be recorded outlining the details of the improvement/modification to be made once back at the NICL facility. Upon completion of the Greenland Field Test a formal standard operating procedure for core handling at WAIS Divide will be produced.*

At the time of deployment, key decisions that impact the final configuration of the core handling area and process had not yet been made. As a result, only a subset of all core handling procedures could be tested for standardization. A draft version of standardized core handling procedures based on the available equipment and our experiences and observations during the test season will be submitted to the SCO by November 15, 2006.

6.8 Evaluation of WAIS Divide Core Database

6.8.1 ***Purpose –*** *NICL is responsible for the development and maintenance of the WAIS Divide core database. While the majority of this system can be tested in the NICL freezer, the actual logging information collected and disseminated on long core lengths are best tested with actual long segments of ice.*

6.8.2 ***Actions –*** *The following aspects of the database will be tested in a polar environment:*

The database must contain information about the core and cross checks to assure all data is entered properly. At the same time it must be user friendly and not require excess time of the field loggers. In actual core production these features will be tested and reported on by the NICL field staff. NICL is responsible for taking detailed notes regarding any improvements that can be made to the core database.

The database taken to Greenland did not perform crosschecks between core runs. Without cross checks between the runs, any data entered could not be verified. NICL feels that these checks are necessary to ensure correct measurements. NICL will work to remedy this prior to Antarctic deployment.

The database also needs a better screen format for user friendliness. For example, larger selection buttons and a larger on screen keypad would help to ensure that gloved hands could enter data simplified data entry screens would help to prevent confusion by cold core handlers. There were also some issues with the interface. Easier ways to define fractures, cracks, etc. within the core would expedite the data entry process. If this database could have a link to the Balluff measuring stick, the process of core measurement may become much more user friendly.

In Antarctica core cards will be printed. NICL is still trying to determine what cards to print where. NICL had problems printing cards in Greenland primarily because the processing set-up was not the same as will be at WAIS. Data was not entered into fields in the correct order.

Back-up procedures, both digital and paper copies, will be tested to assure complete redundancy for all information collected.

Hand written logging was used in the field. Core log books designed around the current database were used. These books were easy to use, and core information entry was rapid. NICL also printed core cards from the current database. The printer and the card layout required some basic re-tooling in order to operate in the field. Printer times were a little slow, but other than this, the cards held all relevant information pertaining to the core.

Digital communications (i.e., computer to computer) between the ICDS drill team and the NICL core processing team will be established so all parties have the same information.

NICL spoke with ICDS regarding digital communications while in the field. At the time of the field test, a direct link between NICL and ICDS was not possible (due to time, wiring, etc.) Both NICL and ICDS will explore this issue further prior to Antarctic deployment.

At a minimum, the WAIS Divide core database should incorporate the following drilling/ICDS information: start drilling time, stop drilling time, break time and tension, surface time, extraction time. NICL will consult with the Chief Scientist/SCO to determine if any other information from ICDS should be captured in the core database.

The database tested in Greenland did not have any fields to enter this information. The information that NICL received from ICDS did not include any break tensions, surface times, or extraction times. NICL timed the tip-down to tip-up times of the drill tower, and the time from tip up until NICL received the core. According to NICL's times, on average, the drill took ~ 1.7 hours from tip-down until tip-up, and from tip-up until the core was received by NICL was ~7 minutes.

6.9 Minimize Impact on other Science Activities at Summit

- ***6.9.1 Purpose –*** *The purpose of this objective is to minimize our disturbance to other science projects at Summit, Greenland. The location of the drill tent in Greenland is approximately 1.5 kilometers downwind from the Summit Clean Air Sector.*
- ***6.9.2 Actions –*** *In an effort to minimize the disturbance to other science activities at Summit, the following protocols need to be followed:*

Ice cores that are no longer needed for the Greenland Field Test will be stored in a vertical position in the snow outside of the drill tent in a sunny location. This will allow maximum volatilization of drilling fluid off of the cores. Upon completion of the Greenland Field Test, VECO and Summit SCO will determine the best disposal solution.

NICL attempted to store all no longer needed ice cores in a vertical position, however due to the brittle nature of the ice, the cores tended to shatter when driven into the snow.

Subsequently, the cores were placed in a banana sled for a short period of time (usually in small pieces) then moved to a designated location and spread out on the surface to finish drying. Since all the cores had been run through the FED, cores tended to dry quickly.

To minimize vehicular pollution sources at the Summit Camp personnel are to only use vehicles to transport heavy items from camp to the drill test site. Normal transport from camp to drill test site is by walking.

This requirement was followed.

CONCLUSIONS AND RECOMMENDATIONS

The following items need further work:

- The saw table was not stable enough to support the large band saw. The floors were made of thin plywood, and moved when a person walked across them. NICL added cross braces to the MK table for increased rigidity, and placed 2 X 4 s under the legs to distribute the weight across the floorboards further stabilizing it. The flooring at WAIS Divide must be robust and stable enough to provide sufficient support for the saw.
- For height adjustment of the table, NICL needs a better system. The current screw levers on the legs are inadequate and dangerous for adjusting such a large saw. We should use a lab jack system with a power drive for ease of adjustment.
- The saw table needs to be attached to the roller track. If the whole system is “monolithic,” then the vibration, as well as stability issues may be fixed.
- Cutting alignment between the 4-meter tray, saw, and 1-meter core tray was not adequate. Wooden trays will never be able to align enough to prevent core damage. NICL needed aluminum trays in order to ensure that exact alignment could be maintained. The wooden V-trays made on site were not sufficient to allow this. Core could slide easily along the 4-meter tray that NICL produced for the DISC test.
- The linear actuator that NICL mounted to the saw arm proved invaluable for calibrating the drop speeds for saw blade tests. The actuator works on a screw drive and has a speed adjustment mechanism. By using it to govern the speed, we could test various blades at specific drop rates through the core. Because of this we could decide on the drop rate based on whether we were cutting brittle or ductile ice. A slow rate of speed worked best for most types of ice. The actuator also allowed NICL to perform other tasks while the saw was cutting the ice, and dampened the vibration found in the saw arm. With an actuator that is more robust, more of the vibration could be dampened, and speeds in the up direction could increase.
- The saw used in Greenland (mainly the large Wilton saw) had drive wheels, which were out of balance. These wheels cause vibration and vertical translation during cutting, due to the fact that blade is constantly out of phase. Ice build up on the drive wheels may also cause this. NICL changed the blade speed of the big saw from about 200 feet/min to about 900 feet/min. This seems to have increased the effects of the drive wheel vibration.
- A blower or suction device next to the saw blade could help to remove “kerf” ice from the blade.
- NICL would have liked to test 0.5-inch blades on core in Greenland, but found that the 0.5 inch blades could not be mounted onto the large Wilton saw. Mounting blades of that size would require major component changes and may possibly damage the saw, rendering it unusable. NICL feels that if 0.5-inch blades were used they could decrease core breaks significantly. A smaller blade may allow less surface area to be present in the core while it is being cut (which means less vibration, etc.) The saw will have to be adjusted for these blade sizes and tested while back at NICL.
- NICL found that blades with 6 teeth per inch, 10 teeth per inch, or 6-10 teeth per inch per second worked the best for cutting core. NICL would like to test these blade types in 0.5-inch thicknesses at our lab in Denver.

- During the Greenland test NICL noted that the large Wilton saw became a reservoir for snow/ice chunks. If the saw had some way to remove the detritus away from itself, this would help significantly. Sealing off the saw base would also help, as this area becomes inundated with the detritus.
- NICL tested the small Unitec Spitnas saw, but found that the mounting was not properly done to allow an easy transition between swap outs. Also, this saw runs too slow a blade speed to allow for a clean cut through the ice (A blade speed of 900+ FPM worked the best, but could only be achieved with the large saw.) If this saw is to be used at WAIS or as a backup, the mounting plates must be totally re-done.
- The Balluff measuring stick was used for making rapid digital measurements of the core, and may be able to remove the human error associated with measuring cores in a cold environment. The stick is fastened along the length of the receiving table, with a core tray laid next to it. The “widget” (magnetic sensor) is then moved along a track to make the measurement. The resulting measurement is displayed on a readout, which is mounted above the core. NICL would like to have the Balluff connected electronically to a computer using Labview or some other program. In this way, NICL could get a real time measurement onto a database, cross referenced with another done using a meter stick. Also, if a laser pointer were to be used on the magnetic “widget,” the core handler could make precise measurements of any breaks, fractures, cracks, etc. while having them stored electronically.
- The two-headed fiber optic lamp was a very useful tool for viewing cores while in Greenland. Because the lamp has two fiber optic lights with adjustable necks, we could position the lamp in a myriad of ways around the core to see into it. Also, because the lights are fiber optic we could get the light fairly close to the core without heating it. NICL would like to mount a track above the core table that would allow the lamp to be located above the core and slid along it. This would alleviate the possibility of hitting the core with the lamp, or dropping the lamp onto the floor. This would be an invaluable tool for the core handler because layers of importance could be viewed and logged before the core is transported back to NICL. Also, a camera could be mounted to the track allowing for photos of layers of importance, cracks, or fractures.
- The Computers worked well in the cold. One had to be vented because it was running too hot inside of the Hardigg case (NICL drilled a small ~1.5” diameter hole in the top with a hole saw.) The computers and Hardigg cases may need to be further modified and tested in NICL’s freezer.
- The molding on the Hardigg computer case does sometimes interfere with the touch screens. NICL will need to adjust the molding prior to WAIS to prevent this.
- The computer stands that NICL made worked well, but a more robust version would be optimal for WAIS.
- Having the keyboard mounted next to the computer with a mouse (even though the computers had touch screens) was invaluable, as they are needed to rapidly correct problems. This will need to be incorporated into the computer stand design.

- The uninterrupted power supplies (UPS) needed to be insulated to work properly. An unintended test during a generator change over proved that the UPSs work fine. The UPS kept the computer running for half an hour before NICL realized that the breakers were still off.
- The receiving table needs to have an HDPE liner on it to facilitate the movement of the 4m core trays.