Ice Coring and Drilling Services
DEBRIEFING – DISC DRILL GREENLAND TEST
August 22 and 23, 2006

On August 22 and 23, 2006, ICDS and other personnel met to discuss the Greenland field test of the Deep Ice Sheet Coring Drill. The primary purpose of the debriefing meeting was to collect feedback from the test team concerning the organization and execution of the test as well as its evaluation of the performance of the drill system. Tom Demke, SSEC Manager of Quality and Safety moderated the meeting.

Attendees: The following individuals participated in the debriefing for one or both of the days:

Name	Job Function/Title	Affiliation
Ed Alexander	***Electrician/Driller***	***Westphal Electric***
Laurent Augustin	***Engineer/Driller***	***ICDS – Visiting Scholar***
Fred Best	Associate Director – Tech.	SSEC
Kristina Dahnert	***Safety Coordinator/Driller***	***SSEC***
Tom Demke	Quality/Safety Manager	SSEC
Scott Ellington	Engineer	SSEC
Brent Folmer	***Electrician/Driller***	***Westphal Electric***
John Fowler	***Driller***	***ICDS***
Scott Haman	***Engineer/Driller***	***ICDS***
Michael Jayred	***Driller***	***ICDS***
Jay Johnson	***Engineer/Lead Driller***	***ICDS***
Bruce Koci	Engineer	ICDS
Don Lebar	Program Manager	ICDS
Bill Mason	***Engineer/Driller***	***ICDS***
Amy Pagac	CADD Specialist	PSL
Steve Polishinski	Electronics Technician	Subcontractor
Lee Powell	Engineer	UW Geology
Hank Revercomb	Director	SSEC
John Roberts	Associate Director – Admin.	SSEC
John Robinson	***Driller***	***UW Mechanical Engineering***
Paul Sendelbach	***Engineer/Driller***	***ICDS***
Alex Shturmakov	Project Manager - DISC	ICDS
Ron Steiner	Engineer	Subcontractor
Don Thielman	Engineer	SSEC
Tony Wendricks	Project Coordinator	ICDS
Will Robus	Shipping/Receiving	SSEC

Bold Italicized names indicate members of field test crew. Nicolai Mortensen, ICDS Engineer, also served on drill crew, but was unable to attend the debriefing.

Season Overview

Jay Johnson provided an overview of the test season with comments from other team members.

- Overview of Summit Camp – Pictures and description of the facilities at Summit.
- Assembly of Drill
    - Jay, Ed Alexander, Brent Folmer and Kristina Dahnert left for Summit on April 18, 2006.
    - Up to 15 people working within the drill structure (erected by VECO at Summit in 2005) at any point in time.
    - Power was run from the generator shack to the drill structure and the structure wired for the drill equipment; the ventilation system was also installed. The previous summer the large gantry crane had been installed, the slot excavated, and the pilot hole drilled and cased.

    - The drill equipment was assembled and ready for operation on May 20. Actual assembly of the drill equipment was completed approximately 2 weeks after the completion of the electrical work.
- Drilling
    - First core was produced June 1 from a depth of about 100 meters.
    - Some ice chips were found on top of the core.
    - Chip removal:
        - Crew found that it was faster to clean chips from screen section by hand rather than using the automated screen cleaning station.
        - Screens were placed in front of power load bank to melt any ice remaining in screen sections.
        - Concern that the operation may result in repetitive stress injuries.
    - Drill fluid:
        - Hose was lowered from surface to below firn/ice transition to add drilling fluid.
        - Fluid added approximately once per shift.
        - Small hose reel used to raise hose – very labor intensive requiring several people. System was very simple for Greenland test but will be much better at WAIS Divide.
        - Pumps had difficult time pulling fluid from barrels – some sort of modification will be needed.
    - Cutter head
        - Some modification to core head (cutting windows) tried to prevent packing of chips in head.
        - Straight cutters resulted in some very small fractures in core; "scoop" cutters eliminated the fractures but resulted in a pronounced helical groove in the core.
    - Core handling – cores pushed out of barrel with "broom" handle with padded hockey puck on end to prevent damage to cutters.
- Visitors – Sigfus Johnsen, Matthew Kippenhan, Alex Shturmakov, and Kendrick Taylor visited July 12-14. Testing was slowed down to allow some coring and other testing while visitors were at site.
- Winch Test
    - Able to achieve 2.9 m/s tripping out of borehole before tripping out generators.
    - Maximum tripping speed into hole was 1.4 m/s
    - Problem with weight-on-bit sensor resulted in knotting the cable when cable payout was faster than sonde was descending. Quick action by Kristina Dahnert and Paul Sendelbach prevented damage to tower. Knot was heard, not seen, coming out of hole. About 45 minutes was required to get sonde out of hole after problem was discovered.
    - Not much splashing of drill fluid except in slot and at top of crown sheave.
- Packing
    - Packing of system for return to Madison was started on July 14 and completed on July 20 (6 days – 13 days originally planned).
    - Chain falls were connected to building supports and used to take down gantry crane.
    - All electrical removed except the generator feed which was under the NICL tent.
    - Would re-arrange a few things in packing of drill to make unpacking easier.
- Left Summit July 25 in Twin Otter.

Core Quality

- Cores were in one piece most of the time
- Quality was excellent; NICL personnel commented that it was the best core they had seen – better than anything in the lab. Some small fractures that captured some liquid.
- Maybe one fracture per core in brittle ice, most cores didn't have any fractures at all.
- Length of core is biggest issue – hoped to produce up to 4 meter long cores; longest was about 3.1 meters and average was approximately 2.4 meters. Length limited by ability to collect ice chips.
- Good core quality is attributed to the straightness and trueness of barrel.

Drilling Equipment

The following are observations about the various components and subsystems of the drill system. Remedies to identified problems are presented in a later section.

- Winch
  - Ran whole season with no major problems
  - Motors and gearbox had to be insulated and heated because of the low temperatures.
  - Questionable whether level wind would function for a full season.
    - Very high friction in drive
    - Plastic guides and guide rails do not seem to be durable – poor design.
    - No provision for keeping drilling fluid from washing off lubricant.
  - Drip pans under winch needed about 1 inch of fluid before it would drain – a lot of fluid and pan should be redesigned.
  - Motors
    - Small "penetration" drive motor could be eliminated and the large motor used with a high efficiency gearbox. Hand-off between motors complicates operation.
    - Were able to run winch at high speed even with the smaller generator at Summit; the acceleration of the winch, however, suffered because of the lack of power.
  - Winch controls
    - There were a couple of electrical shorts in the control cabinet – loose connectors; need protocol to ensure that all connections are tight.
    - Pressurization of cabinet worked well – used all nitrogen (5 bottles).
    - Coolers in cabinet only ran occasionally; didn't have temperature measurement in cabinet so don't know how hot it got, but "air" coming out was not too warm.
    - Break resistors only came into play at lower depths.
- Cable
  - Void filler flaked off at guide blocks, but didn't present any problem. Some of the filler accumulated with ice on the crown sheave.
  - The electrical termination lugs at the sonde end of the cable could be in a more convenient location. This would make the termination of the cable in the sonde easier.
  - Putting a new cable on in the field is possible; termination of the cable at the winch would be somewhat difficult.
- Tower
  - Assembly of tower went fairly well – use of A-frame makes assembly easier.
  - Tower was aligned when assembled and stayed in alignment all season.
  - Hydraulic system a little jumpy when tower is being lowered but is not a problem. System is not noisy at all.
  - Fluid draining down through center of tower hits junction box at bottom (was shielded to prevent damage.) Wipers at bottom of hole and at crown sheave will help alleviate the problem.
  - Hard limit switch tripped each time; problem with limit switch levers breaking.
  - Initial problems with load cells, but once fixed, ok for rest of season.
  - A limit switch was added in field for parking of tower in the vertical position.
  - Tower was stopped so it was slightly inclined to allow fluid to drain away from crown sheave.
  - Heater in hydraulic system not needed.
  - Some problem with wireless remote control for tower – discovered that antenna was not installed.
- Power Distribution/Electrical
  - Problem with PVC coating on power cables falling off in cold; the coating wasn't needed since the cable was armored.
  - The electrical panel originally supplied by VECO was too small. VECO purchased and replaced it with a larger one.
  - The "dry" transformer was very heavy and weight needs to be planned for.
  - Using building structure for stringing cable worked very well.
  - Exhaust fans mostly used to control temperature in structure.
  - Power monitoring done; instrument was excellent for job. Need to interpret data and send to RPSC.

    - Concern for WAIS Divide is switching of generators; will need protection for our equipment.
- Enclosures – MECC, Control Room, etc.
    - Control room
        - Temperature was OK; need space heater at night.
        - Communication would be easier if there were an opening window on the control room so people in control room could talk to those on "floor". Also difficult to see into control room with present windows and to hear drill.
        - Space in control room pretty tight – can rearrange some of the equipment.
        - Crane rail was too close to control building at Summit; clipped corner of building once.
    - Slot
        - Ventilation of slot worked well
        - Trouble calibrating gas detector; never did show much Isopar.
        - Fluid was not very flammable – had a very difficult time getting it to burn.
        - Slot was entered rarely after drilling began unless something was dropped into it.
    - MECC – more permanent wall heaters with central thermostat would help, as would ability to control airflow through roof vents.
- Sonde
    - Electronics/Software
        - Cutter and pump motors were difficult to start; would stay running once started. Connectors appear to have been bad; re-soldering seemed to resolve the problem.
        - Data viewer (historical data) was not useful since data was always more than 10 minutes old.
        - Electrical noise – knew there would be some and planned to fix after test season.
        - Motor power supply would cut out when both cutter and pump motors on high; spikes in noise caused it to trip out.
        - Current sensing – slow response and noisy.
        - Weight-on-bit sensor – biggest problem; noisy to the point of being unusable. Temperature not a problem when tested in Madison perhaps connectors. Found fluid in sensor at end of season – don't know there was fluid all season causing problem, but sensor seemed ok before actual drilling.
        - Problem with winch level wind software faulting.
        - Might have lost one fiber optic connection on rotary joint – not sure.
        - Acoustic sensor (microphone) doesn't seem to be worthwhile.
        - Wires easily pinched when disassembling and assembling instrument sections.
        - Light indicating that pump is on would be useful.
        - Seems to be an "offset" in reading for payout – both level wind and crown sheave.
        - Micro controller would not power up first time, but did on second try.
        - Winch cabinet relay K-2 socket had loose connection.
        - Rail design makes slipping electronics into enclosure difficult.
        - Electrical connectors leaked fluid – wrong connectors for service.
        - Need to be able to print out hard copy of run report.
        - Need to be able to save data on crash of control system.
        - Determining fluid level automatically would help.
        - Need to revisit packing of instrument section – seemed to be some shifting during transport.
        - No backup of drill data – exists only on computer hard drive.
    - Mechanical
        - Not too many problems
        - Need to lengthen anti-torques
        - Question about weakening of mechanical fuses with cycling. Bill Mason didn't think it was a problem since the loads on the fuses were so low, but it is something that could be looked into.
- Fluid Handling
    - Worked pretty well.
    - Pumping fluid from drums was problem.
    - Flow meters didn't work well at low flows resulting from problem with pumping from drums.

    - Centrifuge
        - Filter needs to be changed
        - Nut on lid friction welded itself on – field modification made to eliminate problem – probably need spare nut and socket.
        - Blower motor would lock up if cooled down – need low temperature lubricant.
        - Latch pin easily bent – need something better; solenoid is only thing using air for power.
            - Need more room for centrifuge.
            - Second bucket would make operation more efficient.
- Screen Cleaning
    - Screens "plunged out" using plastic baseball bat someone left.
    - Drip pans need to be sealed.
    - Automation not used – manual cleaning of screen section faster.
- Other
    - Audible alarms to be added for movement of cranes.
    - Other possible alarms, etc.:
        - Turning of core barrel.
        - Monitors outside of control room and possibly in NICL section showing drilling data (status).
        - Monitor to indicate/shut down electrical if problems with power, e.g., loss of phase.
    - Additional tools
        - Wood handle brushes
        - Squirt bottles
        - Hand tools for outside of shop.
        - Complete list should be prepared.

Modifications/Enhancements/Spare Parts

- Core length – options for improving core length need to be evaluated further.
    - Pumping and chip density will improve with the higher fluid density of the Isopar K – 141b mixture.
    - Testing in Greenland by adding screen sections and reducing the length of core barrel did not improve core length – top screens were not filling (design is to fill screens from top down), indicating that the pump wasn't lifting the chips.
    - Perhaps changing pump would help, but this will lead to a major drill redesign, and then we are starting with a new, untested drill. Best course of action is to start where we are rather than changing multiple things at one time, particularly since we really don't understand the problem.
    - Increasing length of screen section has domino effect – longer tower, deeper and longer slot, etc. Need to look at effects. Perhaps slot could be sloped since the ladder end does not have to be as deep.
- Winch
    - New gear train would eliminate the need for the small motor and improve efficiency of winch from ~65% to 94%. Would also lessen the amount of power required.
    - Real questions about the reliability of the level wind with the plastic guides and rails and amount of friction in system.
    - Need to decide how to handle winch motor controller – new one will be needed. Perhaps with simplified control, PLC would work.
- Connectors in sonde need to be replaced.
- Weight-on-bit sensor – actual problem needs to be found and solved. Probably liquid in the sensor was major problem.
- Improvements need to be made to fluid wipers and drip pans.
- Cutter head should be re-designed to improve flow of fluid.
- Spare parts
    - Need to put together comprehensive list starting with the long lead items.
    - Need to consider stocking parts that are likely to be discontinued.

- Biggest software issue is motor control for winch.
- Question about whether waste heat could be used to melt chips and reclaim fluid – bring up with RPSC.

More definitive lists of necessary modifications will be developed.

Staffing Issues

- In Greenland, single 8-hour shift initially, then 2 10-hour shifts, then back to one shift at end as drilling fluid began to run out.
- Things generally worked less well at night when temperatures fell.
- Believe that 3 8-hour shifts should be used at WAIS Divide with probably 3 drillers per shift plus lead driller. Need somebody capable of doing machining, an engineer.
- Skill levels should be high during start-up (2007-08) season.
- Training should include orientation on drillers' control screens and, if possible, some sort of drill simulator. Trainees should be able to talk to people with experience. Should also go through drill cycle.
- Needs to be some sort of data processing to place data in usable format for review.
- Need to consider what types of gear – gloves, etc. worked best. Earmuffs preferred over earplugs. Headsets didn't work well; perhaps system like IceCube has – push to talk with microphone mounted outside on chest and transceiver under clothes to keep batteries warm.

Interfaces with Others

- Need to pursue list server idea so everyone involved has access to e-mails back and forth on technical issues.
- Interface with VECO was really good; VECO got whatever test team needed.
- Interface with DISC team in Madison
    - Interface with ICDS team in Madison seemed to work.
    - Some in Madison felt they didn't know what was going on.
    - List server, FTP server for updates, and telephone communication (maybe Skype) would help.
- Drilling data
    - When computer with data gets back, data needs to be analyzed to understand what was happening.
    - Data should be targeted to get information that we want, otherwise too much data to process.
    - In future run data could be downloaded weekly.
    - Need to plan how we will use data.
- Meetings
    - No regular meetings when drilling; generally talked at dinner, etc.
    - Jay met as needed with VECO; Kristina Dahnert part of weekly VECO safety meeting.
    - May need more formal meetings for WAIS Divide – more players, more complex relationships.
    - Need periodic meeting – teleconference – between field crew and Madison support to make sure everyone is in synch. A teleconference prior to the start of drilling to ensure everyone was aware of the drill status was suggested, but could not be timely arranged.
    - Should get feedback from NICL and VECO on their perceptions of how test went.

Safety

Kristina Dahnert went through safety aspects of the test season with comments from others.

- Six safety related incidents:
    - Cut hand while grinding.
    - Slip and fall on ice
    - Centrifuge malfunction due to wiring problem – corrected and manufacturer notified of need to show proper wiring.

    - Pinched finger.
    - Head hit while core barrel was being rotated.
    - Knot in cable because cable payout exceeded speed of sonde's descent.
- "Unreported" incidents
    - "Overran" tower limit switch while adjusting switch. Hardware replaced.
    - Yellow gantry crane bumped into vertical tower; alarm for movement will be installed, also program deceleration of crane to make operation smoother.
- Safety equipment at test site
    - Chemical – sorbent pads, oily rag can, etc.
    - Air monitors
        - Stationary – was hard to calibrate
        - Portable – battery life a concern
    - First Aid
    - Personal protective equipment – need additional sizes of gloves; drillers would like "corded" earplugs
    - Fall protection – exercise was completed on site using equipment.
    - Fire protection – fire extinguishers are adequate; only one fire alarm station installed at Summit because of configuration of building.
    - Miscellaneous safety equipment – foot guards didn't seem useful at Summit; 2-tier push cart would be useful
    - Signs – numerous warning signs
    - Requested items
        - Mechanics gloves
        - Spotlight for slot
        - Non-skid treads on bottom of drip pans
        - Centrifuge hoist replacement parts; spare centrifuge hoist
        - Audible alarms for gantry cranes
- Training – training provided before test season
    - DISC Drill overview
    - Lifting
    - CPR/AED
    - Fall protection
    - Fire extinguishing
    - Confined space – future classes should more specifically address what needs to be done for slot entry rather than regulations
    - First aid
- Medical staff at Summit – provided by Remote Medical International; knowledge and skills were good
- Communications
    - Safety meeting – one at beginning of season seemed to be adequate
    - Visitor safety – safety sheet (Visitor Safety Analysis) was not used in Greenland; it, or something similar, probably will need to be used at WAIS Divide

Project Management

Alex Shturmakov and Tom Demke went through project management activities that should take place prior to the start of drilling at WAIS Divide. Some of these were identified as the result of the test in Greenland.

- Procedures and drawings
    - Finish procedures for drill by December 1, 2006
    - Drawings (including software documentation)
        - Mechanical – approximately 640 reviewed and approved; perhaps 11 or 12 remaining
        - Electrical – total number of drawings will be between 40 and 70 depending on how they are done; a few have been completed

        - Software – harder to get handle on; software documenting procedures have been developed by SSEC and are being applied to microprocessor software; software developed in LabView may be more difficult. Will probably have to archive versions of programming software that control software is written in since those versions will become obsolete and will probably not be supported for long.
    - Systems documentation – needs to be completed
    - Trouble shooting guide – a guide is suggested as a good way to make sure that knowledge gained through experience is retained and made available to those working on the drill in the future.
    - Change control procedures will be followed as the drill system is modified.
    - Configurations of sonde sections need to be documented and kept current. Document listing the latest revisions of hardware available should also be maintained.
- Design reviews
    - Internal (SSEC) meetings including independent engineers to check design before modifications are completed
    - Review of status during spring of 2007 to ensure that all modifications have been completed and drill will be ready for use at WAIS Divide during 2007-2008 Antarctic field season.
- Test season report – results of test season should be documented and provided to NSF by September 30, 2006.

Future Activities

Alex Shturmakov presented a DISC Drill/WAIS Divide plan for 2006-2013.

- 2006-2007 (FY 2007)
    - Modification and enhancement to DISC Drill
    - Identify and purchase of necessary spare parts
    - Completion of documentation
    - Drill and case pilot hole and install A-Frame at WAIS Divide
    - Develop options for drilling warm ice
    - Begin development of "bedrock" drilling concept
- 2007-2008 (FY 2008)
    - Complete set-up of DISC Drill at WAIS Divide
    - Core to depth of 800 meters at WAIS Divide
    - Complete design and manufacture of equipment for warm ice coring
    - Complete design and manufacture of "bedrock" drilling system
    - Begin development of replicate coring system
- 2008-2009 (FY 2009)
    - Core from depth of 800 meters to 2400 meters at WAIS Divide
    - Complete design and begin manufacture of replicate coring system
- 2009-2010 (FY 2010)
    - Core from depth of 2400 meters to 3400 meters at WAIS Divide
    - Complete manufacture replicate coring system
- 2010-2011 (FY 2011)
    - Complete coring from depth of 3400 meters to 3555 meters at WAIS Divide
    - Complete "bedrock" coring at WAIS Divide
- 2011-2012 (FY 2012)
    - Begin replicate coring at WAIS Divide
- 2012-2013 (FY 2013)
    - Complete replicate coring at WAIS Divide
    - Disassemble drill system and remove from WAIS Divide

General Impressions of Test Crew

- Excellent crew.
- Long season for some crewmembers.
- A lot of work for one season.
- Drill performed better than expected; impressive performance for first use of drill.
- Would have been good if more “experimentation” with the drill could have been done.
- Maintaining communications with everyone is and will be important.
- A lot of work on the “floor” during drill operations and can be tiring, but better than standing around doing nothing.
- Medical staff at Summit was great.
- VECO did a great job.
- Worried that there may be repetitive stress injuries with some of the tasks.
- Might be good to consider letting some of drillers at WAIS Divide take a week off in New Zealand and relieving some of the crew part way through season.