Meeting Notes
Ice Drilling Design and Operations – Technical Advisory Board
September 9, 2013
Pyle Center
University of Wisconsin - Madison
Madison, WI 53706

Meeting Attendees

Name	Affiliation	
Jeff Cherwinka	University of Wisconsin - Madison	Member
George Cooper	University of California - Berkley	Member
Peter Doran	University of Illinois at Chicago	Member
Bill Eustes	Colorado School of Mines	Member
Steffen Bo Hansen	University of Copenhagen	Member
Keith Makinson	British Antarctic Service	Member
Hideaki Motoyama	National Institute of Polar Research Japan	Member
Marshall Pardey	QD Tech, Inc.	Member
Dale Pomraning	University of Alaska - Fairbanks	Member
Alex Pyne	Victoria University of Wellington	Member
Pavel Talalay	Polar Research Center, Jilin University	Member
Frank Wilhelms	Alfred Wegener Institute	Member
Pinlu Cao	Polar Research Center, Jilin University	Guest
Xiaopeng Fan	Polar Research Center, Jilin University	Guest
Jilin Hong	Polar Research Center, Jilin University	Guest
Alexey Markov	Polar Research Center, Jilin University	Guest
Youhong Sun	Polar Research Center, Jilin University	Guest
Gangcheng Wang	Polar Research Center, Jilin University	Guest
Lihua Wang	Polar Research Center, Jilin University	Guest
Rusheng Wang	Polar Research Center, Jilin University	Guest
Huiwen Xu	Polar Research Center, Jilin University	Guest
Chen Yang	Polar Research Center, Jilin University	Guest
Dahui Yu	Polar Research Center, Jilin University	Guest
Nan Zhang	Polar Research Center, Jilin University	Guest
Zhichuan Zheng	Polar Research Center, Jilin University	Guest
Mary Albert	Dartmouth College	IDPO
Joe Souney	University of New Hampshire	IDPO
Mark Twickler	University of New Hampshire	IDPO
Charles Bentley	University of Wisconsin - Madison	IDDO
Chris Gibson	University of Wisconsin - Madison	IDDO
Josh Goetz	University of Wisconsin - Madison	IDDO
Tanner Kuhl	University of Wisconsin - Madison	IDDO
Don Lebar	University of Wisconsin - Madison	IDDO
Kristina Slawny	University of Wisconsin - Madison	IDDO
Alex Shturmakov	University of Wisconsin - Madison	IDDO

Tony Wendricks	University of Wisconsin - Madison	IDDO

Chairperson: Peter Doran

- Welcome and Introductions – Bentley and Doran

- Possibilities for Next IDPO-IDDO – Albert
  - Description of NSF Solicitation for Proposals and the Dartmouth-UNH-UW Proposal
  - NSF has unofficially announced that Dartmouth (Albert – PI) would be awarded a cooperative agreement (CA) for IDPO with University of New Hampshire (Twickler – PI) and the University of Wisconsin (Lebar – PI) as subawardees
  - IDPO-IDDO Mission
  - IDPO-IDDO Goals
  - IDPO-IDDO Organization

- Science Advisory Board (SAB) Updates – Albert
  - SAB consists of experts in various areas of ice science
  - Science driving SAB
    - Climate
    - Ice dynamics
    - Subglacial geology
    - Ice as an observatory
  - SAB recommends technology investments
  - In response to question about change in strategy, Albert answered that the move would be to smaller drill systems until the "oldest ice" was drilled and that would probably require the DISC Drill for the US effort

- Overview of IDDO Equipment – Lebar
  Brief review of the equipment currently in the IDDO inventory

- Update on WAIS Divide – Slawny
  - Five replicate cores at four depth intervals successfully completed
  - To question about reason for retrieving the replicate cores, Mark Twickler responded that the science made more ice from those intervals very desirable

- Update on Replicate Coring System – Gibson
  - Review of presentation to TAB in 2012
    - Main borehole had been completed to 3405 meters depth
    - The 2011-12 test of replicate coring yielded no core
    - Issues to be resolved
      - Stick-slip
      - Sonde deflection
      - Cutter geometry
    - Planned tests
      - Tower test
      - Cutter test
  - Drill plan for 2012-13 was the starting point, i.e., had to decide how the deviations were going to be made
  - Development of equipment in the field during 2012-13
    - Drop ring to replace "bumper"
    - Tools for recovering "debris"

        - Modifications to pump check valve and milling cutters to improve chip recovery
    - All science goals achieved

- Future of the DISC Drill – Shturmakov
    - Develop "Cold DISC" – modification of DISC for very cold temperatures – for coring of "oldest ice" in East Antarctica
        - Altitudes to 3000 meters
        - Temperatures down to -60°C
    - Plan analysis of existing system
        - Cryogenic properties of materials used/needed
        - Logistical – can system be reduced economically in size and weight to reduce necessary logistical support
    - Repairs as well as necessary upgrades to system
    - In response to a question as to whether the cable can be reduced in size with the use of optical fiber, Shturmakov replied that IDDO would look at not using fibers in the cable to make the control system less complex; IDDO does not plan to use a different, smaller diameter cable, because of the cost of procurement of two new 4000m cables – one main cable and one spare, and the fact that this would also necessitate a major redesign of the winch system.

- Review of Projects Using Agile Drills – Slawny
    - Arctic 2013
        - Hand Augers for project in Greenland (David Noone, PI) and McCall Glacier in Alaska (Matt Nolan, PI); PIs provided with equipment but not drillers – work with them to get equipment best suited for their needs
        - 4-Inch for PI Joe McConnell's project in Greenland – two holes cored, one to 213.4 m and the other to 142.5 m
        - Eclipse Drill
            - 120 m and 90 m cores for PI Vas Petrenko in Greenland; also tested components for Blue Ice Drill (BID) – Deep
            - Two 208 m cores for Erich Osterberg in Denali National Park (Alaska) using only wind and solar power
        - Thermal Drill for installation of thermistors in 60 m and 25 m holes for PI Rick Forster in Greenland
    - Antarctic 2012-13
        - Hand augers – a number of PIs supported with equipment
        - Logging tower provided for use by PI Bob Hawley in logging borehole on Roosevelt Island. Weather prevented getting to Roosevelt Island and the logging of the hole.
        - Small Hot Water Drill, without operators, provided to Howard Conway and Paul Winberry for seismic work on the Whillans Ice Stream
    - Planned Projects
        - Seismic work using Small Hot Water Drill on Beardmore Glacier in Antarctica
        - Recovery of large diameter blue ice cores on Taylor Glacier in Antarctica using Blue Ice Drill. Two projects for two PIs.
        - Continuation of Petrenko's project in Greenland using Blue Ice Drill
        - Support of WAIS Divide borehole logging (this was subsequently postponed because of government shut down. IDDO operators instead used Intermediate Depth Logging Winch in support of PI Ryan Bay at Siple Dome in Antarctica.)
        - Test of Intermediate Depth Drill in Greenland during spring of 2013.

        - Continue providing hand augers to PI David Noone for his work in Greenland
        - Provide hand augers to PI Sarah Das for her Disko Bay project in Greenland. Project will continue in 2015 with IDDO providing Badger-Eclipse Drill and operator.
    - Non-NSF Projects
        - Provided hand augers to PI Hinrich Schaefer of Antarctica New Zealand for coring on Taylor Glacier
        - Provided Prairie Dog Drill and driller Jay Kyne for project in Glacier National Park for PIs Robert Kelley of the University of Wyoming and Craig Lee of INSTAAR.
        - Provided Prairie Dog Drill to PI Craig Lee for cores in the Twin Lakes region of Wyoming.

- Blue Ice Drill - Tanner Kuhl
    - Description of the large-diameter drill including performance characteristics.
    - Description of modifications being made to BID
        - Depths to ~200 meters (original BID cores to ~25 meters)
        - Capable of coring in firn - collet
        - Improved slide hammer
        - Crown sheave
        - Captive-spool winch
        - Anti-torque skates on motor section
        - New core dogs (6)
    - Test in Greenland
        - Test of anti-torque skates, collet, core dogs, slide hammer
        - Efficient coring in firn but collet needs some re-design to allow better shallow firn core recovery
        - Core dogs successful in core recovery below about 3 meters
        - Anti-torque performed well
        - Impact strengthened slide hammer successful
        - In response to suggestion that removing some of the six core dogs might yield better core recovery results, Kuhl said six core dogs are needed to support the weight of the large diameter core.
        - In response to question regarding instrumentation to measure force for core breaks, etc., Kuhl responded that the drill will be essentially dumb with drill motor parameters known from read-out on controls
    - Status of Blue Ice Drill - Deep
        - Anti-torque and slide-hammer assemblies complete
        - Cable, winch Lebus shell, and winch gear motor procured
        - Final winch drum and base, crown-sheave, tripod, and collet designs underway
        - System design complete by end of September 2013
        - Full system operational for 2014 Summit, Greenland season
        - Modifications and spares acquisition following 2014 Summit testing

- Hand Augers – Josh Goetz
    - Four varieties – IDDO (new 3-inch), PICO (3 and 4-inch), Sipre (3-inch)and Kovacs (5.5-inch)
        - No Kovacs drills currently in IDDO inventory
    - 20 meter depths normal with up to 40 meters with power accessories
    - New IDDO hand auger

        - 3-inch cores
        - 98 pounds for 20-meter depth kit
        - 8 in inventory
    - Accessories
        - Sidewinder – powered by Milwaukee drill (use 2kW generator) allows powered operation in both drilling and winching; 4 in inventory
        - Prairie Dog – double barrel accessory for PICO 4-inch hand auger used with Sidewinder; 1 in inventory

- 4-Inch Drill and Eclipse Drill – Josh Goetz
    - Specifications for 4-Inch, Eclipse, Thermal, and Reamer systems
        - All wireline deployed
        - Thermal drill and reamer system used with 4-Inch drill system
        - 4-Inch and Eclipse (~3-inch core) are double-barreled, electromechanical coring drills
        - Thermal drill is electrothermal designed to retrieve a 86 mm core from temperate ice and firn
        - Reamer system can ream holes 8-, 10-, or 12-inches in diameter
    - Green Energy System
        - Wind and solar
        - Developed for Eclipse Drill and used on Mount Hunter in Denali National Park – provided 100% of drill and camp power (much better than anticipated)
    - Future Development
        - 4-Inch – make sonde "common" with new IDD; replace Kevlar with steel cable; modify winches
        - Eclipse – make versions' components interchangeable; refurbish/modify drill from UNH
        - Thermal Drill – increase size to 4-inch core, use coaxial cable, provide for ethanol injection
        - New control boxes for agile drills
    - Comment regarding batteries for Green Energy System – NiCad lighter for power output but more expensive; might consider
    - Comments on Sidewinder – not intuitive to use, lack of control on Milwaukee drill somewhat of a problem

- Intermediate Depth Drill – Jay Johnson
    - Project timeline – began detailed design October 2011, test in Greenland spring 2014; ready to ship to South Pole August 2014
    - Drill site layout – manufacture of tent by WeatherPort complete, working on cold temperature electrical system
    - Drill system design
        - Sonde design based on Danish Hans Tausen and deep drills
        - Sonde components designed for -55°C downhole operation; surface for -40°C
        - Peak breaking force of 10kN
    - Description/status of sonde
    - Description/status of tilting tower and winch
    - Description/status of control system and drill motor power supply
    - Description/status of support systems – core barrel pull-out table, core processing, cable vacuum, centrifuge, chip baler, pilot hole system, power distribution
    - Comments and Questions

        - Weight of tower/winch – about 1,500 pounds (Chris Gibson response)
        - What downhole sensors – none currently except weight on bit and "chip chamber full" indicator (Johnson)

- SPICE Core Project – Mark Twickler
    - Collaborative Proposal – UC-Irvine (Saltzman), U of Washington (Steig), U of New Hampshire (Twickler and Souney), NASA Goddard (Neumann)
    - Three field seasons planned (expect drilling to take 2 seasons)
    - Have depth-age scale developed
    - Have location picked
    - Ground penetrating radar survey of site scheduled for December 2013
    - Intermediate Depth Drill being tested in Greenland in 2014
    - 10-person operation, housed at South Pole Station

- Lake Vostok Update – Pavel Talalay
    - An outside point of view
    - 3769 m deep – drill covered with ice
    - Microbiological sampling – from refrozen water
        - No new microbes in upper part of lake reported
        - Contradicted 4 months later – unidentified, unclassified life (DNA)
    - Fifty-eight days of work with January 16-28 replacement of cable
    - Frozen lake ice at 3194 meters, 575 meters from bottom of ice sheet
    - Cored hydrated material from 3415 – 3424 meters depth recovering 2.6 meters
    - Full cores of refrozen subglacial water after 3424meters
    - New borehole to 3543 meters, 226 meters from bottom of ice sheet – no results yet from core of re-frozen water

- Chinese Drilling in Antarctica – Pavel Talalay
    - Dome A
        - Highest point in Antarctica (4053 m), expected oldest ice
        - Hope to retrieve 1 million year old ice
        - In 2011-12 shallow drilling and reaming
        - In 2012-13, construction and installation of deep drill
        - In 2012-13, started deep drilling – three runs to depth of 122.75 m
    - Amery Ice Shelf
        - Objectives
            - Explore freezing and melting process, mass balance, and sediments; make oceanographic observations
            - Boreholes to stay open 3-4 days
            - Drill 5-6 holes per season
        - Hot water drilling
        - BAS – conceptual design of drill
        - Schedule
            - 2012-13 design
            - 2014 manufacture drill
            - 2014-15 test drill
    - Subglacial Gamburtsev Mountains
        - Minimum thickness of ice – 1000 m
        - Mobile drill structure
        - Electromechanical tethered drill

        - Hope to get 2-3 m core of bedrock
        - Schedule
            - 2012-13 – design, manufacture and testing of equipment for Antarctic field test
            - 2015-16 – field test in Antarctica
            - 2016 – improvements to equipment
            - 2016-17 and 2016-17– core drilling, less than 1 month drilling per season

- Japanese Drilling – Hideaki Motoyama
    - Recent drilling activities
        - 2010 – JARE 51, shallow core and firn air sampling (122 m)
        - 2011 – JARE 52, shallow core and firn air sampling (113 m)
        - 2012-13 – JARE 54, shallow core (30 m)
    - Future plans - Antarctic
        - 2015-15 – JARE 57, 500 meter core (drilling wet or dry) near coast; 2 k years BP ice
        - Within next 10 – 15 years – deep ice core near Dome Fuji
    - Future plans – Arctic
        - 2014 – shallow ice core (200-250 m) in Greenland
    - International collaboration
        - 500-700 m core in Dronning Maud Land, Antarctica with Belgium and Norway
        - Austfonna Ice Cap in Svalbard Norway with Norwegian Polar Institute
        - Fedchenko Glacier in Pamir Mountains of Central Asia with US, Germany, and China
    - Hot water drilling on Langhovde Glacier in Antarctica in 2012
    - Various drill testing

- Roosevelt Island – Alex Pyne
    - Drilled to 764 meters in 2012-13
    - Ice processing being done
    - Diatoms on bedrock
    - Model predicts age of ice at bed to be greater than 60 k years
    - Will remove equipment and do borehole science in 2013-14
    - 500 meter elevation at Roosevelt Island

- Andrill – Alex Pyne
    - Most equipment at Willy Field
    - Will sell off equipment if new project is not funded within five years
    - Last proposal had US paying 50% which is probably too high

- Lake Ellsworth – Keith Makinson
    - 12 people on site
    - Winch, cable sterilized in UK and boxed
    - Drilling problems
        - Boiler
            - Burner control faulty – 10 days to get replacement
            - Would not get up to temperature initially
            - Finally got to work fairly well
        - Lack of good winch speed control
        - Severe electrical noise from downhole water pump

        - Damaged winch load cells
        - Bent drill nozzle as a result of the speed control, noise, and load cell problems
        - Could not link the recovery hole with the main borehole at 300 m because of winch and control problems; may have been the result of the bent nozzle preventing a vertical hole from being drilled
        - Not enough time to train crew at Ellsworth properly
        - Comment – IceCube holes essentially straight; drilling too fast can cause hole to curve
    - Did not have enough fuel to complete hole because of problems
    - Future Projects
        - 700-900 m hole at Filchner Ronne Ice Shelf
        - 2200 m hole at Rutford Ice Stream
        - Increase drill capability from 500 m to 1000 m; requires about 50% more power
        - New 2000 m winch being built
        - New hose with no electrical
        - Going through normal funding process – maybe take five years to get to field

- ARA (Askaryan Radio Array) Hot Water Drilling – Jeff Cherwinka
    - ARA is a radio array to detect the radio signature from neutrino interaction with the ice using two pairs of antennas per hole; being built at South Pole and will cover 1000km^2; 37 stations of 6 holes per station planned with 3 stations completed
    - Requirements for ARA drill
        - Dry holes
        - 6-inch diameter
        - 200 m deep
        - Straight holes
        - 2 holes/day
    - Drill is on three sleds and weighs about 15 tons
    - Power of drill is 300 kW with water being pumped at 12 gpm; final pressure is 1000 psi and temperature of 85°C; 6 "Stinger" heaters used
    - Hole is pumped dry through return hose with pump 10 m above nozzle in combined drillhead/pump
    - About 7 hours of drilling (6 hours down and 1 hour up) time to produce 200 meter deep, ~7-inch hole
    - Crew of 5 per shift with 2 10-12 hour shifts
    - Quality of hole varies from firn (0-40 m), transition zone (40-120 m) and deep (120-200); holes were very straight
    - Had problem with hose being crushed on reel when pressurizing valves did not work
    - The 2 hoses are taped together
    - Two hoses and cable on winch
    - Winch and motorized sheave share load
    - Important "take-aways"
        - New drilling concept
        - Performance model worked well
        - Load splitting between hose reel and sheave with no level wind
        - Instrumentation
        - Retain experienced crew members
        - Video logging of hole
    - Response to question as to whether the drill nozzles were changed during drilling – provisions for not changing, but takes about ½ hour so it's not bad

- RAID (Rapid Access Ice Drill) – John Goodge by phone
  - Going ahead with design with changes to Gerasimoff's concept
  - Proposal made March 2012; funded August 2012
  - DOSECC spin-off company working on design since March 2013 and expected to deliver final design report in December
  - Features
    - Diamond rotary rig – modified Boart-Longyear
    - Changed depth requirement to 2500 meters to avoid any water; depths of 3300-4000 capability
    - Reverse circulation (down annulus and up inside drill pipe) with Estasol drilling fluid
    - Maximum borehole diameter of 3.5 inches; core diameter of 1.5 inches
    - Fluid circulation most critical and complicated feature – will use combination of mechanical sieve, ice melting and coalescing fluid; recovery rate of 90%
    - Diesel powered generators – prime mover on rig is electrical
    - Active fire suppression system
    - Auger through firn, case using inflatable rubber packer
    - Bottom hole assembly wireline to recover ice or rock core
    - Drilling cycle of about 250 hours; 5-6 holes possible in one season
    - Equipment "containerized"
    - 5 40-foot ISO containers/flat racks
    - Air down hole to change density and regulate flow
  - Timeline
    - Phase 1 – Design
    - Proposal to continue with Phase 2 submitted in early 2014
    - Phase 2 – Construction and testing in North America in 2015
  - Response to question regarding steps to keep ice from fracturing – keep pressure right; air through flex hose a few hundred meters – air helps buoyancy in return of fluid

- Danish Drilling Activities – Steffen Bo Hansen
  - NEEM
    - Recovered replicate core at bottom
    - Recovered some basal material
  - Proposed new site in NE Greenland – EGRIP
    - 2560 m of ice to bedrock
    - Objectives of studying ice dynamics as well as climate record
    - Surface velocity of ice sheet is 55 m/year toward NE
    - In 2012, drilled 67 m pilot hole – 12 cm annual layer thickness; found annual cycles in dust, water isotopes, and chemical impurities
    - Penn State has done seismic work to ensure safe from crevasses at site
  - Aurora Basin – Antarctica
    - Plan to drill in December
    - Use 4-Inch Hans Tausen and 3-inch Danish Shallow Drill
    - Main hole 4-inch core to 400 meters (to ~4000 ybp)
    - Second hole – 3-inch core to 120 m (~1000 ybp)
    - Reconnaissance for million year old ice
  - Renland
    - Site near coast in east-central Greenland
    - Drill in 2015

        - 400-500 m using Hans Tausen Drill
    - Shallow drilling in Greenland – 21sites in past few years

- Other European Drilling Activity - Frank Wilhelms
    - Various Swiss 3 and 4-inch drilling activities
    - Development of RADIX rapid access drill by Jakob Schwander of University of Bern – aim of making rapid access drill that requires minimal resources and logistics
    - Drill 600-700 m core at DML in 2014

- Discussion of Borehole Logging – Alex Shturmakov
    - IDDO
        - Completed 1500 m Intermediate Depth Logging Winch
        - Finishing 4000 m Deep Logging Winch
        - Downhole camera used with DISC Drill to look at casing and borehole condition at WAIS Divide
        - A vessel for testing drills and logging instruments at pressures to 5000 psi and temperatures down to -60°C available; 10-inch ID x 10 ft. long
        - Ready to build new tools
    - Steffen Bo Hansen comment – important to have logging tools as accessories to drilling system; should be able to be attached to drill cable

- Drilling Fluids for the Future – Pavel Talalay
    - Summary of results of Talalay's investigation of ice drilling fluids
    - Estisol
        - Density vs. temperature – Estisol 140 almost sufficient by itself; add Estisol 165 or Estisol T2887 in small quantities as densifier
        - Simon Sheldon's results for viscosity different than Pavel's
        - Density has almost no effect on viscosity
        - Estisol 140 about 2.3 EUR/kg
    - Looking at low molecular weight fatty acid esters
        - Density and viscosity look pretty good for Ethyl butyrate, n-polypropionate, n-butyl butyrate, n-amyl butyrate, and hexyl acetate
        - Miscible with one another

- Discussion of Hot Water Drills
    - Keith Makinson
        - Trade-offs between multiple lengths of hose and single hose should be considered.
        - Drill with 300-2000 m capability possible with modular design; 60kW modules
    - Dale Pomraning – contamination is of concern
    - Jeff Cherwinka – perhaps 300 m limit for water recovery such as with ARA drill
    - Peter Doran – Need for drill to access lake and sea ice
        - Jiffy Drills not designed for more than a couple of meters
        - Glacial tills on top of lake ice a problem with large on top and smaller as depth increases, also lens of till
        - Need to install sensors and recover samples from location every year
        - Small hot water drill probably best solution for access – pull with ATV
        - Steam drills good to only 2-3 meters

- Long-Range Drilling Technology Plan – Charlie

  - No comments
  - Doran suggested board members look at and email comments

- Peter Doran agreed to serve as chairperson again next year

- Action Items/Recommendations
  - Borehole logging
    - Build logging tools for drilling operations – caliper, hole inclination and, perhaps, azimuth and pressure
    - Cameras – ARA and IceCube cameras were useful for water-filled holes
    - Testing of logging instruments important
  - Drilling fluids – need to resolve differences in Pavel's and Simon's viscosity measurements

- Meeting adjourned – Board members will attend the 7th International Workshop on Ice Drilling Technology in conjunction with the TAB meeting