Ice Drilling Design and Operations – Technical Advisory Board
Tuesday, September 9-10, 2014
Union South – Industry Room, 3rd Floor
University of Wisconsin - Madison
Madison, WI 53706

Name	Affiliation	
Peter Doran	University of Illinois at Chicago	Member, Chair
Steffen Bo Hansen	University of Copenhagen	Member
Jeff Cherwinka	University of Wisconsin - Madison	Member
Bill Eustes	Colorado School of Mines	Member/IDPO
Keith Makinson	British Antarctic Survey	Member
Marshall Pardey	QD Tech, Inc.	Member
Pavel Talalay	Polar Research Center, Jilin University	Member
Frank Wilhelms	Alfred Wegener Institute	Member
Terry Benson	University of Wisconsin - Madison	Guest
George Cooper	University of California - Berkley	Guest
Benton Ellis	Colorado School of Mines	Guest
Dale Pomraning	University of Alaska - Fairbanks	Guest
Mary Albert	Dartmouth College	IDPO
Blaise Stephanus	Dartmouth College	IDPO
Mark Twickler	University of New Hampshire	IDPO
Fred Best	University of Wisconsin – Madison	IDDO
Charles Bentley	University of Wisconsin - Madison	IDDO
Grant Boeckman	University of Wisconsin – Madison	IDDO
Chris Gibson	University of Wisconsin - Madison	IDDO
Josh Goetz	University of Wisconsin - Madison	IDDO
Rory Holland	University of Wisconsin - Madison	IDDO
Jay Johnson	University of Wisconsin - Madison	IDDO
Tanner Kuhl	University of Wisconsin - Madison	IDDO
Zachery Meulemans	University of Wisconsin - Madison	IDDO
Mark Mulligan	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

MEETING NOTES
Tuesday, September 9

Welcome & Introduction of Mark Mulligan (Slawny)

- Welcome by Slawny and introductions by all.

Logistic matters (Wendricks)

- Tony is available to help anyone with any logistics issues over the next couple of days.

Chairman's opening comments (Doran)

- Peter plans to step down as chair.
- Peter inquired about turnover on the panel, as it has been somewhat static. Slawny says that IDDO is open to suggestions for new panel members.

Summary of new IDPO/IDDO structure and purpose (Albert)

- The new structure provides the NSF with ability to look forward to future needs and to task for that. Seven years ago, an RFP went out and 3 CA awards were made to UW, Dartmouth, and UNH. Recently, they wanted to go to a single CA. Submitted by Dartmouth with subawards for UNH, CSM, and UW. Award through 2018.
- Presented vision and mission.
- New organization chart.
  - IDPO: Mary Albert, Blaise Stephanus, Linda Morris, Mark Twockler, Joe Souney, Bill Eustes
- Planning documents: Long Range Drilling Technology Plan
- IDPO responsible for communication, all kept on the website.
- Education and outreach in the US.

Update on the IDPO-Science Advisory Board (Albert)

- SAB Members: Howard Conway, Sridhar Anandakrishnan, Ryan Bay, Ed Brook, Dorthe Dahl-Jensen, Karl Kreutz, Jill Mikucki, Ross Powell, and Jim White.
- Workshop on Ice Coring in Feb 2014 (timed with SPICE Core meeting). Planning another workshop this fall/winter with subglacial group.
- SAB meetings are held in the spring. This year, for the first time, they did it virtually. They plan to have them in person every other year.
- Need to address Chair, membership, and terms of reference. May work on these issues in the fall during AGU.
- The SAB discusses the science goals of the community and then assigns a priority level to each: 1, 2 or 3.
- Currently, four priority 1 items are being worked on, three at IDDO and RAID.
- Hercules Dome selection.
- *Doran: Asks why the TAB was not invited to sit in on the virtual SAB*. Albert agrees that is a good idea and will invite the TAB to future virtual SAB meetings.
- *Albert: Reports that Scott Borg stated that the WISSARD drill was just too big to be sustainable. The US needs smaller, more agile systems. The NSF budget is not growing, which is forcing smaller systems to get the ice/rock for data.*
- *Albert added, that as a community, the ice science community puts out a very high*

number of Science or Nature articles per dollar spent on research.

Recent update of the Long Range Drilling Technology Plan (Slawny)

- Updated annually based on the Long Range Science Plan each June.
- Available on the icedrill.org website.
- Defines each drill system, current status, technical issues, and plans for the future.
- Includes a matrix of the drill systems, which presents their planned uses for the coming seasons.

DISCUSSION OF EXISTING SYSTEMS

Overview of IDDO Equipment Inventory (Slawny)

- *Hand augers*: includes designs from SIPRE, PICO, and IDDO. The PICO equipment is aging and is being retired and replaced. They are shipped out in small kits in padded yellow bags.
- *Shallow Depth Tethered Systems*: includes a 2-inch, Eclipse (successful solar/wind power upgrade), and 4-inch systems.
- *Deep Tethered Systems*: includes the DISC Drill and Replicate Coring Subsystem.
- *Specialty Drills:* These include the Prairie Dog, Koci Drill, Chipmunk, Blue Ice Drill, and Electrothermal Drill systems.
- *Non-coring Drills*: Includes the Rapid Air Movement (RAM) Drill for seismic work and the small hot water drills used primarily for shot holes.
- *Logging Winches*: There are three logging winches: IDDO Deep Logging Winch, IDDO Intermediate Depth Logging Winch, and USGS Deep Logging Winch.
- Development Systems: Include the Intermediate Depth Drill (IDD), Blue Ice Drill- Deep, Agile Sub-Ice Geological Drill (ASIG), 4-inch Drill, IDDO Hand Auger, Scalable Hot Water Drill (SchWD), and DISC Drill.
    - *Doran*: *Inquired about the 4-Inch Sonde, is it watertight?* It is design is to be submersible, it can get wet. The primary design goal is to punch through the ice into the brine or water below the ice.
    - *Cooper: Inquires about the size and scope of DISC Drill.* It was left down there last season due to the government shutdown. May or may not come home this season. We feel it is safely stored down there and is not deteriorating due to the environment.
- *Twickler: Ads that we also have a pressure vessel that will go up to 5000 psig. Three investigators have used it this season.*

Review of past field seasons and plans for next (Slawny)

Past Field Season

- Hand Augers - Antarctic
    - Handled through the SIPs. Less formal than other drill systems.
    - Sent out on an as needed basis. Used to send out all out and they were dispersed in McMurdo. Shipping on an as needed basis provides for better quality control
    - Provided to 6 PIs last season.
- Blue Ice Core

    - Used at Taylor Glacier to support Petrenko, Brook, and Severinghaus. Quite successful even with the government shutdown.
    - Final season is this year.
    - The system has shipped.
- Small Hot Water Drill
    - Used at Beardmore Glacier to support Conway and Winberry.
    - Was out the last two seasons, but has returned to inventory.
    - Science goals were achieved.
    - System is aging. User identified upgrades will be done in PY2015.
- WAIS Dive Borehole Logging
    - Pettit, Bay and Talghader will be using the USGS system to log the DISC Drill borehole.
    - Postponed one year due to government shutdown.
    - Plan to log the hole and disassemble the DISC Drill this season.
- Intermediate Depth Drill Test
    - Full-system test in Greenland this past May, ~3 miles from Summit Station.
    - Achieved most of our objectives. A bit of a late start due to issue with the C-130s. Did not reach brittle ice, unfortunately.
    - Issues have been addressed since return. Will be ready to ship later in September.
- Blue Ice Drill – Greenland
    - Greenland Cosmogenic C-14 Cores for Petrenko (PI), Brook and Severinghaus,
    - This was the second year of a three-season project.
    - Even with some issues to drillers and Scientists, they were able to obtain all of their samples and fully checkout the drill system.
- Hand Augers – Arctic
    - *Midwest US Ice Cores – PI McKay*. First of a 3-year project to collect shallow ice cores from ice-covered temperate lakes and rivers.
    - *Summit Shallow Core Array – PI Noone*. Final year of a 4-year project to collect firn core for isotopic analysis.
    - *Disko Bay Ice Core – PI Das, Co-Is Evans, Frey, & B Smith*. First of 2-year project to collect shallow ice core from Greenland ice sheet, Disko Island, and Nussuaq Peninsula.
    - *NW Greenland Holocene Climate Change – PI Osterberg*. Collected a 20 m core from the North Ice Cap. The goal was 30 m but the drill shorted out after 10 m and the next 10 m was collected manually.

Upcoming Field Seasons

- Intermediate Depth Drill - SPICE Core
    - PIs: Aydin, Neumann, Souney, Saltzman, Steig, and Twickler.
    - The system will be shipping out later in Sep.
    - The system will be deployed near the South Pole Station with a goal of drilling to 700 m.
    - Two-year project with an optional third year.

- Blue Ice Drill - Taylor Glacier
    - PIs: Petrenko, Brook, and Severinghaus
    - Final season for 3-year project
    - 50 holes of 10-100 m deep
- Borehole Logging - WAIS Divide
    - PIs: Bay, Clow, Peters, and Erin
    - Clow and IDDO person will use the USGS Deep Logging Winch
- Disc Drill Disassembly
    - IDDO is sending 3 people to the site to disassemble the system and auxiliary systems.
    - Requires 10-12 flights to get the DISC drill out. Originally planned to do a traverse, but that has likely been abandoned.
- Hand Augers
    - 13 kits have been shipped out to Berg Field Center
- Arctic 2015
    - Continue to support ongoing projects: Midwest US Ice Cores, Cosmogenic C-14 cores, and Disko Bay Ice Core.
    - Adding the Greenland Aquifer Investigation for PI Forster.
- *Talalay*: Jilin University has two deep logging winches. Hoping to test one in NEEM. May go out in two years.
- *Cooper*: The Hercules Dome drilling goal is ~2100m.
- *Twickler*: Should be able to get by at Herc Dome with a canvas tent due to much less snow accumulation, but the project will be over a couple of seasons so it must survive winter. Similar plan to Dome C where they used a plastic tent, but there was a problem deploying it as the plastic shrunk.

Hand Augers, Sidewinders and Prairie Dog (Goetz)

- Hand Augers
    - Three sources: IDDO, PICO, and SIPRE
    - Collect 3-4" diameter cores up to 1.0 m length per run.
    - Manual cores to 20 m and powered systems can reach 40 m.
    - Single operator systems.
    - IDDO: 20 m manual kit weighs 90 lbs. (7) kits available.
    - PICO: 20 m kit weighs 100 lbs. (7) 3" kits and (1) 4" kit
    - SIPRE: 6 m kit weighs 85 lbs. (5) wide kerf kits and (2) narrow kerf kits
- Sidewinders
    - Uses a ¾" drill powered by a 2 kW generator
    - Four in inventory that are all field ready
- Prairie Dog
    - Used with the sidewinder and PICO 4" hand auger
    - One in inventory, field ready
- Future
    - PICO hand augers are aging and we are slowly replacing them, as funding is available.

    - Planning to build a prototype IDDO 4” drill based on the IDDO 3” system. Design is partially complete, just need to move forward with the fab and test in the spring.
    - *Cooper: drill bit wear has been a bit of a problem due to grit in the ice.* Bits are field replaceable if necessary.

Koci Drill (Kuhl)

- System Specs
    - Shipping Wt. = 2040 lbs.
    - Deployed Wt. = 1780 lbs., deployable from a Bell 212
    - Cases each less than 200 lbs., man portable up to 0.5 km on rough terrain
    - Setup is ~3 hours and takedown is 2 hours
    - Minimum 3 operators, with 5-6 being optimum
- A hand auger that has been upgraded for dirty ice drilling. Has been deployed three times in the Dry Valleys, the last time in 2009. Each time it has been upgraded.
- Current Capability
    - Can consistently drill and recover good quality 45 cm long cores in clean ice, ice containing rocks <~160° of kerf, sand frozen in ice, or shallow consolidated sand deposits with trace ice.
    - Depth capacity is 50 m in clean or slight rocky ice, 35 m in moderately rocky ice, and < 10 m in ice containing substantial debris.
    - The depth in rockier areas is limited by heat generation.
- Issues: cutter breakage, core head damage, drill string torsional and flexural rigidity, heat generation from rock drilling, mobile rock, and collection of rock cutting and/or sludge.
    - Cannot use core dogs as the rock shatters the core dogs.
    - Did not flush the bit due to environmental issues and the logistics did not allow for compressed air.
    - Have had breaks due to hitting large rocks.
- Scheduled for use in the 2015-16 season
    - Ohio Range of Transantarctic Mountains
    - Plans some upgrades to get 6-8 holes, 5-30 meters deep
    - The ice is expected to have sand/silt, discrete rocks, boulders, and potentially till above the bedrock.
    - The goal is to recover a 1.4” dia, 20 cm rock. Plan to use Isopar K in the hole, non-circulating.
- Upgrades
    - Change core heads to 304 SS and add carbide ice cutters brazed to SS.
    - Non-hardened collets
    - Improved cutter geometry on rock auger and use a junk basket to clear debris from the hole bottom.
    - For rock coring: use diamond-impregnated bits, collet-type core lifter, potentially a load-triggered slide hammer for core breaking, and vanes for cuttings suspended in drill fluid

- *Eustes: Do you monitor the drill motor power?* There are no sensors; it's a dummy drill.
- C*ooper: Points out that one can only have ~0.5 m of sand before you can't transport debris out of the hole.*
- *Pomraning: Ask about carbide cutters.* Kuhl explains they are brazed on for fracture resistance.
- *Talalay: They have tested PDC cutters. They worked very will with dirty ice/rocks, but they found they needed a bit more load on bit.*
- *Cherwinka: Suggests adding a motor torque measurement / control and a weight on bit load sensor.*
- Kuhl:
  - Is not sure about rocks in Ohio Range. In the past, they have run into dolomite and sandstone.
  - A New Zealand group has successfully used an air compressor to remove chip debris. That would make it more useful for environmentally sensitive areas.

Logging Winches status and investigator testing (Shturmakov, Goetz)

- Intermediate Depth Logging Winch (1500m)
  - Shipping weight: 850 lbs. Winch w/ cable: 700 lbs.
- Deep Logging Winch (4000 m)
  - Shipping weight: 3500 lbs.
- USGS Logging Winch (4500 m)
  - From Gary Clow
  - Wt.: 4260 lbs.
  - Deployed next year to WAIS Divide
  - Funded by USGS
- Logging Tower
  - An accessory used for borehole logging operations
  - 180 lbs.
- Borehole Camera
  - Was not built for logging, but is being purposed for it. Was originally used with replicate coring.
- High Pressure Chamber
  - Rated to 5000 PSIG, but has been used to 6000 psig after a discussion with the vendor.
  - Can be placed in cold chamber at PSL, -60°C.
  - The vessel is from testing IceCube instrumentation during freeze back.
  - Ryan Bay, Erin Pettit, and Merlin Mah have been using it last summer (once) and four times this summer. Some successful tests, some failures.
  - Added a pneumatic pump system to reach their desired pressures.
  - Pressure is much higher than we can reach with a column of water.
  - The logging equipment have a common electrical connection, which is on the chamber.
- Two logging winches allow support in Greenland and Antarctica. Gary's was moving back and forth which is costly to air freight 5000 pounds.

- The federal government owns the equipment. It has federal inventory tags and UW-SSEC tags for tracking while it is here.

4-Inch Drills (Johnson)

- Current Status
  - Fabricating two sets of core barrels
  - Maintenance and inspection of control boxes, winch sled, and winch assemblies.
  - Inventory spares
  - Start design of an IDD style sonde.
- PY2015 Plans
  - Design new sonde
  - Conceptual design for a new winch and tower
  - Preliminary design of a control box for the new drill and winch
  - Build and test drill motor control system prototype
- Deployment is about 1500 lbs., fits in a Twin Otter
- Current Sonde does not have seals to make it fluid tight. Motor section could be modified to be sealed tight to shallow depths.
- The PICO drill mast is tall due to the sonde and the core barrels height. No level wind either so the height helps with winding the drill cable.

Eclipse Drills (Johnson)

- Wind screens available for use with the system.
- Current Status
  - Inventory spare parts
  - Maintenance and inspection of the drill system and control boxes
  - Improve interchangeability of cutter heads and core barrels. Right now, some head can only be used with certain barrels.
- PY2015 Plans
  - Design new control boxes to run the winch and drill simultaneously
  - Develop a readout system
  - Continued maintenance

Open discussion on any issues with existing systems

- Hot Point System in McMurdo Inventory, located at MSC
  - There is an inventory of ~10 hot point system that are "Hotsi-like"
  - The systems can be checked out for use, but do not include a generator.
  - System start up is a bit of challenge until the glycol warms up a bit to reduce viscosity.
  - Hotsy systems are not well maintained. Can we do something with them? Discuss with NSF about assuming responsibility for these systems. Potentially we could assume responsibility and still store and maintain them at McMurdo.
  - We should have an IDDO staff member take a look at the hot points and the Kovacs Enterprise HWD this year.
  - The possibility of IDDO staff supporting a Jiffy Drill Operation to learn more about them was discussed as well.
- Doran Small Hot Water Drill Discussion

- Doran inquired about a very small hot water drill system
- He tried to use the Kovacs system in McMurdo, but it broke the first time he took it out. He was told it was due to an undersized pump.
- He met offline with Jeff Cherwinka and the came up with the conceptual design below:

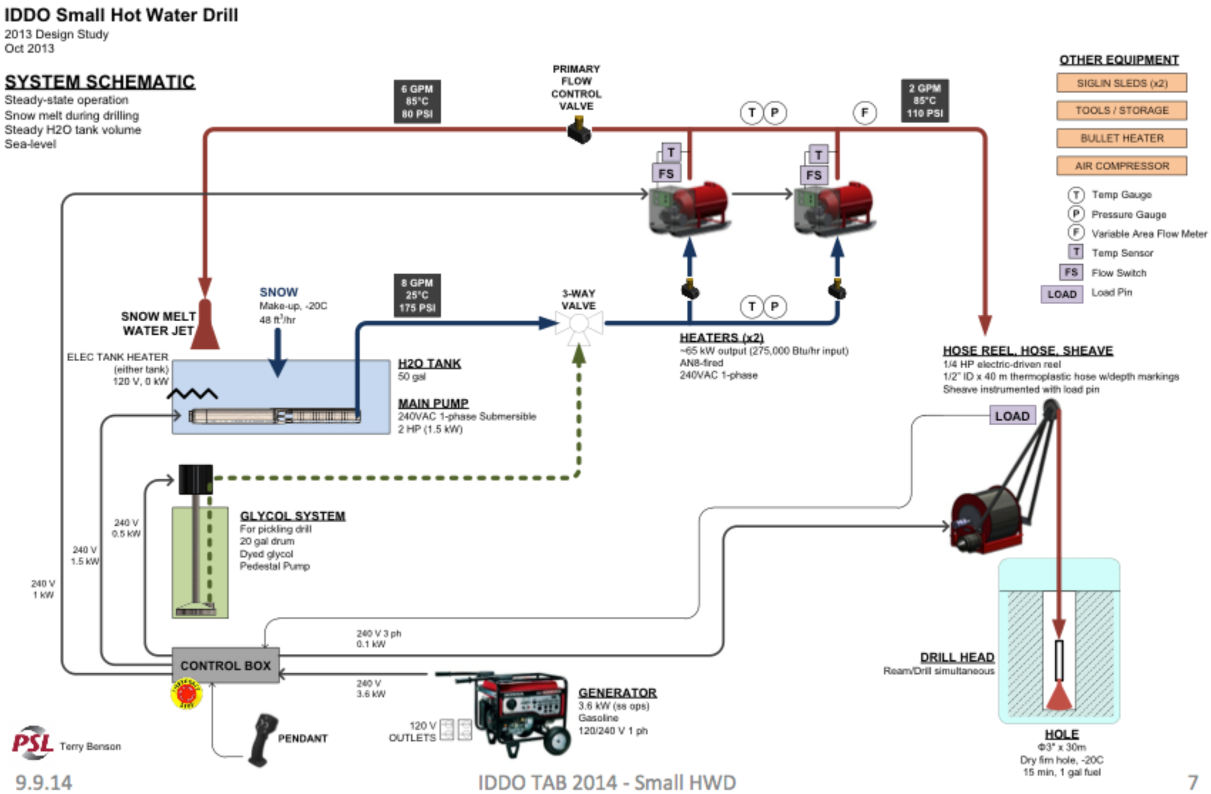
- Disposable System
  - *Cooper: Asks about the future of drilling, are disposable system that you just drill down and leave being considered.*
    - The Norwegians have a Badger System that drills down, compacts chips behind it, and keeps going down. Think is uses a fiber optic cable. It stops at the bottom and is left behind.
    - There is a IceMole system being used by the Germans. There is an article about it in the current Annals of Glaciology.

DISCUSSION OF SYSTEMS UNDER DEVELOPMENT

Small Hot Water Drills (Gibson / Benson):

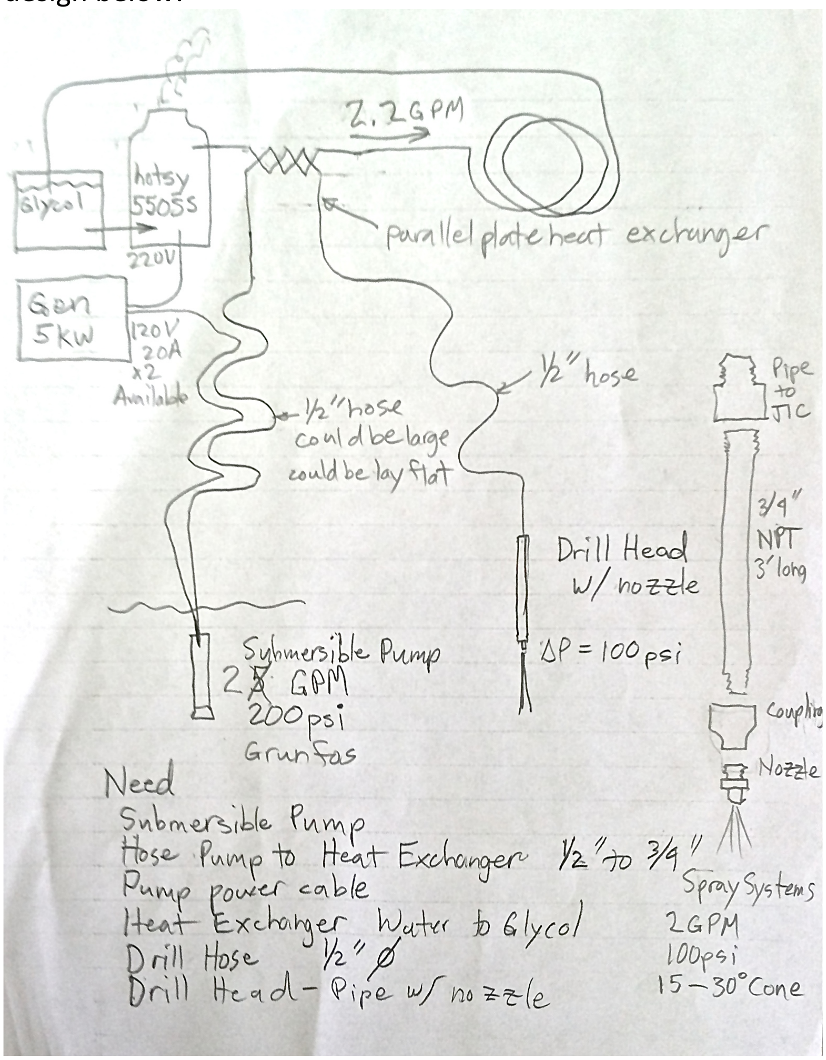
- *Summary of current status*
  - Have two systems that are in need of repair and improvements. They have created 2.5”dia holes to 25-30 m in ~12 min.
  - The plan is to get them to their original specs while increasing depth to 60 m.
  - Will field test in Alaska and McMurdo
  - Penn State has a system that was designed with a focus on low weight and cost. It is capable of a 2.5” dia holes to 15-25 m depth in 30-40 min.
- *Review of conceptual design and plans for upgrade (Gibson/Benson)*
  - The key requirement is the ability to transport the system. Everything must fit in Twin Otter and then be movable by a snowmobile.
  - Performance requirements are falling out of the logistics requirements. Users are very concerned about the logistics and assembly. Less concerned about the performance.
  - Heaters: switch from thick-walled pipe to thin-walled tubing. Improved controls on heaters.
  - Main pump is submersible as opposed to a piston-driven system. Used on Makinson system.
  - Loss water system – we do not recover the water from the hole, bleeds into the firn.
  - Wt.: 1500 lbs., down from 2200 lbs.
  - Max component wt.: 280 lbs. (heater)
  - Primarily off-the-shelf components with the exception of the hose reel and derrick.
  - Plan to start next May 1 to be ready for the 2016-17 season.
  - Future: pump out water, fully dry hole, equipment power density and efficiency improvements

- Shot Holes: if the explosives were frozen in, they would be more effective. Sridar wants a dry hole to 60 m. Unclear what effect the pressure would have on the explosive.
- Design Schematic:



- Doran Small Hot Water Drill Discussion for Lake Ice
  - Doran inquired about a very small hot water drill system
  - He tried to use the Kovacs system in McMurdo, but it broke the first time he took it out. He was told it was due to an undersized pump.
  - Doran is interested in a very small system with recirculation, 6-meter depth. Perhaps half the size of this system. This could replace using a jiffy mechanical drill. A hot point could be used to make it wider.
  - Used in Dry Valleys. Glycol pickling may be tricky. Compressed air blowout is challenging or ethanol could be used.
    - Can you separate a glycol or ethanol water mix?
  - Potentially, shrink this to one sled. Remove the hose reel and derrick and manually lower the hose.
  - The hot point uses a 5 kW generator and a hot water heater. A Hotsy system may make for an all in one system.
  - South Pole Traverse uses something like this.
  - Frost plugs as a safety in case someone does not safe the system.
  - A hand auger is a problem due to dirty ice.
  - Jiffy drill takes 1-2 hours to drill a hole.
  - Seed water needed to start and then the lake could be used.

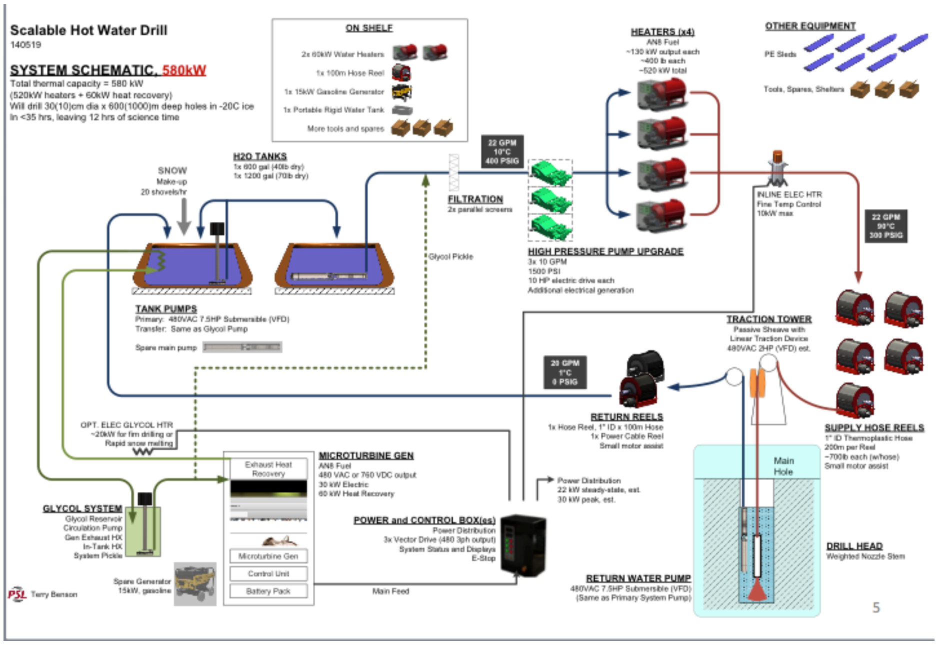
- 4-inch diameter ideal, 2.5-inch acceptable.
- If sea ice were drilled, there would be corrosive issues to deal with.
- *Mary suggests Terry, Chris, and Jeff work with Peter to create science requirements.*
- *Doran: The Kovacs HWD is just sitting at MEC. Perhaps ship back here and take a look at it?*
- Doran met offline with Jeff Cherwinka and the came up with the conceptual design below:



Scalable Hot Water Drill: Review of conceptual design and plans for building system (Gibson/Benson)

- Science Requirements:
  - Produce access holes through ice depths between approximately 50 – 1000 m.
  - The drill should be modular, with built-in redundancy, so that one of the modules is used for shallow depths and small diameter holes, and other modules are added for deeper access holes or for larger diameter holes.
  - Diameter of holes needed will vary, with most likely in the 10-30 cm diameter. Small diameter holes can be drilled deeper than large diameter holes

- Drill should be operable in -30°C environments.
  - The drill should be agile on site, in order to drill multiple holes within 500 m of emplacement, possibly moved around by skidoos.
  - Setup time for the drill on site should be within 48 hours.
  - The design should include the ability to maintain a 30 cm diameter, 600 m deep hole and keep it open for 8 hours after initial drilling.
  - The drill should be able to be transported by helicopter sling load, Twin Otter, Basler or light ground traverse.
  - The drill should have stand-alone capability for operation at small field camps at remote sites
  - Minimal staff (4 pax for setup, working 2 per shift for drilling and reaming) should be required for drilling operations in the field; other field camp staff in support of drilling operations to be provided separately
  - Drilling depth and rate of drilling progress should be recorded.
  - The design does not require "clean" access for most applications, but the drill should be designed and constructed with fittings and components that will facilitate adapting the system to "clean" drilling in the future.
  - The design does not require operation to depths beyond 1,000 m for a 10 cm diameter hole, but to allow for future expansion of the system, the hoses and fittings shall be suitable for the operating pressures required to achieve a 1,500 m, 10 cm diameter hole.
- Tried to stick to tried and true technologies, but the design uses some new technologies and new applications for proven technologies to best meet the science requirements.
- New Technology: microturbine generator. Has higher efficiency due to electricity and thermal heat recovery. Attractive as well because it has a high power density, low maintenance and low emissions, but they are expensive and unproven in polar environment.
- Using a submersible pump as main pump supply has been done by BAS. The system is pressure limited to ~400-500 psi, but otherwise a lot of upside: lighter, simple, reliable, safe, deadhead ok.
- Planning to use fuel-fired water heaters like other HWD systems, but utilize electric water heaters for finer temperature control.
- Using a linear traction drive for hose support and controlled payout. This avoids bending the hose while under axial load. Used by WISSARD. Evaluating integration issues and failure scenarios. *Pomraning likes this idea.*
- Use portable flubber tanks for water reservoirs (BAS). They need to level.
  - *Pomraning: has used a tank with a frame. Allows easier access to water.*
  - *Doran: Do they need insulation?* Just on the bottom so that they don't melt in.
- Digital controls instead of analog and visual information.
- Plumbing is all stainless steel to keep the water clean. It is more costly but well worth the investment.
- Schematic:



- Scalability Table:

DEPTH [m]		0-60	60-100	100-300	300-400	400-600	600-800	800-1000
System		SHWD-L	SHWD-L	SHWD-L	SHWD	SHWD	SHWD	SHWD
Thermal power required [kW]		120	120	190	260	330	455	580
Electrical power required* [kW]		10	10	15	18	20	25	30
Total drill time/hole [hr]		9	12	19	18	23	21	21
Total fuel/hole [gal]		64	82	180	180	280	350	430
Technique		lost-water	lost-water	water recovery	water recovery	water recovery	water recovery	water recovery
Item	Unit Weight, lb	Number of Units Deployed to Site						
GENERATOR								
Main Microturbine Generator	1600	0	0	0	1	1	1	1
Gasoline Generator, 15 kWe	450	1	1	2	1	1	1	1
PUMPS								
Main surface pump, submersible with shroud	120	1	1	2	2	2	2	2
Downhole pump, submersible	120			1	1	1	1	1
Water tank transfer pump	50					1	1	1
Glycol system circulation pump	50	2	2	2	2	1	1	1
HEATERS								
130 kW Water Heater	450			1	1	2	3	4
Electric Water Heater, ~10kW	50				1	1	1	1
60 kW Stinger Water Heater	300	2	3	1	1			
HOSE, REELS, AND HOLE OPERATIONS								
Main Hose Reels - 200m	650			1	2	3	4	5
Hose reels - 100m	300	1	1	2	1	1	1	1
Tower Equipment	640	0.5	0.5	0.9	0.9	0.9	0.9	0.9
Down-Hole Equipment	440	0.3	0.3	0.5	0.6	0.8	1	1
OTHER WATER SYSTEM COMPONENTS	1155							
OTHER ELECTRICAL SYSTEM COMPONENTS	935							
OTHER	1275							
TOOLS	809							
PACKAGING	616							
FUEL								
55 gal drum	400	3	3	7	7	11	13	16
Total Drill Weight (no Fuel) [lb]		4262	4712	7008	9335	10678	12199	13411
Total Weight w/ Fuel [lb]		5462	5912	9808	12135	15078	17399	19811
Approx Twin Otter Flights Drill Equip and Fuel (100km)		3	3	5	6	8	9	10
Assumptions: 10cm Dia, Science Time 8-12hrs, Sea Level, -20°C Ice. No spare pump or gen on-site systems < 100m.								

- Can the system be scaled down into a single twin otter or at that point should it be one of the smaller systems?
- Work is not scheduled to start until the Nov 2015 project year. Two-year development. Approx. cost is $1.5M
- *Talalay: Is a 10 cm dia. hole large enough for the supply and return line hoses?* The top of the hole would be larger to accommodate both hoses. Top of hole would be at least 20 cm.
- *Pomraning: What size hose?* 1-inch.

- *Cooper: Mentioned snubbing unit used in the oil industry for hose grabbing*. WISSARD has one that works well, but it is large.
- Hose Transfer between reels:
  - *Makinson: Points out that the traction drive's utility is limited when the hose is depressurized.*
  - Considering a single large reel.
  - *Wilhelms mentions an acoustic signaled valve to close to not lose the column of water in the hose.*
  - *Pardey: mentions a ball going down to seat against a seal that pops through when pressure is turned on.*
  - *Eustes: Suggests an "arrow" to seal off the hose.*
  - Any solution may not be worth the potential complication as the only water loss is down to where the water starts to pool, i.e. the height of the firn.
- Pomraning questions the trade between weight and what is gained with the filtration system.
- Microturbine Discussion:
  - Have been looking at Capstone. Seem to have a fair fraction of the market and have used their systems on the North Slope.
  - *Makinson: Battery is about a 1/3 of the weight.*
  - Turnkey system is about 1200 lbs. Have been talking to them about where we can save some weight. Batteries (lead acid), frame, split the system…. the system is down to (2) 400 lbs. components plus battery box. The batteries are used for backup and start up.
  - *Pomraning: Has seen mictroturbines at pipeline surplus auctions.* They appear to be in use in the oil industry.
  - *Cherwinka: Dick Armstrong is working with a company to put some systems in at McMurdo. Unsure what the plan is for these. Was presented at the Polar Technology Conference.*
  - Using one increases the need for a test season.
  - *Twickler: Robustness?* Unknown. Cherwinka added that they are used in buses. Rotor is on an air bearing.
  - *Cherwinka: Unlike a generator, they do not mind low load conditions.*
  - *Cherwinka: Payback on general maintenance alone is 5-years.*
  - Benson: Fuel savings is significant. May pay for itself in a couple of seasons.
  - *Mackinson: Sometimes the fuel savings get lost since it comes from a different bucket.*

Blue Ice Drill (BID) & BID-Deep: Summary of current status and results of 2014 Greenland test (Goetz)

- Goetz has assumed responsibility for the drill system from Kuhl.
- Did coring at Taylor Glacier during the 2013-14 season
- Upgrade takes it from 30 to 200-m.
  - Collet for shallow firn core recovery
  - Anti-torque blades on motor section

    - Improved slide-hammer
    - Steel electro-mechanical cable
    - Crown sheave assembly
    - Captive-spool winch
    - Winch motor control
- Test season for BID-Deep at Summit, Greenland in May 2014
    - Drilled down to 187 m. Somewhere around 135-140 m started getting poor core. ~10 fractures in a meter section. Was not an issue for this season, but could be in the future. After consulting with other drill engineers, it is suspected that it may have been that the cutters were too aggressive (60° vs. 45°)
- *Talalay: Asked about the number of core dogs?* Six.
- *Pomraning: Inquired about the cutter heard.* It is a 3 cutter head. The drill speed tended to drive the chips up well.
- *Twickler: Thinner vs. Wider Curf?* Thin works well with ice. Wider curfs work well in firn.
- *Talalay: Was the split ring used to break ice?* Did break one core in the ice, but that was deep in the hole in the highly fractured ice.
- *Pomraning: What was the motor power?* 2.5 HP. 60 RPM at the cutter head.
- *Talalay: What was the core length?* 1.5 m firn, 1.1 m in ice.

Intermediate Depth Drill

Summary of current status and results from the 2014 Greenland field test (Johnson)

- Overview
    - Six-person drill team deployed to Greenland (10,600 ft.). Experienced a 10-day delay at the start due to a C-130 issue. Resulted in not reaching brittle ice.
    - Stopped a few days early to make sure they could get everything out due to limited flights. If they had continued drilling, they still would not have reached the brittle ice.
    - Location was 3 miles north of Summit Station. Summit was full, but they also wanted to reduce pollution at Summit.
    - Cargo: 21,300 lbs. total. (1440 ft^3)
    - Dug a 5 foot trench and packed due to “sugar” snow density.
    - Built drill tent offline and pulled it over the top.
    - Cut slot with chainsaws.
    - Used an old Summit 70 kW generator. Bigger than needed (12.6 kW max), but what was available. The 30 kW generator was not set up to run at altitude.
- Drill Ops
    - Monitored drill ops using LabView
    - Descent: 0.75 m/s
    - Ascent: 1.4 m/s (max)
    - 2.0 m long cores
- Dry Drilling
    - Chip chambers is sized for dry drilling.
    - Core dogs did not always break the firn core free. Will use longer core dogs at South Pole

- Occasionally had issues removing cores from barrel.
    - Tried drilling with both 126.0 and 129.6 mm cutters.
    - Dry drill depth was 101.6 m
- Danish Core Barrel Test
    - Fit our drill perfectly fine, chip removal was the equivalent to IDDO and it experienced the same core removal issues.
- Reaming and Casing
    - Reamed in two steps, first to 7" and then to 9". Reamer worked well and reamed 84.5 m in 26 hours.
    - Took 5.5 hours to set the 18 sections of casing. Threaded connections were sealed with landscape adhesive
    - Weld seams on casing cuffs had to be removed on site. Caused some problems with the seal at the top.
- Wet Drilling
    - Drill produced good quality 2.0 m core
    - Chip chamber was properly sized.
    - Most drilling was done with dry barrels using 2 boosters
    - Both the 126.0 and 129.6 mm cutters were tested.
    - 13 drill runs were done using the wet core barrel and pump. The chip chamber was less densely packed with the pump. Did not tune the pump and drill for better performance.
    - Chip chamber had 7200 x 1.5 mm holes. Added a poly shield to contain fluid spray.
    - Chip slurry was processed in a 19 L capacity centrifuge (1500 RPM) with a 15.6% drilling fluid loss to the chips.
    - Tried collecting two cores at once like DISC, but only had a 60% success rate.
    - Bayonet coupler was hard to work with.
    - Anti-torque bearing section froze up frequently, had to add ethanol between most runs.
    - Anti-torque blade screws were found to loosen frequently. Checked each run but still lost some screws that had to be recovered.
    - Final depth of 285.3 m.
- Drilling Fluid
    - The fluid performed well for drilling but was challenging for the staff.
        - Fluid fumes were a strong irritant. Need to increase the air circulation.
        - Plan to keep gloves and aprons away from work areas.
    - Loss rate was 27%.
    - PVC gloves lasted about 2 days, nitrile about a few hours. Solution is yellow gloves from Japan, a polyurethane hybrid.
    - A vacuum was used to dry the cable (explosion proof). (Steff reports while this was taken from the Danes, it was originally taken from IDDO for cleaning cores.)
    - Extensive material compatibility testing at UW following the test season.
- Core Processing
    - FED was used to remove drilling fluid from cores.

    - Cardboard tubes were used to store brittle ice. Was tested in Greenland.
    - 15.0 m of wet-drilled ice were boxed and shipped to NICL
    - *Wilhelms*: *Concerned that the netting may go through a transition at -40°C. What was the material? Polypropylene?* Jay thought it was that or polyethylene (confirmed that it was in fact polyethylene during the meeting).
- Bailer and Conical Tool
    - Bailer worked well to recover chips and the conical tool efficiently enlarged the borehole from 126.0 to 129.6 mm.
    - *Wilhelms: Suggests slotted holes and conical holes, larger on the outside.*
- Packing
    - Took 5 days for the 6-man crew to pack the system.
    - Were able to use a hand crank to winch heavy equipment out of the trench. Allowed prep time ahead of the heavy equipment arrival.
- Upgrades
    - Improved control room ventilation to 1 air exchange every 67 seconds
    - Removed bayonet coupling from the dry core barrels.
    - Simplified the centrifuge control.
        - *Wilhelms: Suggests a change to filter on the descent.*
    - Add air intake vents to drill tent end walls
    - Tune the level wind control to improve tracking capability
    - Add seals to the anti-torque bearing section to prevent chips from entering
    - Bevel one edge of the anti-torque blades
    - Improvements to the LabVIEW display
    - Add fluid collection tray under the core push out station
    - Add chip-diverter plugs to the conical tool to direct chips into the flights
    - Add a valve above the lower booster to prevent chips from flushing from the chips chamber
    - Modify the bailer to work in the 126.0 mm hole
    - Update all motor section MPS's to current version
    - Tune the winch for better speed control at low speeds
    - Estisol-140:
        - Use Dailove gloves.
        - Use Tychem CPF-3 sleeved aprons
        - Add a meter to monitor Estisol-140 vapors
        - Determine safe exposure limits to vapors
    - Working on a means to unstick the drill at -57°C. Uses a polystyrene plug that dissolves and releases methanol and ethylene glycol.
        - *Wilhelms: has seen "glycol bombs"*

Plans for coring at South Pole Station (Kuhl)

- Goal is 1600 m of continuous core. Try to get 700 m this season. Three year plan.
- Staff is set.
- Planning to work 3 shifts per day, 7 days a week with a rotating day off. Will have 2 people on shift on off days. Tanner is a float.

- Borrowing the Mech from IceCube.
- Hole temperature will be -55°C.
- *Benson: Drill tent weight?* Shipping weight is 5,000 lbs.
- *Wilhelms: Viscosity testing results?* Waiting for some results, but Benton Ellis will present his results.

Agile Sub-Ice Geologic Drill

Review of conceptual design (Kuhl)

- Presented science requirements
    - Produce a 700 m borehole to base of ice and retrieve 10 m of bedrock core and / or unconsolidated frozen sediment core beneath the ice sheet.
        - Max dia 33 mm (1.3")
        - Drilling depth of each core collected should be determined and recorded.
        - Drilling and core handling history should be recorded.
    - Ice drilling will include the possibility that the ice is entrained with rocks.
    - Ice drilling will be to dry, frozen-bed conditions, and will not be done in areas where there is sub-glacial water.
    - Retrieve several short ice cores (~50 cm long) at up to 700 m depth.
    - Ice drilling may be in ice that is within 2.0 C of the pressure melting point.
    - Required ability to drill at ice borehole temperatures as low as -40 C, and surface temperatures as low as -30 C.
    - Maximum site altitude for the design should be 2,500 m.
    - Maximum time at a site, including set up and core retrieval, should be 6 days.
    - Stand-alone capability required for small field camps at remote sites.
    - Minimal staff (4) for drilling operations in the field; other field camp staff in support of drilling operations to be provided separately.
    - Drilling fluid or a fluid "system" (to be determined) will be immiscible with water.
        - Drilling fluid should not be a boron-rich fluid.
    - Drill system must be transportable by Twin Otter, or helicopter with sling load.
- Bedrock Core: With a wireline system, theoretical limit is 5 meters of sub-glacial material (Talalay). Previous attempts have reached 1 meter. Gerasimoff researched this for the RAID design.
- Planning to modify a standard coring drill.
    - Top-drive rig with fully hydraulic operation
    - Utilize 3-meter drill rods
    - Tubular drill rods transmit rotation and feed pressure to drill bit
    - Hydraulic-driven flush pump for drilling fluid circulation
    - Drill fluid brings bits to the surface
    - Assembled in field.
    - Synchronization between head chuck and foot clamp for safety
    - Automated drill rod joint make-up/breaking
    - Wire line capable
    - Modular diesel power units for field transport
    - Cold-tolerant components and factory-modifications

- Crews: 2 experienced drillers and 1-2 core handlers per shift. Need 4 people for transport and assembly.
- Ops: Casing setting, Ice Borehole, Bedrock Coring, and Filtration
- Drill Time Estimates:

	200m Depth (hours)	700m Depth (hours)
System Set-up	48	48
Pilot Hole/Set Casing to 40m depth	10	10
Drill Ice Borehole to Bedrock, no Core	4	14
Bedrock Coring to 10 meters: wire-line (conventional)	5 (9)	9 (22)
System Teardown/Packing	34	34
Total: wire-line (conventional)	**101 (105)**	**115 (128)**

- Borehole diameters: basing it on B but could expand to N or H. Depth is reduced with larger diameter core.
- Logistics Estimates
  - 200 m system will weigh 12,710 lbs. and require 6-8 Twin Otter flights
    - Consumables 7,430 lbs. and another 4-5 flights
  - 700 m system will weigh 17,497 lbs. and require 8-10 Twin Otter flights
    - Consumables 12,554 lbs. and another 6-8 flights
  - Flight requirements for a Bell 212 are about the same
- *Review of schedule (Gibson)*

Agile Sub-Ice Glaciological Drill Project Milestones	
Requirements Defined	3/15/14
Conceptual Design Complete	8/31/14
Drill Rig Ordered	11/1/14
Drill Rig Received	4/1/15
Detail Design Complete-Design Review	5/31/15
Ready to Ship Antarctic Traverse Materials [i.e. Fluid, Casing]	8/15/15
System Components Received	10/31/15
Complete Assembly, Integration-Testing	3/15/16
Field Test of Drill System Complete	6/15/16
Ready to Ship Drill System to Antarctica	8/31/16

- Pomraning has some experience drilling through 700 m of ice. Pulling out tough. Was working on a glacier, so they needed to be in and out of the rock in 24 hours as the ice was moving.

Fusion welding techniques for installing borehole casing (AJ Shturmakov)

- Proposed objective is to develop a process to connect liners for the borehole casing up to 12" diameter. The primary benefit is that the assembled casing is leak tight and the welded joint strength is comparable to the material itself.
- Not recommended below -20°C (-4°F). Need a means to preheat the liners from -40°C.
- *Cherwinka: Inquires about the internal bead?* Would need to be removed.
  - Boeckman: it's a manual operation with a "catcher" to keep the bead from dropping.
- *Cooper: Mentioned that he built his own drainpipe for the sewer lines with a heated collar that joined the sections of pipe. Cost advantage.*

- Considered for SPICE Core, but a conventional casing will be done.
- *Wilhelms: Likes the method. Concerned that it is normally used for pipes that are used in horizontal applications where the joints don't carry the load. He would want the joints tested.*
    - Shturmakov: would test during testing to build statistical data.
    - Cherwinka: Could test in place to ensure the joint is strong.
- *Cherwinka: What is wrong with the current process?*
    - Johnson: Long-term leak tightness is an issue. We have one leaky case.
- *Pomraning: Material?* Same as current material (HDPE).
- *Twickler: System weight?* Unsure, but it is made to be manhandled.
- *Talalay: What about not using casing?* Would only be used for cased holes.
- *Wilhelms: Feels the biggest issue is having a controlled process in the field*.
- TAB, in general, thinks it's worth exploring.

Conceptual Study on DISC Drill East Antarctic Enhancements (Shturmakov)

- Current capability
    - Current System is capable to operate at -40^{o}C
    - Coring up to 4,000 m of ice
    - Able to operate at altitude of at least 3,000 m (~10,000 ft.)
- Would like to reduce logistics requirement: weight and volume (currently 120-140,000 lbs.)
- Enable operation to -60°C.
- Schedule
    - 2015-16: Feasibility study and conceptual design
    - 2016-17: Detail design
    - 2017-18: Construct and test
    - 2018-19: Ready for drilling
- *Talalay: Consider extending depth of IDD to perform this drilling*. Does not have replicate coring capability.
- *Cooper: Inquires about the changing properties of ice below 3600 m?*
    - Wilhelms: We would be drilling to shallower depths. Thinner layers of ice.
- *Albert: Need to figure out what we want to do with the drill before it is taken to Herc Dome.*
- *Cherwinka: Need to define what we want to do before we can conduct a proper feasibility and optimization.*
- *Wilhelms: Suggesting cable changes*. Bigger point is understanding / factoring in the shipping costs? Do design changes pay for themselves in shipping costs?
    - Need to keep in mind engineering time to redesign.

MEETING NOTES
Ice Drilling Design and Operations – Technical Advisory Board
Wednesday, September 10, 2014
Union South – Industry Room, 3rd Floor
University of Wisconsin - Madison
Madison, WI 53706

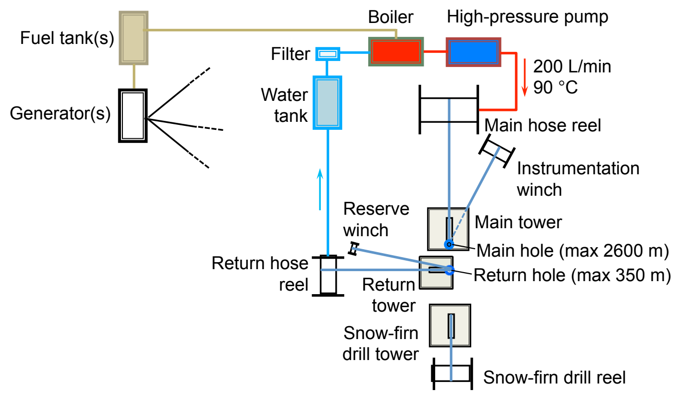
Next TAB meeting (Slawny)
- Should we review all systems each year?
- *Doran: Feels it's useful to go through them, but we could probably skip hand augers.*
- Frank Wilhelms "volunteers" to be the new chair of the TAB.

Travel expenses reimbursement information (Wendricks)
- Tony distributes TERs to the travelers and provided instructions.

DISCUSSION OF NON-IDDO DRILLING AND SYSTEMS

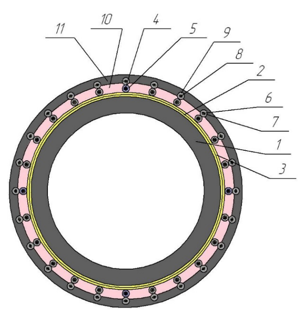
Recent progress in Chinese ice drilling projects in Antarctica (Talalay)
- Dome A Deep Ice Drilling Project
    - 2012-13: Installed system and conducted 3 runs with the JARE deep drill.
    - 2013-14: Skipped due to the construction of the new inland station at the midway of the traverse Zhongshan – Dome A.
    - 2014-15: Continuing drilling, but a short season, 20-25 days. Drilling down to 400 m.
- Subglacial Drilling at GSM
    - Requirements
        - Target depth is 1,000 m and then 2 m into the bedrock
        - May try to reach 4 m depth
        - Rocks: magmatic (gneiss or basalt) up to XI grade
        - Borehole temperature: -58°C
        - Surface temperature: -50°C
        - Storage temperature: -90°C
        - Estimated ice core production: 25 m/day
        - Transport type: snow vehicle
    - Updated the Ice and Bedrock Electromechanical Drill (IBED) to meet the requirements.
        - Designed 6 modules or subsystems for the drill and mix and match them to meet the drilling needs: dry core drilling, dry core drilling with large-diameter auger, wet core drilling with bottom fluid reverse circulation, and bedrock core drilling.
        - In a build and test phase
        - Drilling Fluids
            - Estisol 140 – ruled out due to odor / irritant
            - Low Molecular weight fatty acid esters – have odor issue as well.

            - Dimethyl Siloxane Oils – work well but it is pricey. $8-10/liter need about 20 m^3.
    - Drill Shelter
        - Will have a mobile drilling structure.
        - Each component of the shelter will be less than 2 tons (metric?) and fit inside a 20' Iso container. Longest component is 2.5 m
        - DIM: 7.5 x 4.5 x 2.8 m
        - Deployed mast is 12 m tall. It folds over for transport.
        - Total weight is < 25 tons
    - Winch and Cable
        - Designed and produced by Pskovgeokabel, Russian company
        - Total Wt. 3214 kg
        - Capacity 1500 m
        - Disassembles into 2 components.
        - Cable: 9 conductors (5 power & 4 signal), OD 12.6 mm, & 85 kN break strength
    - Power & Workshop
        - Two 50-kW diesel generators
        - Size will be the same as the drill shelter
        - Store the logging winch (same as cable winch)
    - Traverse
        - Need three vehicles to pull.
        - Should be ready to drill 2-3 days after arriving at the site.
        - ~1000 km from the Zongshan Station
    - Funding & Participants
        - Funding: China NSF and Geological Survey of China
        - Participants: Jilin University; Polar Research Institute of China; & Institute of Geomechanics, Chinese Academy of Geological Sciences
        - Just started this year with 5 years of funding.
        - Test season in 2015-16 near Zhongshan Station
- Amery Ice Shelf Hot Water Drilling Project
    - Funded by Ministry of Science and Technology of China
    - The ice thickness varies in the proposed site from 200 – 2000 m thick.
    - Plan for 10-12 holes along ice shelf.
    - Conceptual Design:



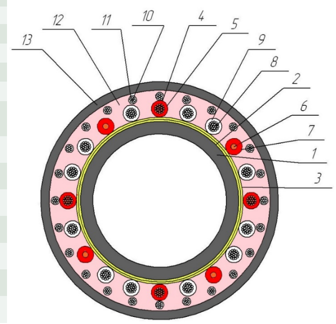
- Working with Pskovgeokabel for instrumentation winch & cable and the return hose reel.
  - Integrated hose and cable.
- Main Hose & Reel
  - Drum Drive Motor: 15 kw
  - Level Wind Motor: 1.1 kw
  - Trip Speed: 0.5 m/s
  - Hose Length: 2600 m
  - Drum & Hose Wt: 4000 kg
  - Total Reel Wt: 7950 kg
  - Level Wind Wt: 1270 kg
  - Specs:

#	Structure	Diameters, mm	
1	Polybutylene terephthalate (PBT) + Poly Ethylene (PE)	32/38	38/46
2	Kevlar lines 24×2=48 (1st layer)	39	47
3	Kevlar lines 24×2=48 (2nd layer)	40	48
4	Signal lines 4×0.5 mm²	0.93	0.93
5	Isolation Polyphenylene Sulfide (PPS)	1.8	1.8
6	Carrying-load rope 20×7	1.2	1.2
7	Cover layer High Density Poly Ethylene (HDPE)	1.8	1.8
8	Carrying-load rope 24×4	0.5	0.5
9	Cover layer High Density Poly Ethylene (HDPE)	1.8	1.8
10	Foam Poly Ethylene (FPE)	45	52.6
11	High Density Poly Ethylene (HDPE) + Thermoelastoplast (TEP)	49	56.6
	Max working pressure, MPa	14	7
	Weight, kg/km	990	1270
	Total weight (2600 m), kg	2574	3302
	Max working temperature, °C	90	90
	Breaking strength (not less), kN	80	80
	Outer diameter, mm	50±1.5	57±1.5
	Density, kg/m³	855	896

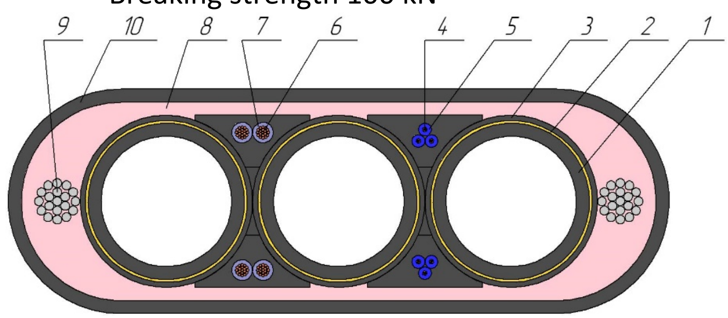


- Return Hose & Reel
  - Drum Drive Motor: 7.5 kw
  - Level Wind Motor: 1.1 kw
  - Trip Speed: 0.5 m/s
  - Hose Length: 350 m
  - Total Reel Wt.: 3920 kg
  - Specs:

#	Structure	Diameters, mm	
1	Polybutylene terephthalate (PBT) + Poly Ethylene (PE)	32/38	38/46
2	Kevlar lines 24×2=48 (1st layer)	39	47
3	Kevlar lines 24×2=48 (2nd layer)	40	48
4	Power lines 4×4 mm^2	2.6	2.6
5	Isolation Polyphenylene Sulfide (PPS)	4	4
6	Thermal heating lines 4×1.8 mm^2	1.5	1.5
7	Isolation Polyphenylene Sulfide (PPS)	4	4
8	Carrying-load rope 12×7	1.2	1.4
9	Cover layer High Density Poly Ethylene (HDPE)	4	4
10	Carrying-load rope 24×4	0.5	0.5
11	Cover layer High Density Poly Ethylene (HDPE)	2	2
12	Foam Poly Ethylene (FPE)	53	62
13	High Density Poly Ethylene (HDPE) + Thermoelastoplast (TEP)	57	66
	Max working pressure, MPa	14	7
	Weight, kg/km	1800	2400
	Total weight (2600 m), kg	630	840
	Max working temperature, °C	90	90
	Breaking strength (not less), kN	100	100
	Outer diameter, mm	57±1.5	66±1.5
	Density, kg/m^3	1030	1050



- Independent snow-firn drill umbilical hose
  - Hot point with supply and return line
  - Plus a sub pump to pull out the water.
  - Integrated hose and cable Specs:
    - Length 150 m
    - Working pressure 3 Mpa
    - Weight 3900 kg/km
    - Total weight 585 kg
    - Max temperature 90°C
    - Breaking strength 100 kN



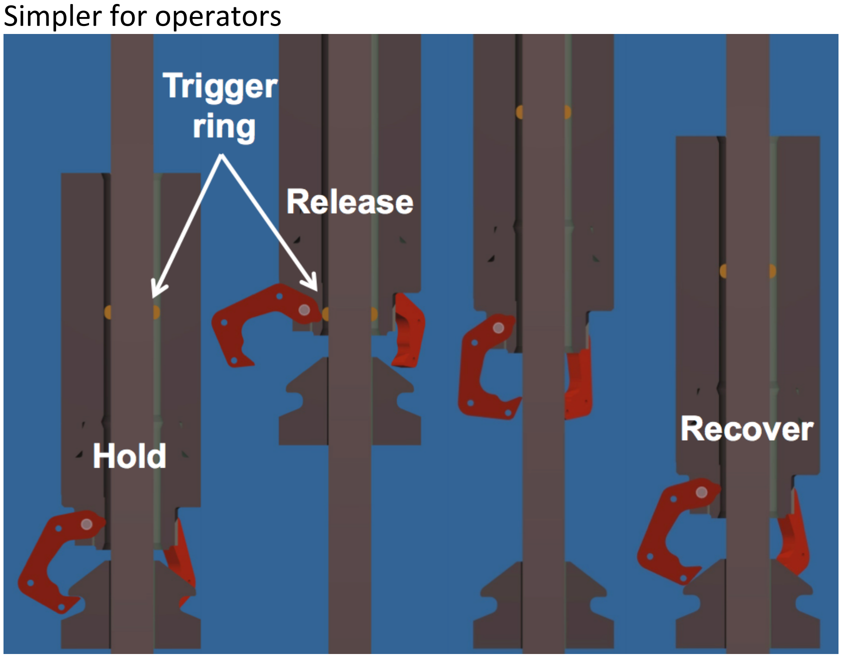
  - ID/OD 25/30 mm
  - Signal lines 6×0.5 mm^2
  - Power lines 4×4 mm^2

Update on BAS drills and future activities (Makinson)

- Basal conditions on Rutford Ice Stream: Bed Access, Monitoring and Ice Sheet History (BEAMISH)
  - Delivery Site: Ronne Ice Front. Drill site is ~ 1000 km away near or on the Rutford Ice Stream
  - Currently planned to drill during the 2017-18 season
  - Shipped the reel, hoses, and fuel out last year due to logistics constraints. 55 tons of cargo including 450 drums of fuel (45,000 liters).
  - Ice Thickness 2200 m
  - Shipped hose and spares as well

- Delivered and stored at the Ronne Ice Front. Some staff will be reviewing it this year. Some will be delivered. Rutford Ice Stream

- Campaign to study processes beneath the Filchner Ice Shelf
  - Joint campaign between Alfred Wegener Institute & BAS
  - 2011-12: Drilled 5 holes at 3 sites on 2 ice shelves to 2200 m depth
  - 2014-15: BAS drills 3 holes to approximately 800 m
  - 2015-16: AWI/BAS two sites ~ 100 km apart
  - 2016-17: AWI/BAS two sites ~ 100 km apart
  - Upgraded from a 500 m to a 1000 m system. More power, heater capacity, and larger pump and reel.
  - Added secondary heat exchangers to the heaters.
  - Using 72' x 8' plastic sledge
    - ½" thick black plastic to reduce surface friction.
    - Metal frame on top to store cargo.
    - Plastic rolls up for shipping.
  - Coring
    - 3 m long core barrels
    - 33 kg core hammer
    - Use a snowmobile to remove the core. Have gone to a depth of 1000 m.
  - New Corer Hammer
    - Auto release
    - Auto grab
    - Increased impact
    - Clearer load indications
    - Simpler for operators



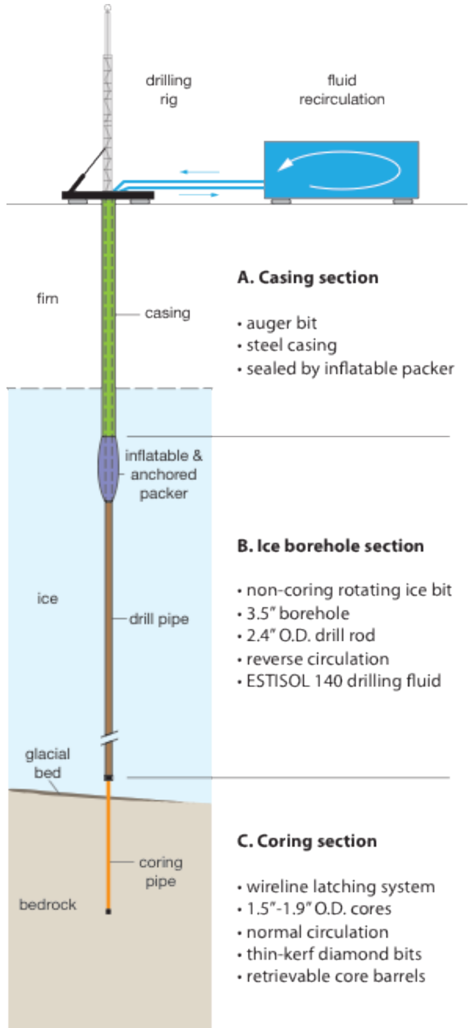
- Greenland
  - Store Glacier (2014)
    - Center for Glaciology, Aberystwyth University

        - ~30 km inland from the margin of Storegletscher, Greenland
        - Elevation ~1 km
        - High in ablation area so the melt is about 1 – 2 m of ice per year.
        - Surface is <u>heavily crevassed and bumpy</u> at a scale of meters to tens of meters
        - Ice thickness ~605 – 620 m
        - Ice temperature: warm at top; @~400 m -21°C, warm at base
        - Ice velocity: ~650 m/a
    - 2015: Petermann, Oregon State University
    - 2016: AWI
- Proposal for sub-ice cosmogenic isotope rock cores
    - Short test season in 2016/17 at Rothera to test anti-torque devices
    - Greenland season in 2017
    - Main Antarctic season in 2018/19, Southern Peninsula and Ellsworth Mts
    - BAS Arctic HWD is available in Greenland following 79N in 2016
    - BAS Antarctic HWD is available following the 2nd AWI season in 2016/17
- Rapid Access Isotope Drill (RAID) – Julius Rix and Robert Mulvaney
    - Goals:
        - Continuous isotope profile to ~LGM
        - Borehole temperature profile
    - Design Criteria
        - 20% of ice sheet depth
        - Rapid – 10 days per site
        - Transport by Twin Otter
        - Drill and drilling team in two Twin Otter flights
    - Drill
        - Wire line design
        - 3” OD. No core, just collect chippings, which will be analyzed for temperature → age.
            - Bagged/bottled at point of drilling
        - Hole then used to deploy distributed temperature measurement system.
            - Left in the hole for thermal stabilization and revisited the following year for accurate temperature profile.
    - Planning some tests this season, 3 weeks in January.
    - Planning 6 holes near Dome C in 2015-16 season.

RAID (Albert)

- (Slides taken from the Scientific Drilling Town Hall meeting in San Francisco, 2013 with permission)
- Deep drilling of basal ice sheets and sub-ice bedrock in Antarctica
- PI: John Goodge (UM-Duluth) & Jeff Severinghaus UC-San Diego & Scripps Institution of Oceanography
    - Other scientists: Gary Clow, Arnold Law, and John Rashid
- New DOSECC Exploration Services responsible for design work

- To be used on East Antarctic area for many years.
- Capable of obtaining rock core
- Conceptual design from Gerasimoff



- In Jan they will have a test season somewhere in North America.
    - *Stephanus: Picking a site for test season, Utah or Wyoming*
    - *Cherwinka: Concerned about the concept of the sleds. WISSARDs containers were torn apart by similar sleds.*
        - Stephanus: They are aware of it and he believes they have a solution in hand.
- Have completed phases I and II.
- Currently constructing the system and planning to deliver in Nov 2015 to Port Huenme and have a vessel shipment to McMurdo.
- 2016-17: Testing at Hut Point Peninsula and then traverse to the South Pole.
- 2017-18: Begin scientific drilling

WISSARD (Albert)

- Slides from Ross Powell
- Was funded out of the stimulus funding from the federal government

- Focus on the lower portion of the Whillans Ice Stream on the Siple Coast in West Antarctica. Main sites are the active subglacial lakes and a region of the grounding zone downstream of the lake
- Frank is leading this out of the Univ of Nebraska
- Have had some publications, Julie presented 2013 and 2014
- They are going out in the field this year. Believe this is the final year.

ARA Drill System (Cherwinka)

- 600 m, x OD dry holes
- Drilled during the 2012-13 and developed a list of drill upgrades/lessons learned
- Currently, there is no ARA funding, so it is on hold.
- ASC asked ARA project to drill the new sewer line. Leveraged this request to fund the upgrades to the system identified in 2012-13.
- Upgrades:
  - Replaced plywood heater panes with MGO board for a wind shield.
  - Repaired the damaged hose bundle with 90 m of hose
  - Repaired a hose reel brake
  - Fixed and reconfigured pendants
  - Replenished critical spares
  - Upgraded the sheave assembly
  - Developed hot water reaming tools
  - Reconditioned the IFD hot carrot for drilling with recirculating glycol
  - Procured live-feed down hole camera
- 2013-14 Season
  - Goals
    - Provide an access hole in RW2 for the new station outfall
    - Provide a hole for the new station emergency outfall
    - Extract the failed Rodwell 3 pump that supplies the station's water
  - Achieved all of their goals
  - System started right up
  - Upgrades and repairs worked well
  - The camera proved to be an essential tool
  - IFD hot carrot worked really well
    - Speed was 0-3 m/hr, but worked best at 2m/hr to maintain straight hole
    - Ran into debris near the surface
    - Ran unmanned with periodic checks
  - Measured the hole closing rate of holes drilled in 2007. It is approximately 1/16" per year or 1.6 mm/yr.
  - Made measurements of the radial firn ice density (distance from the hole wall) vs. depth.
  - Issues
    - Debris and obstacles in hole, specifically at RW2 location
    - Continual clogging of strainers from sludgy glycol batch and dirty snow
    - Gas engine driving pump, coil failure – engine replaced with help from

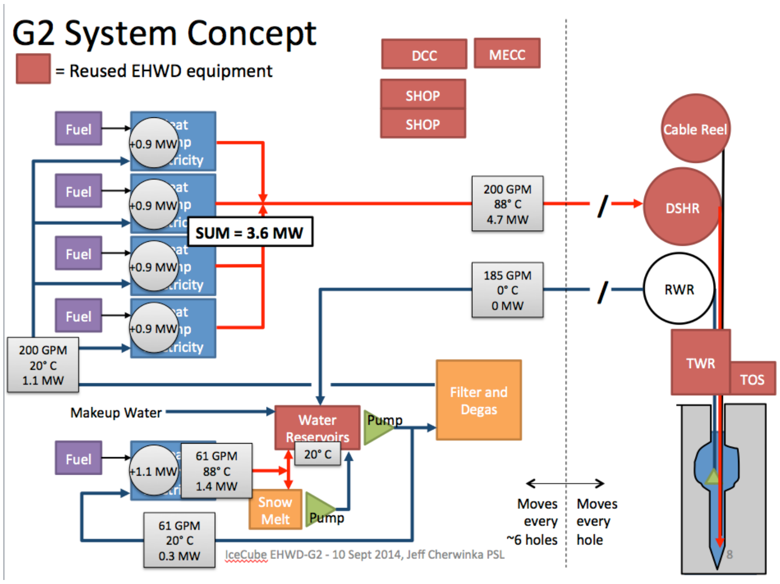
Heavy Shop

- ARA system is ready to go
  - Does require a 200 m hose, only equipped with a 90 m
  - Further improvements:
    - Increase longevity and performance of hose and bundle (critical)
    - Streamline firn drilling operation, decrease overall drill time. Possibly use overnight drilling with small recirculating glycol drill head.
    - Improve reliability of pump unit
    - Improve hose reel motor drive capabilities
- Egress Shafts – additional help to ASC
  - May drill 1-2 egress holes per season starting this year.
  - Mount new ladders
  - Maybe get them to pay for some ARA holes as well, but this has not been bought into yet.

IceCube's Future Plans & the EHWD-G2 (Cherwinka)

- IceCube is currently under the Wisconsin IceCube Particle Astrophysics Center or WIPAC. It is IceCube and a few other smaller physics projects.
- IceCube would like to add strings to improve the knowledge of Neutrino Mass Hierarchy (PINGU) and low energy resolution. They need a wider array for the former and more densely packed strings for the latter.
- PSL staff are conducting a study for IceCube on the next generation of drilling to meet these needs: EHWD-G2
- Requirements:
  - Meet or exceed EHWD performance and efficiency
  - Mobile
  - Hole specs
    - Diameter ~ ϕ60 cm
    - Depth 2450+ m
    - Spacing 20 m (PINGU) to 240 m (IceCube High Energy Extension)
    - Hole lifetime 30 hr or less
  - Improved hole water quality: Minimize particulates & Degas hole water
  - Deliver 136 holes in 9 field seasons or less. EHWD did 80 holes.
  - Minimize drilling time, fuel consumption, crew size, setup and tear-down time
  - Assumption: Drill can be traversed to Pole
- Highlights of changes from EHWD
  - Thermal plant is based around microturbine combined heat and power technology
  - Reels, Towers, TOSs, Drillheads, Water Tanks, and Independent Firn Drill from EHWD will be reused
  - System packaged onto traverse-style air sled concept being developed by CRREL, allowing entire system to be moved many times throughout a season
  - System built up in McMurdo and transported to South Pole by traverse
  - Design is modular, allowing for scaling of system capacity

    - Interconnects minimized, allowing for shorter setup and tear-down times
    - Advanced microturbine controls and modulating electrical resistance heaters provide a stable and reliable supply of hot water
    - Overall thermal plant efficiency of 80% standard and expect we can do 90%
- Schematic



- Makeup Water
    - Need about 15 GPM. Considering:
        - Mini Rodwell at top of hole
        - Deeper hole pump-out
        - Larger diameter at top of hole
        - Melt snow
        - Prior hole refreeze recovery
        - Condensate collection – causes hole contamination
        - Shorter weight stack (less water loss at start of hole)
        - Heated weight stack
- Concept Study Status
    - General architecture almost finalized
    - CAD concepts good for presentation and discussion
    - Looking further into packaging, possibly 5 turbines per sled, 3 power plant sleds
    - Will seek more insight on turbine and heat exchanger cold-weather, high-altitude performance
    - Starting to look at specific equipment in more depth
    - Refining thermal estimates and performance expectations
    - Thinking about how to repackage tower site equipment
    - Developing equipment cost and weight table

Update on CIC drilling activities (Hansen)

- Completed large drilling program at NEEM two years ago.
- Aurora Basin, East Antarctica
    - Temperature -44°C

    - Ice is 3600 m thick
    - 15 cm of water equivalent precipitation per year
    - Provided a 400 m hole for an Australian group
    - Trying to reach 1,000,000 year old ice
    - Stuck at Casey Station for 2-3 weeks due to weather. Needed 2 days of clear weather to fly in. The traverse is 1300 km.
    - First priority upon arrival was to groom a skiway in the high sastrugi area to allow planes to land & take off for fast access.
    - Second Priority: bring in 40 tons of equipment.
    - Took approximately 3 weeks to get to 303 m
    - Used Estisol 140 for drill fluid. Had a small facility to dry out the clothes. The 140 actually dried out. With the 240, the clothes remained wet.
    - Separated the chips from the Estisol by melting the ice. Surface temperatures were -25° to -10°C. A noticeable odor could be discerned, much like fly repellent. Good ventilation is desirable.
- Bear Camp (Visit to IDD Test)
    - Use drillhead and core barrel on the IDD system. Used some step cutters. Worked well.
    - Tested a slightly different core barrel
    - Impressed with how Jay's groove design worked for chip transport
    - Steff's design had 18,756 x 1.4 mm dia straight holes. He did not use a taper.
- REnland ice Cap Project, RECAP
    - Greenland Jan 14 – Dec 16
    - Partners: Center for Ice & Climate, AWI, University of Kansas Center for Remote Sensing of Ice Sheets, University of Colorado Boulder INSTAAR and the Earth and Environmental Systems Institute
    - Conducted a radar survey to identify the ideal site.
    - The main objective is the arctic sea ice.
    - Steff would like an IDDO staff member on-site for technology transfer
    - Previously drilled there in 1988.
    - Planning to use Estisol 140.
    - Planning to use new fiberglass barrels.
    - *Kuhl: Inquires if they will be casing the hole?* They will not be casing the hole.
- EGRIP
    - Site on the North Greenland Ice Stream
    - Proposal in and waiting to hear back if it will be funded.
    - If funded, they will start next summer moving equipment from NEEM.
    - They have tested digging a trench, inserting a large balloon, and backfilling with snow to form a roof. Test went well and they may use it at EGRIP.
    - Getting through brittle ice will be challenging. Don't believe what they are doing during drilling is effecting the cracking. They believe it's due to thermal shock on the surface. To mitigate the issue, they are planning to extract the brittle ice cores into a cooled Viessmann.

Drilling Fluid: Temperature vs. Viscosity & Cuttings Transport (Ellis)

- Tested seven drill fluids
    - Estisol 140
    - Isopar K
    - OMC 1049
    - Puredrill IA35
    - C14 Esters
    - Citrofol B1
    - Edenor IPL
- Estisol 140: viscosity was insensitive to speed
- Isopar K: Same
- OMC 1049: Small variations with speed. Slightly shear thickening. Oil based fluid made be Petro Canada
- Pure Drill IA35: Petro Canada product. Very small speed variation. Gelled up at -45°C.
- C-14 Esters: Chevron. Solid gel at -45°C.
- Citrofol B1: Maxed out viscometer at -10°C.
- Edenor IPL: Petro Canada
- Density linear with temp. Viscosity non-linear.
- Planning to test particulate.
- Conclusions
    - Tested seven candidate fluids for viscosity versus temperature from -60°C to 10°C
    - These are Newtonian fluids where viscosity stays relatively constant regardless of the shear rate (more or less)
    - The viscosity is highly dependent upon the temperature getting thicker with lower temperatures
    - There is a temperature at which the viscosity rises nonlinearly
    - Density varies linearly with temperature
    - We are looking into more candidate fluids
    - Please let us know if you have any fluid candidates you wish to test
    - Next step is to test various size and density particle slip velocities in multiple fluids at differing temperatures
- *Talalay: Asked if he compared his results with published results?* Ellis has looked at the paper from Tanner and feels the results are similar.
- *Ellis:* To convert to centistokes, divide by density.
- *Eustes: They are willing to test any other fluids if members send them a sample.*

Titanium Hand Auger (Pomraning)

- Required to drill 1-meter of sea ice with no iron in the drill.
- Originally wanted an entirely plastic drill, but requires cleaning - 30 days in sulfuric acid.
- Used Type-2 Titanium, nearly entirely titanium. It is not as high strength as the titanium with other alloys.
- Used two cutters instead of three. More traditional design.

Martin Truffer Hot Water Drill (Pomraning)

- Took some parts from the Barclay Kamb system
- Want to have more data, inclinometer and temperature data in it.

Update on AWI and European Activities (Wilhelms)

- Auro Basin: 305 m of core has been collected
- Roosevelt Island: Completed bedrock coring. Processing in Wellington this summer
- EXPLORE: Drilled a 110 m core at Point Barnola
- Neumeyer Hinterland: AWI goal is ice dynamics & 30 ka record during 2014-18 seasons.
- COFI: Goal is 2 cores on the Dome F ice divide for densification studies
- EASTGRIP: 6-year project to drill to 2550 m. Traversing infrastructure from NEEM using the US GRIT traverse. Plan to start setting up camp in 2015.
- Renland: Funded and planned for 2015.
- SUBGLACIOR Probe: Developing a tool to rapidly drill and analyze in situ. Testing in Concordia in 2016-17 season. Plan to reach 1000 m. Using a silicone oil drill fluid.
- RADIX: developing a rapid access drill to be tested in the Alps this summer and in Renland 2015.
- UK 500: Rapid access chip drill to be tested this austral summer
- Germany has announced plans to have a continuous core drill in which the core would come up the hole to allow for faster drilling.
- A large diameter core is planned to 180 m for Greenland 2015 for organics and CO.
- Aurora Basin North: 100 m drill used a casing like Shturmakov was suggesting.
- *Wilhelms:* Suggested IDDO contact Olivier Alemany to discuss his experience with fusion welding of casing.
- Dome C: 120 m hole with reaming and setting up of a new light PEHD watertight casting
- Drill Developments at AWI
    - Shallow Drill & Winch
    - Tiltable Tower
        - Weighs 160 kg
        - Looking at commercial product for erecting stages capable of an 8 ton lift.
    - New spooling mechanism: reel moves back and forth on linear guides.
    - New coupling design
    - Slotted holes
    - Using three motors tied to one drive to run it.
    - Welded sections
        - Broached the interior. About half the tubes met dimension specs, but they could correct those that did not.
    - Dry hole Motor
        - EC motors (Brushless DC)
        - Core through the middle of the motor, 98 mm, hollow design

Wrap-up and action items

- *Wilhelms: Suggests a driller meeting sometime during the year, possibly in Europe.*
- *Slawny: Have engineers present at European meetings.*

ADJOURN