

## **TAB Meeting – Notes on discussions during presentations**

**March 7, 2017**

**Varsity Room – Union South**

**University of Wisconsin - Madison**

### **Technical Advisory Board Members:**

Jeff Cherwinka	Physical Sciences Lab UW – Madison
Peter Doran	Louisiana State University
Steff Bo Hansen	University of Copenhagen
Keith Mackinson	British Antarctic Survey
Dennis Nielson	DOSECC Exploration Services
Alex Pyne	Antarctic Research Centre Victoria University of Wellington
Pavel Talalay	Polar Research Center Jilin University
Frank Wilhelms, Chair	Alfred Wegener Institute for Polar and Marine Research

### **Other**

Terry Benson	Physical Sciences Lab University of Wisconsin – Madison
George Cooper	University of California – Berkeley, retired
Brian Shaw	DOSECC Exploration Services

### **Ice Drilling Program Office**

Joe Souney	University of New Hampshire
Mark Twickler	University of New Hampshire

### **Ice Drilling Design and Operations**

Grant Boeckmann	Space Science & Engineering Center UW – Madison
Anna Claussen	Space Science & Engineering Center UW – Madison
Chris Gibson	Space Science & Engineering Center UW – Madison
Josh Goetz	Space Science & Engineering Center UW – Madison
Jay Johnson	Space Science & Engineering Center UW – Madison
Jim Koehler	Space Science & Engineering Center UW – Madison
Tanner Kuhl	Space Science & Engineering Center UW – Madison
Zach Meulemans	Space Science & Engineering Center UW – Madison
Mark Mulligan	Space Science & Engineering Center UW – Madison
Chris Niendorf	Space Science & Engineering Center UW – Madison
Kristina Slawny	Space Science & Engineering Center UW – Madison
Tony Wendricks	Space Science & Engineering Center UW – Madison

### **Field Programs – Anna Claussen (1:00-1:10)**

- Summarized drilling results from 2016-17 Antarctic Drilling season
- Summarized planned drilling for 2017 Arctic Drilling season

### **ASIG Drill Season – Tanner Kuhl (1:10-2:20)**

- Presented the 2016-17 drilling season and the plans for the off-season.
- Pyne: Whatever the leak was at the bottom of the hole it was responsive to static pressure.
- Cherwinka: Where was the fluid going? Was it moving the glacier aside?
  - Seemed so, perhaps with a vertical crack, but we do not know for sure.
- Cooper: You would expect one vertical crack based on the experience of the petroleum industry. Abnormal stresses in the ice could make this even more confusing.
- Kuhl: The transition to rock was very apparent. Drilling vibration and noise greatly increased.
- Twickler: At the ice to bedrock transition, was the ice core stuck to the rock?
  - We never saw it. PI Stone covered the top of the first core in foil to keep sunlight off of it to protect the integrity of his first measurement.
  - Wilhelms: Do you know how long the rock has been covered with ice?
    - No, we have not been told that number yet.

- Kuhl: Cores switch from rock to ice to rock. It was not clear why.
- Pyne: Were all of the outside bits scalloped on the PCD coring bit?
  - Yes. We think particulates were gathering on the outside of the hole and wearing the bits down.
  - Boeckmann: What happened when you lost penetration with the bit?
    - We needed to increase speed, but then Clayton felt the bit was done. We pulled it out. We, maybe, could have gotten one more run out of it.
- Kuhl: The lightweight drill fluid did work surprisingly well, better than expected. It did leave chips behind, as it was apparent after bit changes.
- Nielson: What was the annular space?
  - The bore was 62.5 mm in diameter. The drill rod was 53.2 mm. [4.65 mm annular space.]
- Nielson: What is the density of Isopar K?
  - 0.7 to 0.8. Need to confirm.
- Mackinson: Inquired about the assembly/disassembly time.
  - Assembly could be greatly improved if you do not have to disassemble quite as much, but that requires more logistics support. They did take advantage of the traverse equipment to minimize disassembly for the move.
- Cooper: The observed hydrofracture behavior is perfectly normal.
  - Agrees, but they were surprised at the low pressure at which it occurred. Very careful on the second hole to avoid any kind of pressure shock.
- Pyne: What was the ice temperature?
  - Ice temperature was -26°C in the field and -20°C at the PSL test site.
- Twickler: What was the quality of the ice core above the bedrock?
 

It was quite milky. Unclear if it was like that or if we caused it. It is being evaluated by Jeff Severinghaus.
- Twickler: What was Clayton's opinion of Isopar K?
  - He thought it was weird, but understood why traditional drilling mud was not used.
- Bo Hansen: What was the core break force?
  - Unknown, but it broke easily.
- Nielson: What is a continuous flight auger?
  - The flights run from the bit to the surface to transport chips.
- Shaw: How did the fluid and water separate?
  - They self-separate and refreeze. Isopar K turns brown as well from dissolved grease, rust preventative, hydraulic oil, etc.
- Twickler: How did you know the circulation was not working?
  - It was apparent that the circulation was not working because the chips going up the annulus were triangular shaped and fused together as the stack increased.
- Slawny: How long to trip the rods out at 150 m?
  - It took, maybe, an hour. We tried to minimize doing that, as we did not want to pull the rods. Ideally, we would use a single bit for the entire rock core.
- Pyne: You stole heat from the glycol loop on the engine?
  - Yes.
- Boeckmann: Did you chill the fluid before you put it in the hole?
  - Yes, but it took awhile even though it was sitting on the snow surface in buckets.
- Mackinson: Do you think 19,000 lbs is a realistic weight for a 200 m system?
  - Yes. Certain systems can be optimized. It was heavy, but we took a very conservative approach for this first season. For example, we had another complete set of drill rods.

#### **Winkie Drill – G Boeckmann (2:20 – 2:50)**

- Like ASIG, it was very apparent when they hit bedrock. The auger would vibrate quite a bit.
- Wilhelms: How were the Kovacs augers?

- Ok, but the results were poor using the recovery tools. One did bring the chips up well; however we were using them deeper than their design depth, perhaps deeper than anyone Kovacs is aware of. Their deepest use may have been 22 meters previously.
- Boeckmann: VFDs kept tripping GFCIs on generators. Did a work around with a pigtail. Future generators will all have GFCIs, so we may need to figure out why they were tripping.
- Mulligan: Why did you camp remote from the drill site?
  - Camped remotely due to wind tunneling effects of the terrain.
- Bo Hansen: How loud was it?
  - We used hearing protection.
- Pyne: What material are you drilling this coming year (2017-2018)?
  - Sandy, silty ice.
  - Is it Blue Ice?
  - Yes. Site will have sediment and dirt for ~0.5-meter on top of blue ice.
- Talalay: Could you have drilled deeper?
  - Yes, but we stopped because we met the requirements.
- Twickler: Did you recover the Isopar K?
  - No, well, only what flowed into the recovery well.
- Pyne: Drill bits?
  - The bits were set in tungsten.
- Bo Hansen: Which drill bit did you like?
  - American Diamond Tool AmSet bit.
- Mackinson: Do you plan on a fluid recovery system?
  - Would have bailed the hole this year with more time. You just add a cap to the drill rods and trip them down hole. This displaces a lot of the fluid into the recovery well.
- Talalay: Why did the air drill head get plugged with the chips?
  - Do not think it was due to the air being too warm. We believe there was enough air to move the chips, but maybe it could not clear the bit?
- Pyne: When you trip the drill rods out, do you trip them out with the unipress/drill frame?
  - Could lift 40 m of rod by hand and it ratchets up.
- Slawny: In the 50 m hole, did you expect rock?
  - Yes, at 46 m we expected rock.
- Talalay: Were the augers continuous?
  - Yes.

## **Break 2:50 – 3:25**

### **Rapid Air Movement Upgrades – Gibson (3:25 – 3:50)**

- Twickler: Inquires about the cost of the Hornet system.
  - Unsure of its cost.
  - Nielson: It uses a dual wall drill pipe.
- Dual-walled hose would have a series of hoses on the outer annulus with a single opening in the middle. Chips would come up the center.
  - Cooper: How do you get the chips out at the top?
    - TBD, but a manageable problem.
  - Nielson: That is consistent with the mining industry.
- Tissue Sock
  - Ran a successful prototype test at PSL.
  - Cooper: Is that a throw away material?
    - Ideally, no, because it's an expensive material and you want to drill a lot of holes.
  - Pyne: How do you collect it?
    - At PSL, they placed it on a tube as it raised out and stuffed it back in the "tissue box".
- Pyne: What fraction of the weight are the compressors?

- They are 6,000 lbs. each. Need 2, have 3.
- Cherwinka: What altitude?
  - It will be at WAIS, which is not as high as South Pole.
- Cherwinka: As you decrease your hole size, you increase your pressure losses.
  - Agreed and aware of it.
- Nielson: How do you maintain the quality of the borehole?
  - RAM drill creates clean, straight holes. Sridhar Feels he can tighten the hole since it is so clean. It will not be as clean with a hot water drill.
- Wilhelms: With umbilical, how much higher pressure do you need?
  - Do not need a higher pressure because the air motor/drill head are at the end of the hose. The supply air is 100 psi greater to account for the pressure drop through the motor. We will probably run at 200 psi.
- Nielson: Why do we use augers to get through firn instead of air?
  - Weight. Augers are light. Compressors are heavy.
  - RAID has a 200 CFM system. Augers are 40-50 lbs./5-foot section. Reverse circulation (RC) rods could be used. A custom RC rod may weigh 30 lbs./meter.
  - RAM compressors are 400 CFM. Needed a 3<sup>rd</sup> at Pole. (Cherwinka)
  - RAM drills each hole in 20-30 min.

#### **Sediment Laden Lake Ice Drill – Goetz (3:50 – 4:12)**

- Doran: Isn't the steam drill mostly for firn?
  - Yes, but some studies suggest it has similar behavior in ice.
- Cherwinka: Does the hydronic heater have its own fuel pump?
  - Yes, you get a fuel pump kit.
- Pyne: What is the power?
  - 24 VDC, 12 A
- Doran: The Mini-Monsoon pump, it's battery operated. Does it plug into the generator?
  - Goetz: Yes, it connects straight into 12-volt source.
  - Doran: We used them in the Dry Valleys. It's really a sediment pump, as it will handle quite a bit.
  - Goetz: It was selected primarily due to its size.
  - Doran: If you can, you want to leave the sediment behind.
  - Mackinson: How much sediment do you collect?
  - Doran: On order of a foot. As long as the drill head mixes it, you are fine.
  - Slawny: What is the weight of the Cherwinka pump?
  - Goetz: Less than 10 lbs.
  - Cherwinka: Diameter?
  - Goetz: 1-1/2 – 2 inches, 9 lbs.
  - Doran: It works very well. Drain it out and let it freeze.
- Doran: Inquires about the pickling process.
  - Goetz describes it. Doran suggests they do not run glycol through any of the down hole water loop portion of the system. He could see using the system in the Dry Valleys or other environmentally sensitive areas which do not allow for any contamination.
- Pyne: Can you make a single fuel system?
  - Have not been able to identify appropriate components that are all gas or diesel.
- Wilhelms: What is the water temperature?
  - 88°C
- Pyne: Josh described a slot in the drill head for a stuck/frozen-in cable to slip into to free it. Pyne stated based on his experience, the slot may not be necessary and may actually cause the drill to bind to an existing cable and get stuck itself.
- Talalay: What about an off-the-shelf Kovacs system?
  - They are only about 15 kW. We need 30 kW.

- Doran: Most applications use a helo or sled for transport. Think about using Hardigg boxes for cases, which double as secondary containment.
- Wilhelms / Mackinson: It takes about 750 kW to get to 1000 m.
- Cherwinka: Suggests that you could put the heat exchanger in the water tank to melt snow.

**Hot Water Drill Table – Gibson (4:12-4:20)**

- Pyne: NZ did test their new HWD. It's a modified version of the BAS 1000 m. It had a "successful" test season.
- Pyne: 840 kW ANDRILL system in containers. It has a titanium heat exchanger. Its deepest depth has been 250 m. It is primarily stored in Christchurch. Each hose drum holds 480 m of hose. You could couple two hoses together and potentially reach a depth of 800 m.

## **TAB Meeting – Notes on discussions during presentations**

**March 8, 2017**

**Northwoods Room – Union South**

**University of Wisconsin - Madison**

### **Technical Advisory Board Members:**

Jeff Cherwinka	Physical Sciences Lab University of Wisconsin – Madison
Peter Doran	Louisiana State University
Steff Bo Hansen	University of Copenhagen
Keith Mackinson	British Antarctic Survey
Dennis Nielson	DOSECC Exploration Services
Alex Pyne	Antarctic Research Centre Victoria University of Wellington
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Jim Koehler	Space Science & Engineering Center UW – Madison
Tanner Kuhl	Space Science & Engineering Center UW – Madison
Zach Meulemans	Space Science & Engineering Center UW – Madison
Mark Mulligan	Space Science & Engineering Center UW – Madison
Chris Niendorf	Space Science & Engineering Center UW – Madison
Kristina Slawny	Space Science & Engineering Center UW – Madison

**Agreed to hold the next TAB Meeting March 6-7, 2018.**

### **Rapid Access Ice Drill – Brian Shaw (8:40-9:45)**

- Test Season in Utah
  - Learned many lessons from the test season. The system used a lot of liquid carbon dioxide to freeze the water.
  - Had a thermistor string in the hole to monitor the test hole freezing.
  - They did run into the casing while drilling.
  - Adding ice cubes with water did not work well. There were trapped pockets of air in the frozen column.
- Test Field Season in Antarctica
  - Cherwinka: Traverse team was quite happy with ISO-3 skis.
  - Talalay: Does the 79 tons include fuel?
    - Believes that figure only includes equipment. They had 24,000 gallons of fuel.
- First Hole
  - Talalay: What was the ice temperature?
    - -20°C
  - Pyne: What type of glycol?

- Standard issue.
- Second Hole
- Packer Troubleshooting
  - Talalay: Did you take a core sample to get a density measurement?
    - Tried to get a sample with one of the tools, but the sample melted on the way out of the hole.
  - Cooper: What did the core look like?
    - Solid, the exterior had clearly melted. Cut through it with a chainsaw. It was a combination of virgin firn and cuttings.
  - Talalay: It might be better to use a different drill and get core density measurements.
  - Wilhelms: How high is the tower?
    - 40-45 feet.
    - Wilhelms: How long will the auguring run?
      - Only for firn. Used it for 6 hours on 2<sup>nd</sup> hole.
    - Wilhelms: How long did the chip fishing take?
      - Couple days.
    - Wilhelms: Standard shallow drilling could be done in 2 days and will provide all the data you need on firn density.
      - Plan is to have enough augers to get 10% past firn depth and not need to clear the cuttings to install the packer.
  - Pyne: Please review the cuttings removal process. Was the process compacting the cuttings?
    - No, the cuttings were light and fluffy. Felt like sand.
- Winterizing
  - Cooper: What are the covers made of?
    - Vinyl.
- Fuel Use
  - Pyne: You were not processing the chips, correct?
    - No. While there will be less power contingency up on the plateau, RAID still should be okay with chip processing.
- Slawny: What is SPoTSA?
  - South Pole Traverse Staging Area
- Slawny: Firn/Ice Transition
  - Are you sure you weren't past the transition?
    - Jeff Severinghaus did not feel we were past it.
- Cooper: What is the plan for next season?
  - Unsure. We want to go down with a full complement of augers for testing. We need NSF approval.
  - The scope of work is tied to SALSA. We were supposed to sit idle while the tractors supported SALSA, but if SALSA is delayed, we could use the tractors for a test season.
  - Where would you test?
    - Minna Bluff again.
  - Your presentation seemed to imply you were in a snow drift. Would another location be better?
    - Originally 3 sites had been picked. We could go to one of the other 2.
  - Talalay: Suggests collecting all core as they descend.
    - We are looking into that.
- Bo Hansen: Did you vary speed during drilling. Sometimes slower is better.
  - There was some discussion about that. Started at 100 RPM and slowly ramped up to 300 RPM.
- Wilhelms: It took a few days to make the pad?
  - The first pad was done in a day. The 2<sup>nd</sup> and 3<sup>rd</sup> did take multiple days, with more careful compaction.
  - Wilhelms: If you have issues with the density of the pad, a snow blower can help with that.
- Wilhelms: What science programs are planned?

- Concerned about the lack of shallow core samples. An agile drill could be sent ahead to a site and the hole could be prepped for RAID.
- Slawny: We could potentially send a 4-inch drill out on a helicopter to prep a hole for testing.
  - RAID can bring out 300 m of augers, but the 4-Inch Drill is potentially a good idea.
- Cherwinka: Did you run the camera down to the location around the packer?
  - Yes. Lots of video. It did look good.
  - What happens if you add water to the hole? Pyne: It goes away into the firn. Firn is a sponge.

### Break (9:45 – 10:00)

### Recent Chinese Deep Ice Drilling in Antarctica – Talalay (10:00 – 10:30)

- Deep ice-core drilling project at Dome A
  - Wilhelms: How was the ice at Dome Fuji?
    - No issues drilling there.
- Subglacial Drilling Project at GSM
  - Wilhelms: Can a Basler land there?
    - Yes, but never landed there. Pilots are afraid to land. They circled and departed.
  - The idea is to meet the traverse in between Zhongshan Station and GSM?
    - Yes.
  - Wilhelms: Which thread was best, conical or cylindrical?
    - Cylindrical.
- Hot Water Drilling project at Amery Ice Shelf
  - Cherwinka: What is the hose length (reel in container)?
    - 2200-meters
  - Cherwinka: Drill nozzle can direct water up or down?
    - Yes. Did not work perfectly.
  - Cherwinka: ROP? Rate of Penetration?
    - Yes. The ROP was 38.6 m/hr. in test well.
    - Cherwinka: Is that how fast you want to go?
      - Yes, it meets requirement.
  - Pyne: What was your power?
    - Unsure. 3 boilers running, one spare.
- Subglacial Lake Exploration
  - Cherwinka: The cross-section view of the cable jacket, is the white space air?
    - Yes.
  - Wilhelms: You can transmit more power while the cable is spooled since the resistance changes as the cable is unspooled.
    - Agreed.
- Bo Hansen: At Dome A, it seems you had too little power and were making fine chips. Did you not have step cutters? This is an understood issue with a solution.
  - They did not have step cutters. Did at IBED.
  - Bo Hansen: We will use step cutters at East GRIP.
- Bo Hansen: If your cables are kinking, you should implement a strain gauge in the crown sheave and compare that data with the length of cable spooled out to prevent kinking.
  - We are trying to move the technology we use at Dome Fuji to Dome A, but it is slow.
- Pyne: Are you planning additional tests to understand how a hole freezes?
  - Cherwinka: IceCube looked into this extensively. Lee Greenler has an empirical model on it based on thermal input.
  - Pyne: But, Talalay will be making a hole through to the ocean. You end up with stratified water from salt to fresh.
  - Cherwinka: Could use the model and tweak the input.
- Cherwinka: Where is the thermal drill?



- Changchun. Are planning to deploy it in 2018-19.

#### **Chemical De-icers to recover stuck Ice Drills – Talalay (10:30-10:55)**

- Bo Hansen/Wilhelms: Frozen glycol was used frequently at NGRIP. It Freezes at -12.6°C. It was hard to freeze the glycol. It would super cool at -20°C.
  - Heyoshishun suggested small crystals of frozen glycol be added to the supercooled glycol. It instantly froze.
- Bo Hansen: In 1997, we sent down a container of glycol. We called them torpedoes. It did not have a valve but a block of ice as a plug. The glycol would melt through it and flow out. Unfortunately, it did not unstuck the drill.
- Bo Hansen: Glycol and ethanol behave differently. Glycol can rise, refreeze and plug. Need to send enough the first time. You need to consider this when using it.
  - Wilhelms: Remember, you release gas when you melt ice.
- Wilhelms: You mentioned salts; you need to pay attention to their density. We have used Stokes to predict descent time and it worked well.
  - Calcium chloride, how dense or heavy is it?
    - Heavier than NaCl
  - Pyne: Calcium chloride creates a lot of heat when it dissolves. Need to consider that. I think it's exothermic.
  - Cooper: Thinks it's endothermic.
    - Cherwinka: Exothermic (looked it up online).
  - Doran: Definition of zero is so much ice and sodium chloride. It's how you make ice cream.
  - Wilhelms: Ammonium Nitrate is endothermic.
    - Cherwinka: Confirms.
  - Cherwinka: Airplanes use potassium acetate. More environmentally friendly but you don't want to eat it.
- Johnson: Heated capsule, given the length of the drill sondes, is there any useful heat by the time the fluid hits the drill head?
  - Needs to be tested.
- Kuhl: Dave Ferris did a bit of research on this for SPICE Core for South Pole. It is colder at the South Pole.
  - Jay: He had a mix he was going to use, which included glycol, methanol and toluene.
- Pyne: Silicone oil behaves differently?
  - Yes.

#### **Hot Water Drilling on Filchner Ice Shelf and Future Deep Drilling – Mackinson (11:15 – 11:45)**

- Cherwinka: What was the ice depth?
  - It was 600 meters this season, it was 900 meters during the previous season.
- Cooper: How much memory in the GoPro?
  - 128 MB cards and you choose your resolution. Not a problem to get hours of video.
- Benson: How do you tie depth with video?
  - Use water pressure sensors and the line out measurements. It's part of a suite of instruments.
- Cooper: What is the water depth from the bottom of the ice to the ocean floor?
  - Thinks it was 600 meters.
- **BEAMISH**
  - Umbilical:
    - ARA will be adding pneumatic line to control a valve to keep the hose pressurized as they spool back on.
    - Benson: The hose member is the strength member.
    - Cherwinka: The hose curves a bit due to differences in thermal contraction. If weight is on it, it straightens out.
  - Cherwinka: Is Ellsworth drill in field?
    - No, in England, but incomplete.

- Cherwinka: Do you ream on the way out.
  - Yes, pullout at about 6 m/min.
- Cherwinka: Do you measure diameter?
  - Yes, the camera has an acoustic gauge. Unfortunately, they do not have a live feed, so it's evaluated once the camera is on top.
- Talalay: Are you using your own model for freeze back or IceCube data?
  - Using their own experimental data. Have run the experimental data past Lee Greenler and they agree.
- **RAID (Rapid Access Isotope Drill)**
  - Pyne: Are you still in firn at 100 m at DOME C?
    - Wilhelms: Yes, 110 – 130 meters.
  - Pyne: Is the barrel grooved on the inside?
    - Mackinson/Wilhelms do not think so. Uses the friction on the walls.

#### **Cherwinka Drill – Doran (11:50 – 12:02)**

- Standard system has a MoGas generator.
- Exchanger weighs on order of 28 lbs.
- Pump has seized up. Warm it and it runs.

#### **Summer Field Program 2017 – Bo Hansen (12:05 -12:35)**

- Cooper: How did the caves survive?
  - Unknown, expect they are fine.
- Talalay: Drilling fluid?
  - Estisol 240 plus Coasol after a lot of discussion. Scientists could not provide a justification for requiring Estisol 140. Drillers feel 240 is a bit more user friendly.
- Cherwinka: Do you traverse the snowblower in and out?
  - No, it remains in camp. It's a large piston-bully.
- Bo Hansen: Need to be sure to have shoulders alongside the length of the pit to hold the ceiling load of the arch.
- Pyne: What was temp?
  - -15°C
  - Wilhelms: Sintering will occur at even lower temperatures.
- Bo Hansen: By building the snow arch, we saved 3 Herc flights in lumber into camp. Balloons can be used again and again.
- Doran: How long do you wait?
  - 3-4 days is all that is required. Depends on conditions.
- Bo Hansen: Measured density and it is equivalent to ice density at 20 meters depth.

#### **Lunch (12:35-1:30)**

#### **Recent Developments - Wilhelms (1:30 -2:00)**

- Talalay: Is the trolley on the tower mechanically driven?
  - No, it's just on rollers and is driven by a piece on the drill sonde that catches on the trolley when the drill comes out of the hole. Provides for much more control when bringing the drill to a horizontal position.
- Cherwinka: The motor cable goes through a 90-degree bend?
  - Yes.

#### **Final Discussion & Summary**

- Pave felt it might be time for himself to step down from the board and suggested a few names from the international community that might make for a good replacement.