Intermediate Depth Drill Science Review
Wednesday, 10/17/12 11AM EDT

Attendees

- NSF: Julie Palais, Hedy Edmonds
- IDPO: Mary Albert, Mark Twickler, Joe Souney
- IDDO: Charlie Bentley, Alex Shturmakov, Krissy Dahnert, Jay Johnson, Jason Goetz, Nicolai Mortensen
- Science Community: Eric Saltzman, Murat Aydin, Eric Steig, Tom Neuman, Karl Kreutz, Ross Powell, Sridhar Anandakrishnan

Action Items

#	Description	Responsible Person(s)
1	Set date in March for final IDD engineering review	Shturmakov
2	Provide a table of seal components with each fluid	Johnson
3	Work with community to determine what drill fluid will be used	Twickler
4	Contact DPP/PEHS about possible new drill fluid	Twickler
5	Send T. Neumann a copy of the Estisol-140 viscosity vs temperature data	Twickler
5	Conduct Costs/Benefit analysis on generators for drilling	ASC

Overview

This review of the Intermediate Depth Drill (IDD) was scheduled for the Principal Investigators who first plan to use the drill to collect a 1500m ice core from the South Pole, starting in the 2014-2015 field season. Members of the IDPO-Science Advisory Board were also invite to join. On July 26th, 2012 there was and engineering review of the drill in Madison and a final engineering review will be conducted in March, 2013. Ideally this engineering review will occur at a different time than the South Pole PI meeting on March 19, 2013.

Web Presentation

Jay Johnson and Jason Goetz gave web-based presentation of the current status of the IDD being designed by IDDO. The presentation was organized by different components of the system (Sonde, Tilting Tower and Winch and Support Systems)

Sonde

The Sonde design is based on the Danish Hans-Tausen design with several new components. The slip ring will be enclosed, yet designed to allow drilling fluid to enter and be retained so that if the drill encounters liquid water, it will not short out the electrical components. This was a lesson learned from the NEEM project. The anti-torque section also features a new cable termination design that permits easy removal of the anti-torque from the winch cable while keeping the electrical connector intact. Changes to the motor section include an updated design of the transmission and seal assemblies. The outer barrel will be composed of a Filament-wound fiberglass epoxy tube rather than the usual stainless steel tube. This permits the internal grooves to be molded into the tube when it is made. The new tubes will have better straightness and roundness than the metal version and they can be made for a much lower cost. There was minimal discussions on the other components of the Sonde since they are basically a clone of the Danish design with a few improvements

Tilting Tower and Winch

The tilting tower and winch is a brand new design by IDDO using a lot of new technological advances from the DISC Drill. Since this is mostly engineering there was only one concern raised about "cold starting" of the motor control system. While the motor control system will be in a warm box while drilling, when the drill is shut down, there will be no heat in the control system and it will be at ambient temperatures (minus 30 to minus 50). IDDO addressed this issue by stating that when the drill is powered on; you wait for the components to warm up before starting any of the control systems.

Support Systems

Support systems consist of the needed infrastructure to operate the IDD.

-Core barrel pull out table/Core Processing: As fully adjustable table with a hand winch to remover the core barrel, which is then hand carried to the core push-out station. Core is pushed out through a fluid evacuation device (FED), similar to the one that is used at WAIS Divide, onto the core measurement station with an adjustable height tray system. A circular saw, from WAIS Divide, with a smaller diameter blade with reduced kerf is used to cut the core into 1-meter sections before moving to the core packing station.

Discussion:
It was noted that there might be minimal science sampling on the core by yet unfunded science that would require the use of a band saw. IDDO felt there is currently enough room to accommodate this.

-Centrifuge: This will recover drill fluid from the chips created by drilling the core. It is determined that the centrifuge doesn't need to be an explosion proof system.

-Fluid handling system: A system to deliver drill fluid into the borehole is being designed based on the DISC system. Improvements include a removable lid on the fluid tank to allow easier cleaning and simplified control system.

-Vacuums: Will utilize the same vacuums as at WAIS Divide for the FED and cable cleaner.

-Pilot hole system: A polyethylene casing, same type as WAIS Divide, will be used with a 2 stage reaming process down to ~125 meters. IDDO estimates that the pilot hole, reaming and casing should take less than 2 weeks.

-Structures: Weatherport tents will be utilized for the drill and generator structures. Working floor for the drill tent will be 1.5 meters below grade. Flooring will be the same that is being used at RICE (GEOBLOCK polyethylene grating).

Discussion: The working level of the drill will be in the "winter" cold wave zone, making the work area very cold. It was asked if the un-insulated tent would have any solar gain to warm the trench. IDDO did not know how much solar gain would be available. It was also highly recommended that some kind of flooring insulation be used in working areas (i.e., core processing, drill control area). There may also be a small heated tent for the drill control station.

Power systems: The IDD science requirements require the drill to be transportable by Twin Otter. To meet this requirement a modular multi-generator system is planned with load balancing done manually. De-rating for South Pole elevation will require 27kW.

Discussion: While IDDO is building the IDD to the community science requirements it was discussed that for the South Pole drilling, due to LC-130 support that we may consider using one large generator to power the drill. This may significantly reduce the fuel usage required to drill the core. The PIs suggested costs/benefits be done to help in this decision.
Drilling fluid: When the South Pole proposal was submitted the plan was to use Isopar-K as the drilling fluid. Danish engineers tested a new drilling fluid this summer, with promising results. This fluid, Estisol-140, is being recommended by the testing team for cold drill sites. It is estimated that 132 (200 liter) drums of drilling fluid will be needed.

Drilling fluid: When the South Pole proposal was submitted the plan was to use IsoPar-K as the drilling fluid. Danish engineers tested a new drilling fluid this summer, with promising results. This fluid, Estisol-140, is being recommended by the testing team for cold drill sites. It is estimated that 132 (200 liter) drums of drilling fluid will be needed for the 1500m deep hole. This assumes that the fluid level will be maintained at 75m in the borehole, a 30% fluid loss rate, and 200 L per drum. Jay Johnson discussed that we may want to purchase more fluid if we want to bring the fluid level up to the surface of the borehole at the end of the project, and/or if we want to maintain the fluid higher (than 75 m) in the borehole during drilling.

Discussion: A decision needs to be made on the drilling fluid for the South Pole ice core. IDPO has sent samples of Estisol-140 to US ice core analysis laboratories to see the possible affects it may have on their analyses. The issue of polymers used in drill seals was raised, in the sense that particular drill seals (notably buna-n) may contribute to chemical contamination of the drill fluid and ice. It was requested that there be further discussion with the PI's about selection of seal materials as decisions about drill fluids become finalized. It was also suggested that IDDO provide a table of the various seal components that would be used depending on which drill fluid is used. It was also suggested that IDPO contact Adrian Dahood at DPP/PEHS to inform about the possible change in drill fluids for the South Pole drilling. Tom Neumann asked to receive a copy of the Estisol-140 viscosity vs temperature testing data.

Safety: IDDO will provide a complete safety manual for the IDD operation.

How to handle brittle ice: There are several ways to try working with the brittle ice and netting will be used:
- Cut and pack as with ductilel
- Short duration 2m buffer, then cut into 1m sectionsand pack in tubes
- Trench off of drill tent for over winter storage of 2m cores
- Drill two 1m cores in one drill run

Discussion: Current planning is to winter-over 2-meter long cores in a relaxation trench, then cut into 1 meter sections the following year for shipping. The method used with the DISC drill was to drill one meter, perform a core break, and then drill another meter. IDDO does not know if this will work with the IDD drill mostly due to the different pumping systems. This will be tested in Greenland to see if it is possible. If this method does work there should be discussion about possibly doing this on all the ice as to not lose core material to the 1-meter core cuts.

Drilling schedule

Dry drilling will be to 135 m, then borehole will be reamed to 125 m and casing set. As previously mentioned this is expected to take less than 2 weeks before the fluid drilling starts. Core collection will begin at the bottom of the slot (~5 meters below surface grade). Drilling shift will consist of 2 drillers and one core handler and we have the personnel to drill a 24/6 schedule.

Discussion: Since we will not be starting on the surface several shallow (6m) hand drilled cores will be required. The science team will collect these while IDDO is assembling the drill.

IDD Science Review

Science requirements

Document #: 8671-0003

SCIENCE REQUIREMENTS – INTERMEDIATE DEPTH DRILL

#	Parameter	Requirement
1.0	**System Requirements**	
1.1	Target Depth	Up to 1,500 m
1.2	Absolute Borehole Depth Measurement Accuracy	0.2% of depth
1.3	Borehole Inclination	Not to exceed 5°
1.4	Drilling Fluid	System should be compatible with existing fluids, e.g., Isopar-K or Butyl Acetate
1.5	Maximum Field Project Duration	One field season for max 1,000 m depth; two field seasons for 1,500 depth
1.6	Replicate Coring Capability	None
2.0	**Core Requirements**	
2.1	Ice Core Diameter	98 +/- 3 mm
2.2	Core Length	2 m
2.3	Core Quality Requirements	
2.3.1	Core Recovery	Complete core recovery over entire borehole, as close as possible
2.3.2	Ice Pieces	Ice pieces to fit together snugly without any gaps
2.3.3	Non-Brittle Ice	In non-brittle ice, the packed core should have no more than 12 pieces of ice per 10 m section of core
2.3.4	Brittle Ice	In brittle ice, there may be a lot of pieces in a single ~ 2 m core segment, but the pieces must fit together retaining stratigraphic order; more than 80% of the ice volume must be in pieces that each have a volume > 2 liters
3.0	**Environmental Requirements**	
3.1	Minimum 10 m Temperature at the Site	-55°C
4.0	**Transportation Requirements**	
4.1	Transportation Type	Twin Otter or similar size aircraft

Engineering Requirements

1.0 PURPOSE

1.1 This document outlines the engineering requirements that are consistent with the Intermediate Depth Drill System Science Requirements, REF. 3.2.

1.2 Engineering requirements for the Intermediate Depth Drill System and its sub-systems are presented in relation to the individual components that make up the complete Intermediate Depth Drill System.

2.0 SCOPE

2.1 This document applies only to the Intermediate Depth Drill functionality.

3.0 REFERENCES

3.1 8614-0005, Intermediate Depth Drill Design Concept

3.2 8671-0003, Intermediate Depth Drill Science Requirements

4.0 DEFINITIONS

4.1 **IDDO** – Ice Drilling Designs and Operations group

4.2 **UW-SSEC** – University of Wisconsin-Space Science & Engineering Center

4.3 **PI**- Project Principal Investigator

4.4 **PM** – IDDO Project Manager

4.5 **QA** – Quality Assurance

5.0 RESPONSIBILITIES

5.1 The project PM is responsible for ensuring that acceptable engineering requirements are created for the project.

5.2 IDDO Engineering is responsible for the creation and updating of this document.

5.3 SSEC QA is responsible for ensuring that appropriate procedures are followed for the creation, review, approval, updating and maintenance of this document.

6.0 ENGINEERING REQUIREMENTS

6.1.1 **General Requirements**

6.1.1.1 Drill system shall be capable of collecting science-quality ice cores to a depth of 1,500 m.

6.1.1.2 The winch shall be capable of spooling cable at an averaged line speed of ≥ 1 mps.

6.1.1.3 Ability to operate at temperatures down to -55°C.

6.1.1.4 Ability to operate to within 2°C of the pressure melting point of the ice.

6.1.1.5 Ability to drill in silt laden ice.

6.1.1.6 Drill system should be ready for testing in Greenland by 03/31/14.

6.1.2 **Core Characteristics**

This section defines the quality of the cores that will meet the science requirements.

6.1.2.1 The core diameter shall be 98±3 mm.

6.1.2.2 Minimum core length of 2.0 m.

6.1.2.3 In non-brittle ice, the packed core should have no more than 12 pieces of ice per 10 m section of core

6.1.2.4 In brittle ice, there may be a lot of pieces in a single ~2 m core segment, but the pieces must fit together retaining stratigraphic order; more than 80% of the ice volume must be in pieces that each have a volume > 2 liters.

6.1.3 **Borehole Characteristics**

The hole needs to be uniform and vertical. Post-initial core drilling operations may include logging of the hole and re-entry of the hole at later dates.

6.1.3.1 Absolute borehole depth measurement shall be 0.2% of depth.

6.1.3.2 Borehole inclination is not to exceed 5°.

6.1.4 **Drilling Fluid**

The drilling fluid assists in the cutting of the cores and balances the glaciostatic pressure of the ice. As the depth of the bore hole increases, glaciostatic pressure causes the ice to flow more rapidly back into the hole, closing it off, unless the hydrostatic pressure of the drill fluid balances the pressure of the ice. The fluid shall not dissolve the ice, or mix with any water generated during drilling. It shall also be able to be removed from the core pieces, core segments, ice chips, the drill cable, and the sonde.

6.1.5 The drill system shall be compatible with Isopar-K and/or n-butyl acetate drilling fluids.

6.2 **Transportation**

A Twin Otter or similar sized aircraft are the smallest aircraft that will be used to transport the Intermediate Depth Drill System.

6.2.1 All components should be capable of being broken down into sub-components that will fit into a Twin Otter or similar sized aircraft.

6.2.2 Volume of payload, as per the attached file titled "Twin Otter DHC – 6 Capacity".

6.2.3 All sub-components, as defined in 6.2.1, shall require no more than 4 people to move.

6.2.4 The entire drill system shall be able to be assembled and taken down without the use of heavy equipment.

6.3 **Core Handling**

Engineering Requirements

The handling of the core needs to be accomplished in a manner that preserves the cores without contamination and allows traceability of the drilling data to a specific core segment.

6.3.1 Ability to measure the length of each core to within 0.001 m.

6.3.2 Surface temperature of the core after removal from the drill.

6.3.2.1 Core temperature never to exceed 0°C

6.3.2.2 Core temperature never to exceed -2° C for >2 minutes.

6.3.2.3 Core temperature never to exceed -10° C for >20 minutes.

6.3.2.4 Core temperature never to exceed -15° C for >1 hour.

6.3.3 Core segments to have a length of 0.90 to 1.10 m.

6.3.4 Ability to know the drilling and core handling history of each core segment.

6.4 **Structures**

The drilling operations and power generation systems must be enclosed within structures to allow operations to continue in times of poor weather and to provide protection to equipment during the winter months.

6.4.1 The drilling operations and core processing shall be housed in one structure and power generation in a separate structure.

6.4.2 Soft side tent type structures should be used.

6.4.3 Set up and take down should not require the use of heavy equipment.

6.4.4 Structures shall be capable of remaining set up for one winter over.

6.5 **Power System**

6.5.1 Diesel fuel powered generators should be used.

6.6 **Safety**

Safety of personnel on this program is paramount, due to the hazardous nature of the operations, severe environmental conditions at the drilling locations, and the extremely long travel time to advanced medical and life support facilities. Even small mishaps may have severe consequences in this environment. In addition to personnel, preventing damage to the equipment is important, because of the difficulty and cost of repairing the equipment in the field. The failure of a single piece of equipment that cannot be field-repaired could potentially cause the loss of an entire drilling season.

6.6.1 Create a safety plan that identifies hazards to personnel and equipment and defines hardware or procedural solutions to each of the identified hazards and incorporate this into the process documents.

6.6.2 Provide an analysis of mechanical/physical/chemical personnel hazards for the system and provide training and/or devices to mitigate those hazards.

6.6.3 Provide hardware protection devices that prevent damage to the equipment due to overloads in the system, such as torque limiters, over-current protection, pressure limits and mechanical fuses.

6.6.4 Safeguard the health of the drilling team while working on the system.

6.6.5 Minimize environmental impact of the drilling operations.

6.6.6 Minimize safety and health risk from exposure to drilling fluid.

6.6.7 Incorporate fluid handling and chip handling safety equipment and procedures.

6.6.8 Provide identification and protection from dangerous voltages.

6.6.9 Provide safety interlocks (Lock-Outs) to prevent the in-advertent operation of the equipment that would endanger personnel.

6.6.10 Provide emergency stop and emergency power-off systems to respectively halt and power-off the equipment in the case of an emergency. The emergency power-off systems in some cases must have fail-safe brakes such that the removal of the power will engage the brakes. (An example is the winch or tower mechanisms, which must engage the brakes and hold their last position in case of a loss of power.)

6.7 **Operations**

Operations must be done in a manner as to allow personnel to work safely and efficiently, and to be able to deal with exceptional (non-normal) cases as they arise.

6.7.1 Provide fundamental levels of operation for all equipment as needed for exceptional cases and diagnostics.

6.7.2 Provide hardware interlocks for safety and emergency operations. Co-ordinate these interlocks and operations with the other subsystems in the drill system.

6.7.3 Create an operations plan and procedures for normal drilling and surface operations of the system, and for engineering checkout of the equipment.

6.7.4 Design the drill system to be operated by 3 persons per shift.

6.8 **Logistics**

The cost of moving equipment and personnel to and from the drilling site and support of those resources is a major portion of the cost of this program.

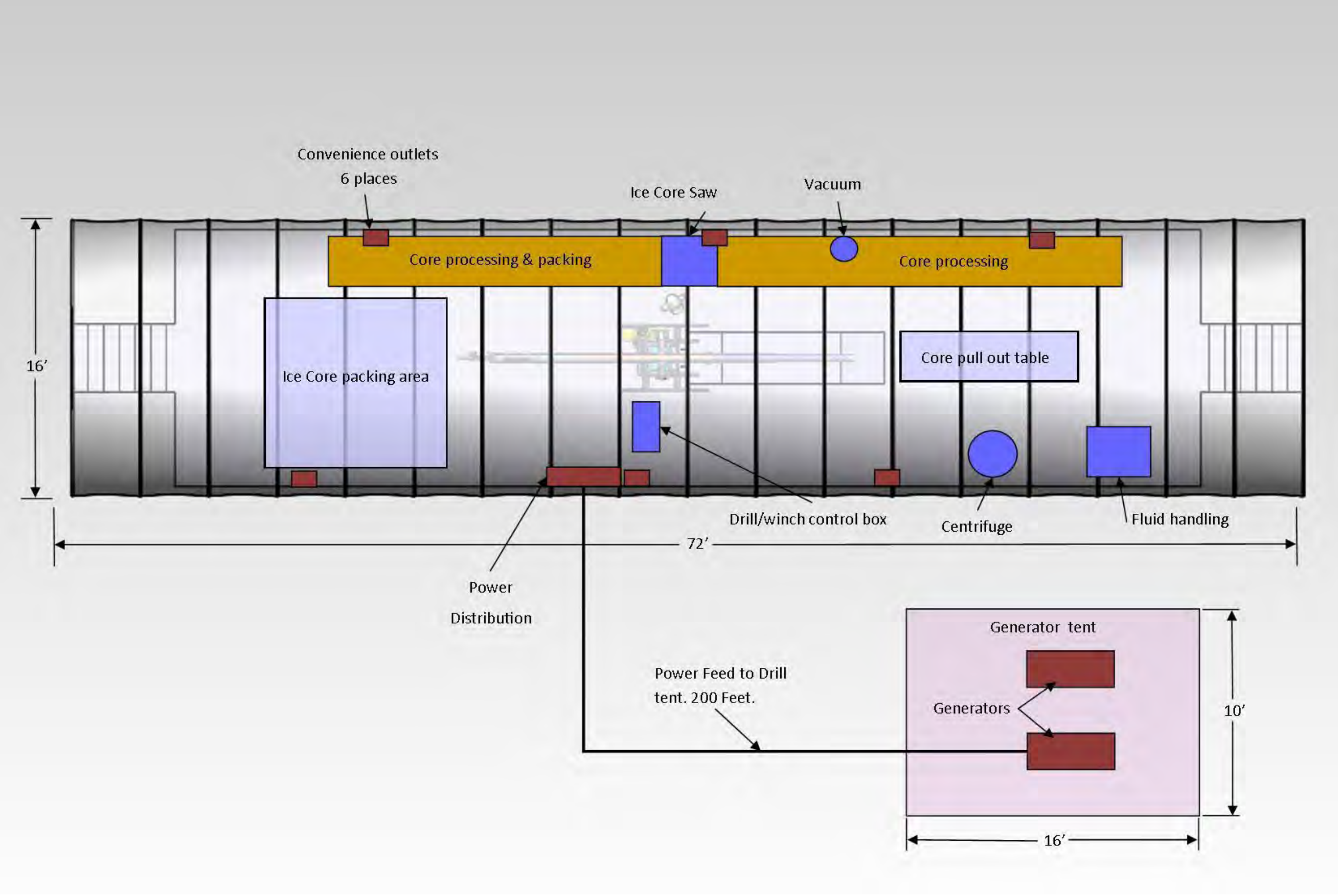
6.8.1 Keep logistical needs and expenses at the minimal reasonable level.

6.8.2 Reduce the time needed to drill and recover cores to a minimum and maximize safety.

6.8.3 Design the system for rapid set-up and check out, and subsequent removal at the end of the season.

6.8.4 Design and provide for on-site diagnostics, repair and refurbishment of the system, including tested spares where possible.

Drill site Layout



Drill System Design

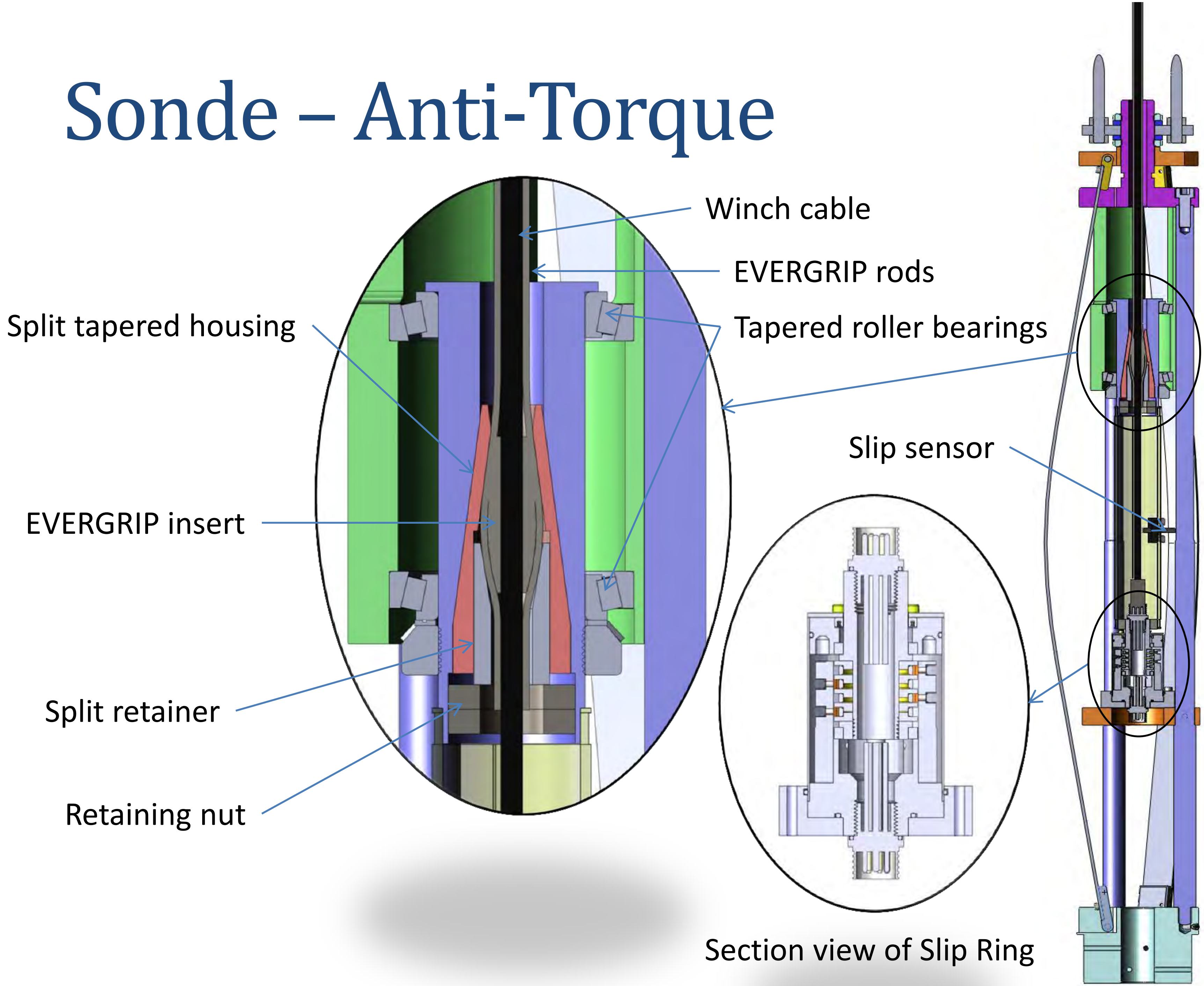
- All surface equipment is being designed for operation to -40°C
- All Sonde components are being designed for operation to -55°C
- The Sonde is based on the Danish HT and Deep Drill designs
- System is designed around a peak core break force of 10 kN

Sonde

Sonde – Anti-Torque

- Winch cable can be removed with the electrical connector attached
- Cable is secured using a modified EVERGRIP Termination from PMI Industries, Inc.
- Sealed 4-channel Slip Ring from IEC Corporation
  - The Slip Ring will be filled with drilling fluid as the borehole pressure rises
  - If water enters the borehole, the seals will retain the drilling fluid and prevent the water from causing an electrical failure
- Sealed electrical connectors
- Anti-Torque slip sensor
- Top recovery loop
- Single adjustment moves all three blades

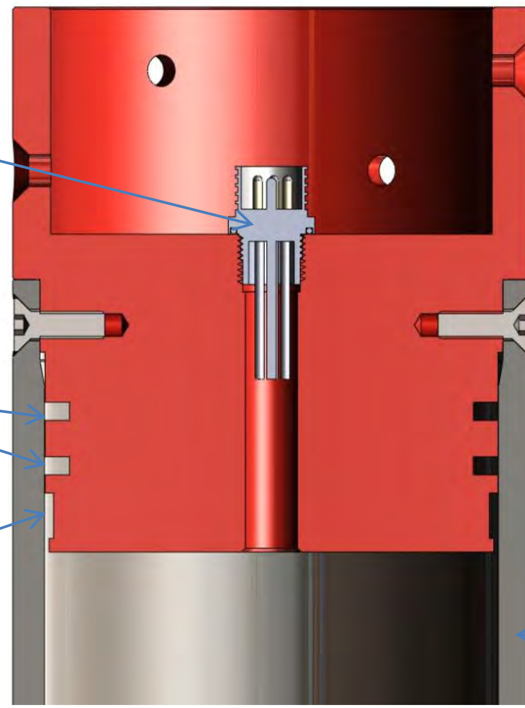
Sonde – Anti-Torque



Sonde – Motor Section

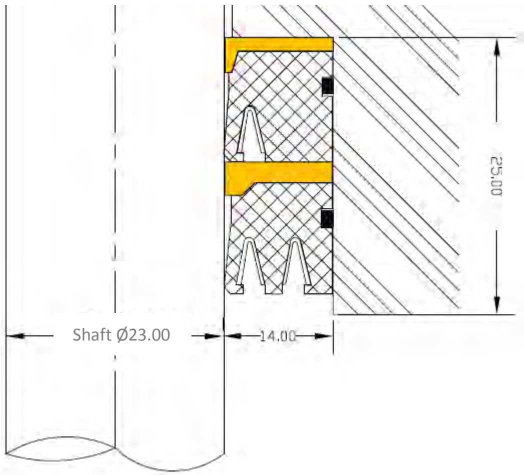
- Permanent magnet brushed DC motor
  - Manufactured by Minnesota Electric Technology (MET)
  - 500w (0.68hp)
  - 280v
  - 5400rpm
- Harmonic Drive speed reducer
  - 80:1 ratio
- Minimum pressure rating of 4,000 psi
- Tapered roller bearings carry the core break force
- Custom static and shaft seal package designed by American High Performance Seals
  - All seal materials are compatible with both Isopar-K and Estisol 140

Sonde – Motor Section

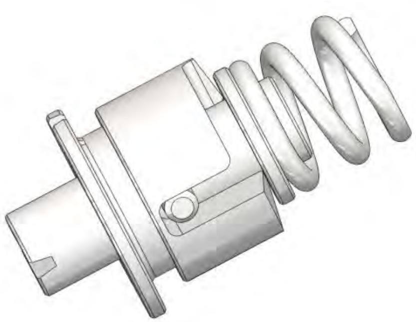


Top Plug

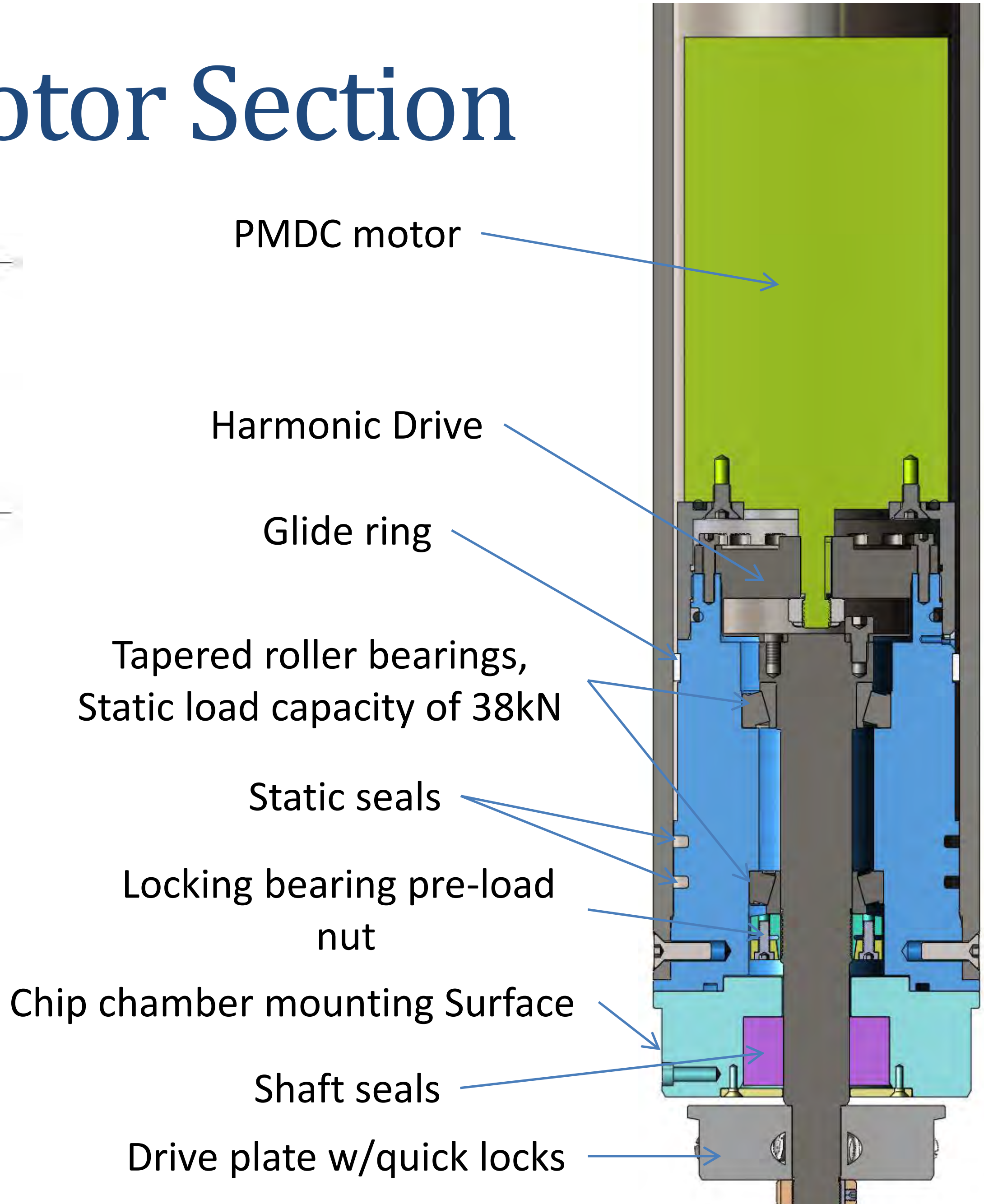
Sonde – Motor Section



Shaft seal detail

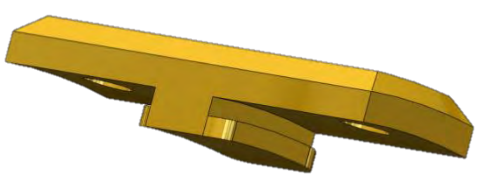


Drive plate quick locks

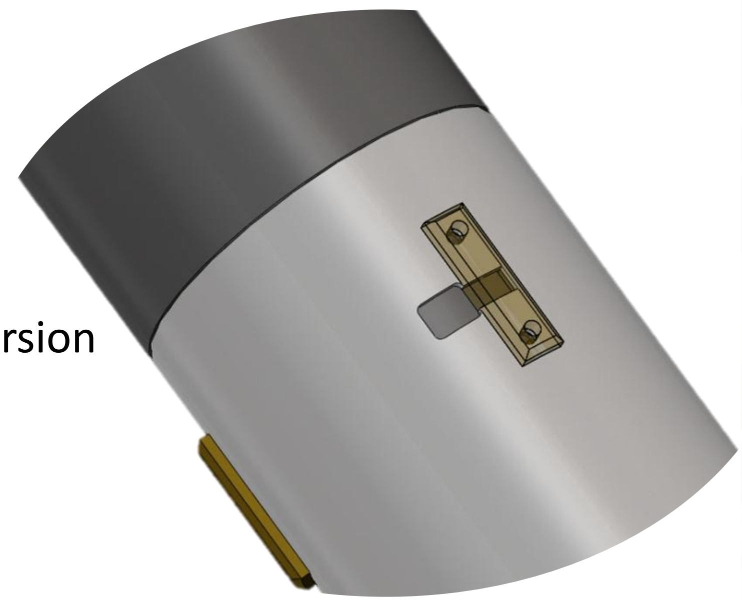


Sonde – Chips Chamber

- Seamless 304 Stainless Steel tube
  - 114.3mm OD, 110mm ID
  - 0.2mm/m straightness
- 2m of length for chip storage
- Outer tube mounts to the chips chamber with three locking pieces
- Two barrel configurations
  - No filter holes in tube
  - Filter holes in tube
    - 11,952 1.4mm holes in NZ version

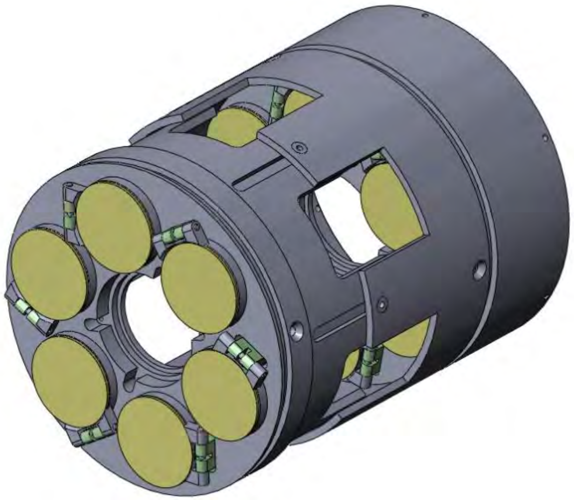


Barrel locking piece

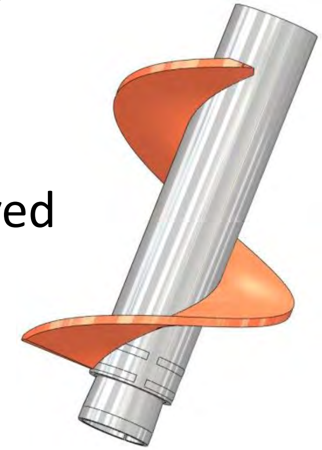


Sonde - Drive Shaft and Pump

- Using the Danish design
- Drive shaft runs booster, pump, and turns the core barrel
- Booster helps pack chips in the chips chamber
- Valves at the top and bottom of the chips chamber open during descent to reduce fluid drag
- Piston type pump
  - Used for wet drilling for improved fluid circulation



Pump assembly

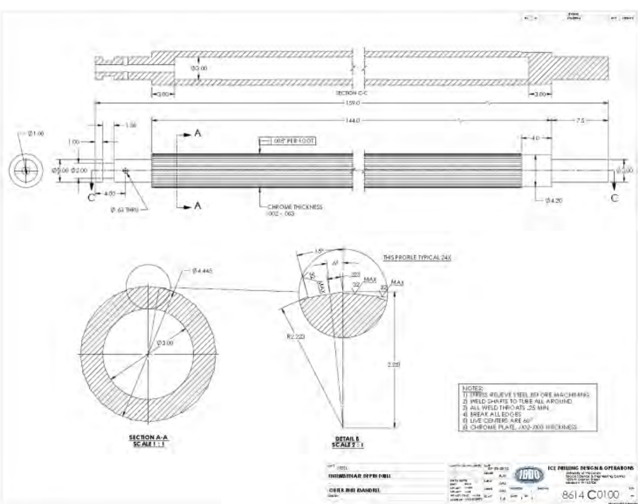


Booster

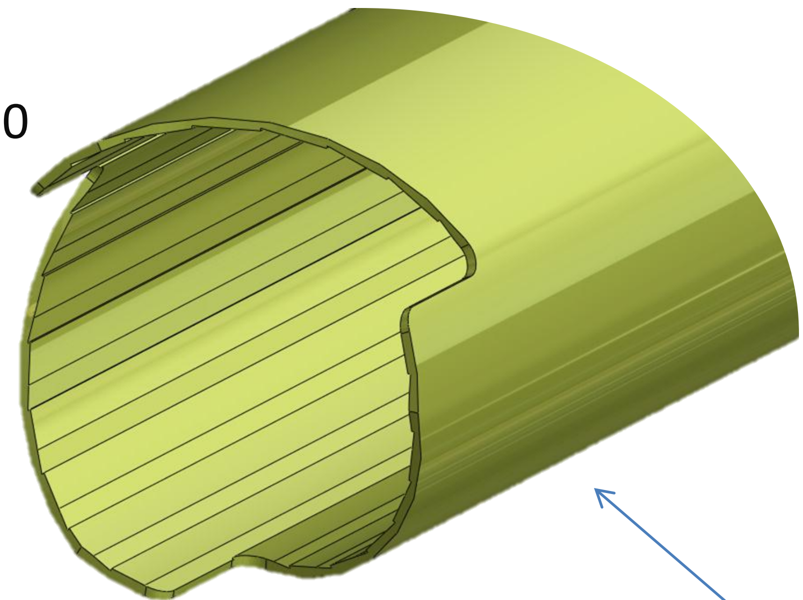
Valve assembly

Sonde – Outer Tube

- Filament-wound fiberglass epoxy tube
  - Wound on a mandrel with the required internal geometry
  - 118mm OD, 113mm ID
  - 0.08mm/m straightness
  - 0.05mm circularity
  - ID tolerance +0.15mm -0.0

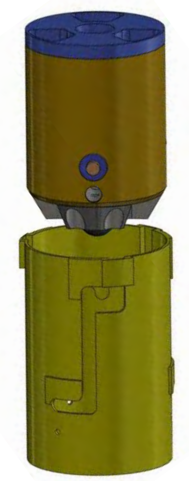


Tube winding mandrel



Sonde – Core Barrel

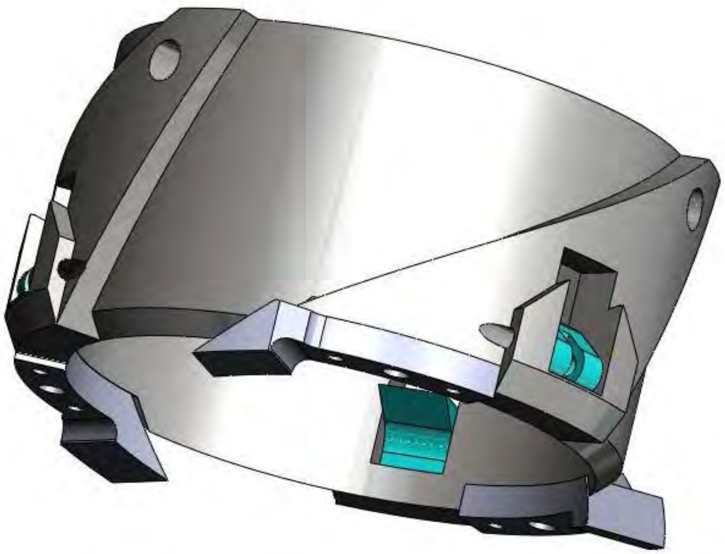
- Based on the Danish drill design
- 304 Stainless Steel core barrel tube
  - 104mm OD, 100mm ID
  - Fusion welded tube
  - 2m long core capacity
  - 0.02mm/m straightness
- Flights
  - Full height polyethylene flights for dry drilling
  - Partial height aluminum flights for wet drilling
- Bayonet coupling with “Supper Banger”

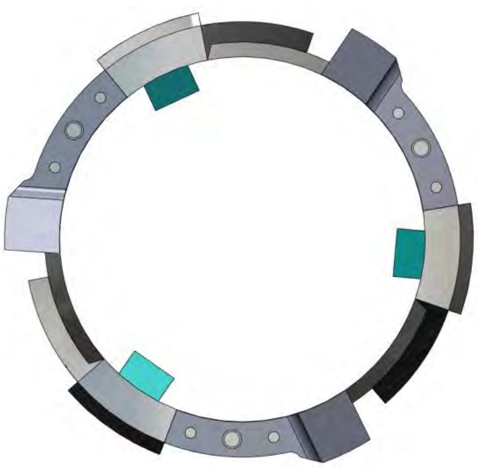


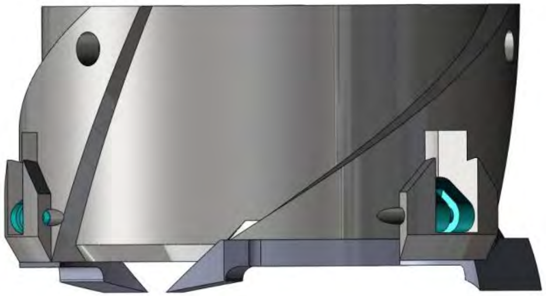
“Supper Banger”

Sonde – Cutter Head

- Based on the Danish drill design
- Three cutters and three core dogs
- 98.0mm Ø core
- 126.0mm Ø for dry hole
- 129.6mm Ø for wet hole
- Cutters
  - 10.0° relief angle
  - 42.5° rake angle



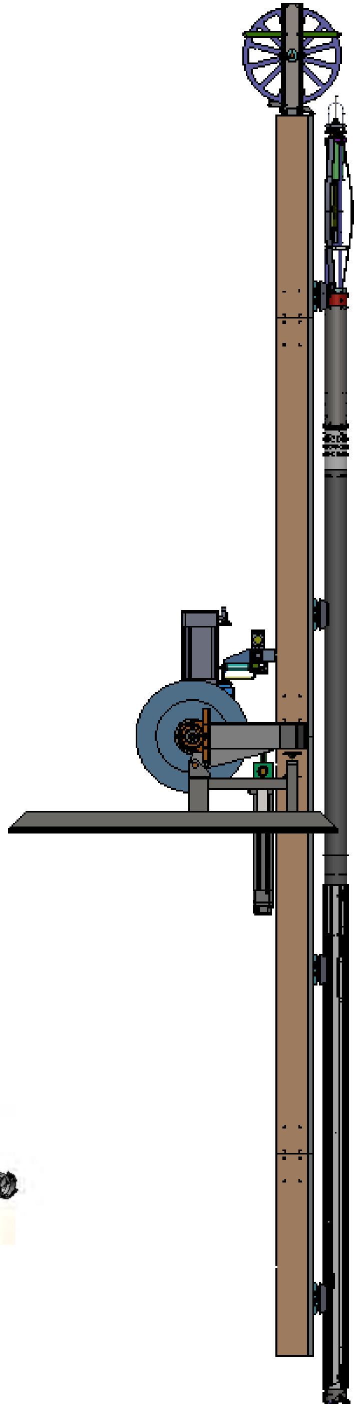




Tilting tower and winch

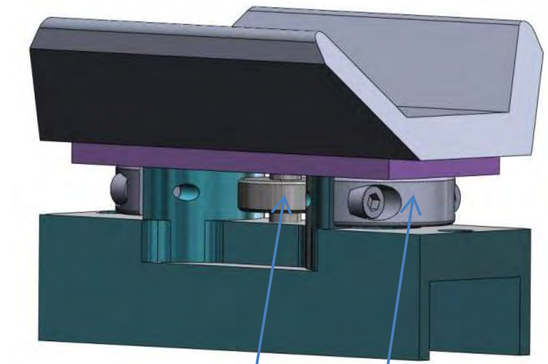
Tower

- Tilting Tower and Winch
  - Drill remains stationary as the tower tilts
  - Permits removal of the drum without rigging
- Square aluminum tube
  - 152.4mm square with a 12.7mm wall thickness
- Modular bolt-together 1m and 2m long sections
- Stainless steel drip pans
- Sized to work with reamers up to 280mm Ø



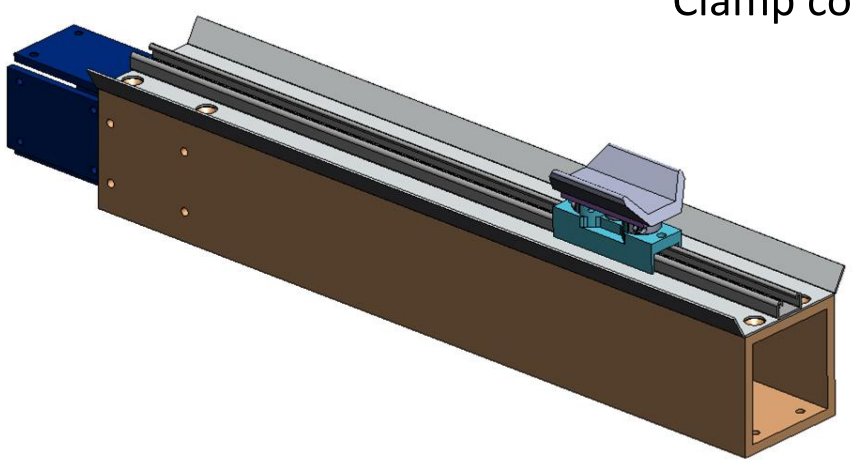
Tower – Drill Supports

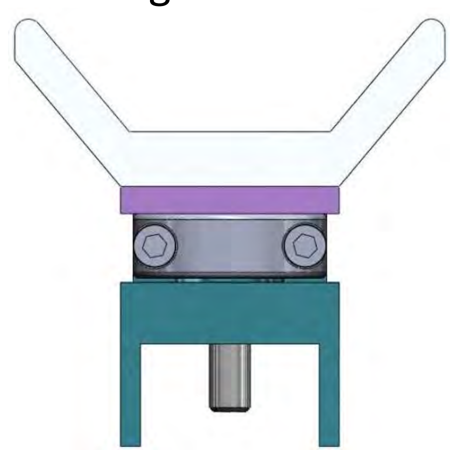
- Mount on a rail running the length of the tower
- Can be positioned at any place on the rail
- 0.75” (19mm) of height adjustment
- Drill working height with tower horizontal is 1.0m (39.4”)



Height adjustment knob

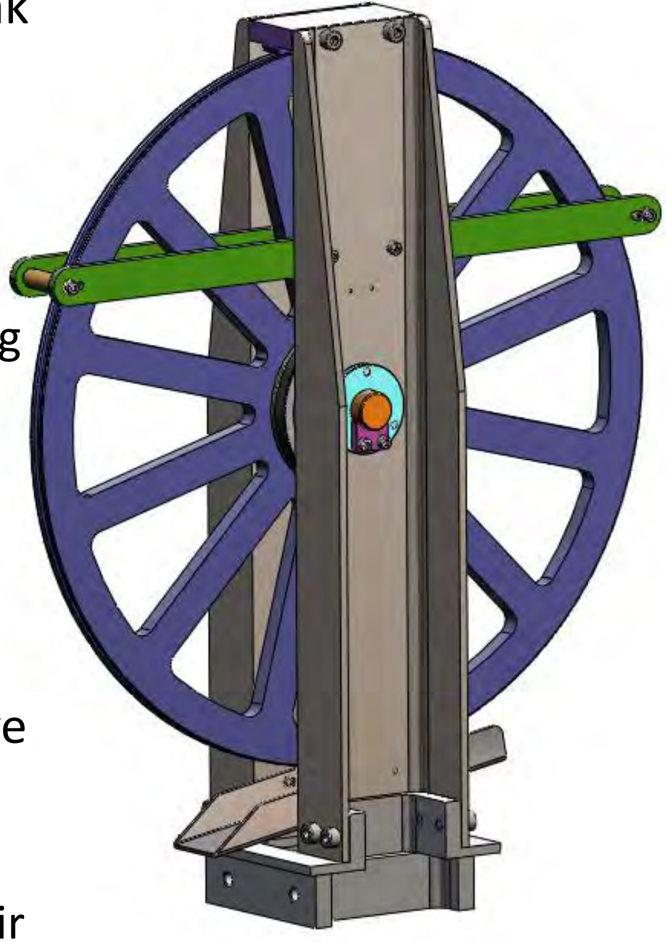
Clamp collars fix rest height



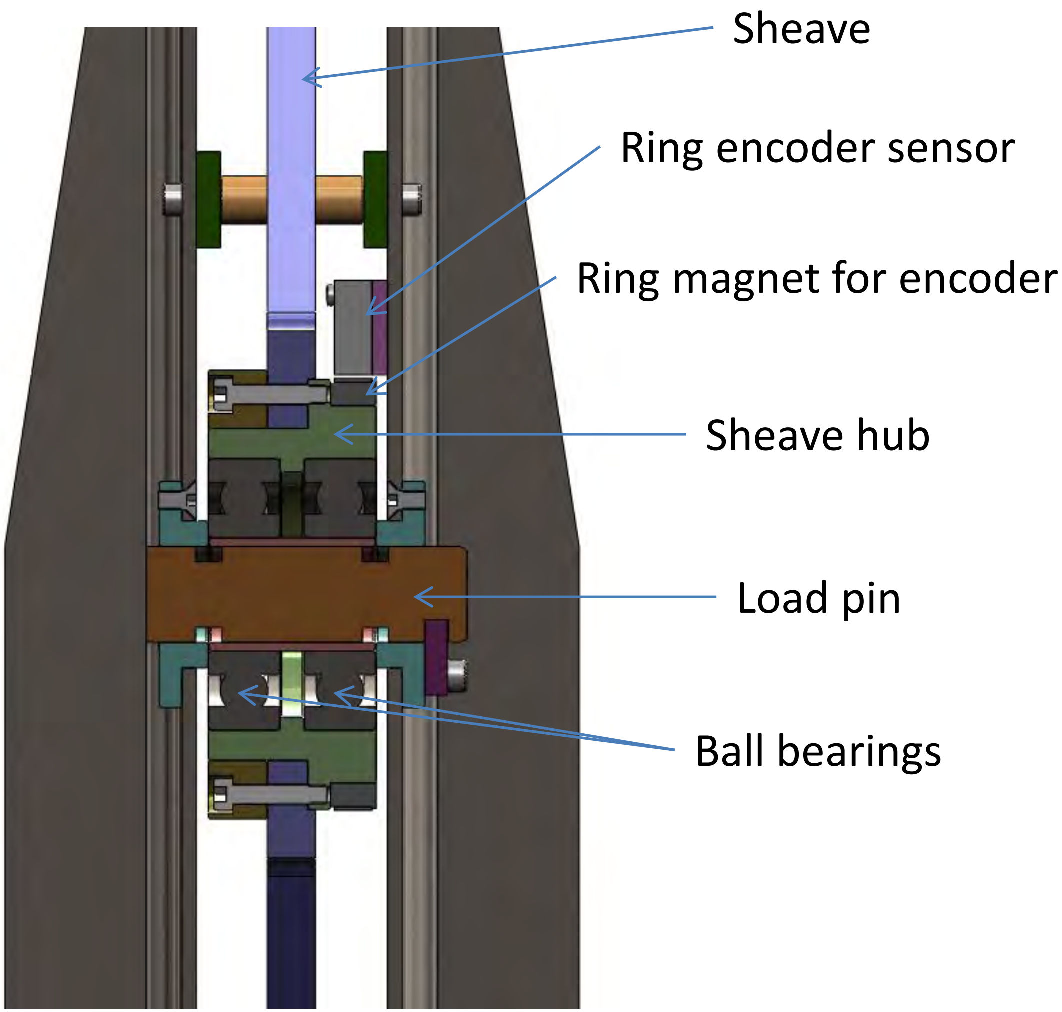


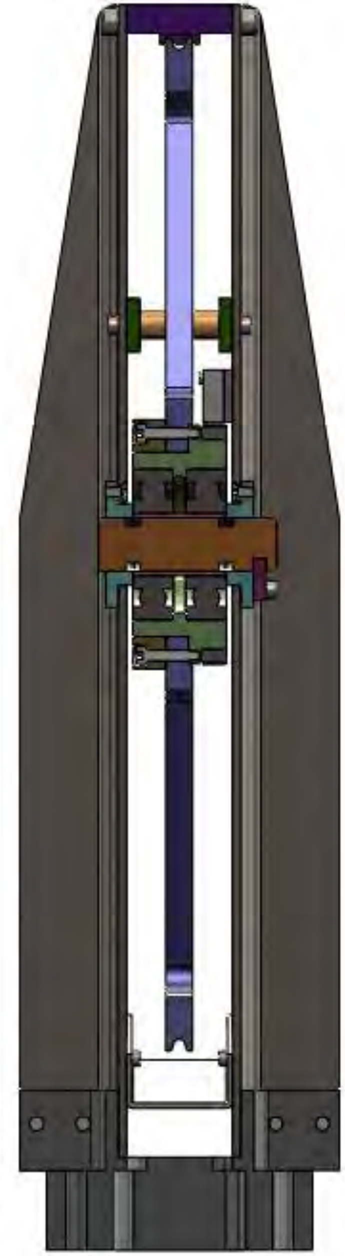
Crown Sheave

- Max load at 1,500m and a 10kN core break is 12.9kN
  - Load pin and bearings would see 25.9kN
- Load pin
  - 22.2kN (5,000lb) rating
  - 33.4kN (7,500lb) capacity before effecting calibration
- Sheave circumference is 1.5m
- Cable payout read by a magnetic ring encoder
  - Resolution better than 0.5mm
- Sheave supported by a pair of deep groove ball bearings
- Static load rating of 32.0kN for the pair
  - Dynamic load rating of 59.2kN for the pair



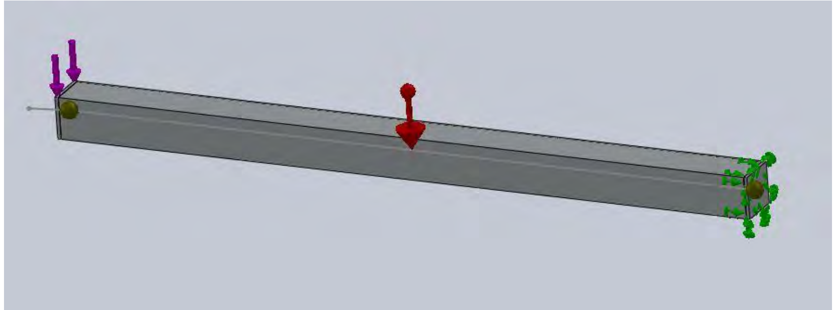
Crown Sheave





Tower – horizontal loading

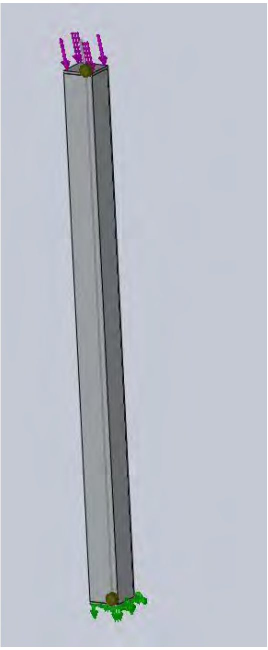
- Tower Geometry
  - Modeled with 'beam' feature
  - Trunnion and sheave represented as 'solid' feature flat plates
- Tower Loading Conditions
  - Fixed constraint at trunnion
  - 1.3kN (300lb) load at 3.0m
  - Gravity applied
- Results
  - Max Deflection: 9.0mm
  - Max stress (bending surface fiber+ axial): 17.0MPa
  - Safety Factor: 16.3



FEA tube model

Tower - Vertical Loading

- Tower Geometry
  - Modeled with ‘beam’ elements
  - Trunnion and sheave represented as ‘solid’ element flat plates
- Tower Loading Conditions
  - Fixed constraint at trunnion
  - 50.0kN (11,236lbs) load 10° from vertical
- Results
  - Max Deflection: 52.0mm
  - Max stress (bending surface fiber+ axial): 92.0MPa
  - Safety Factor: 3.0
  - Error analysis showed stable model <1% variation

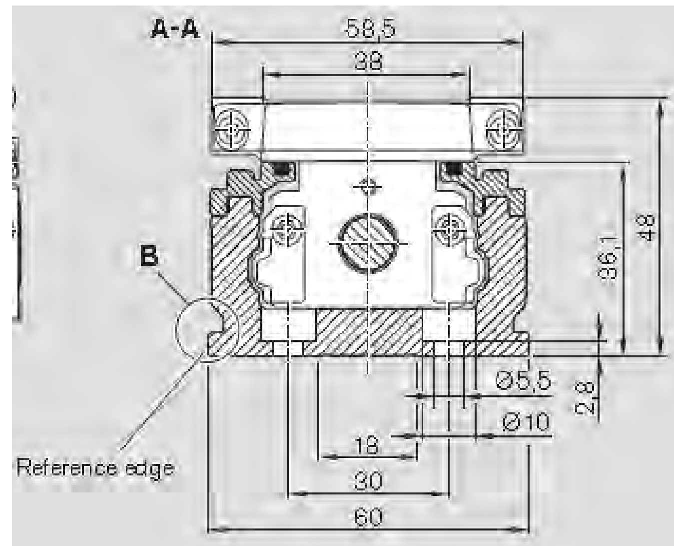


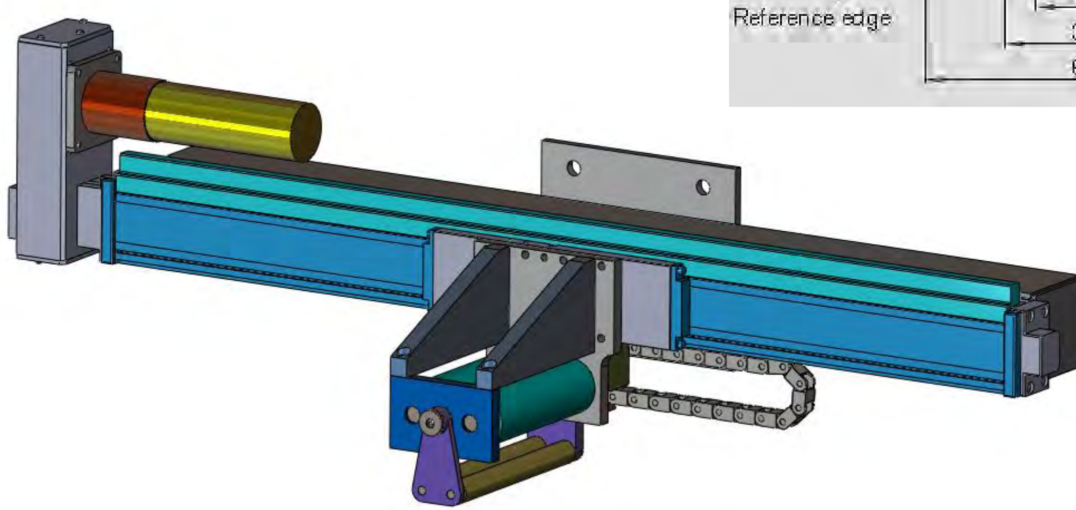
FEA tube model

	Cantilever Deflection (mm)	Cantilever Stress (Mpa)	CableLoad Deflection (mm)	Cable Load Stress (Mpa)	Weight N (lbs)	Hand Calc Cantilever Deflection (mm)	Hand Calc Cantilever Stress (Mpa)
6" Sq X .25"Wall	14	27	90	164	294 (66)	16	26
6" Sq X .5"Wall	9	17	52	92	570 (128)	11	16
7" Sq X .1875" Wall	13	31	73	205	267 (60)	13	24
8" Dia X .5000" Wall	6	15	47	83	605 (136)	8	14
12"x12" Truss	7	28	30	145	360 (81)		

Level Wind

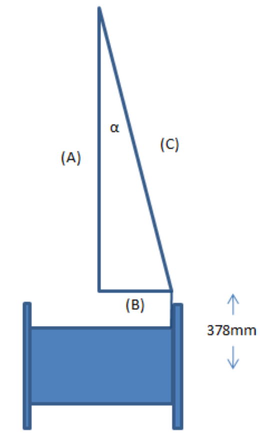
- Stand-alone design similar to the DISC Drill Level Wind
- Bosch Rexroth linear slide
  - Ball screw drive with ball rail system
  - Magnetically sealed cover strip
  - Built-in reed contact limit switches
  - 485mm travel





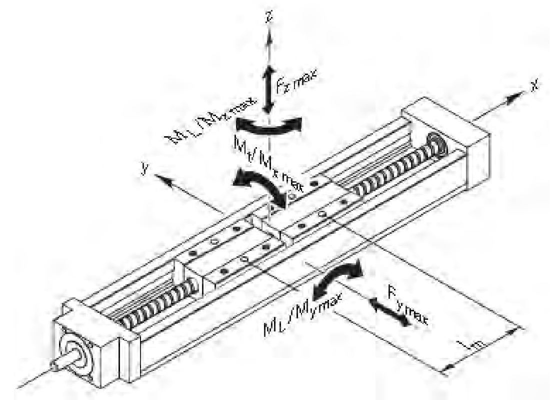
Level Wind

- Travel speed of 6.25mm/s with a line speed of 1m/s
- Drive
  - Maxon 40mm Ø DC motor with failsafe brake
  - 150W
  - 12:1 Planetary gearhead
- IDDO built control
  - Based on the proven DISC Drill system



Max loads at core break @1500m		
Dimensions		units
A	12945	N
B	877	N
C	12975	N

Max load while tripping in fluid (1m/s @1500m)		
Dimensions		units
A	5943	N
B	403	N
C	5957	N



M_L is rated to 541 Nm

M_{Ly} = 63 Nm when B = 403 N

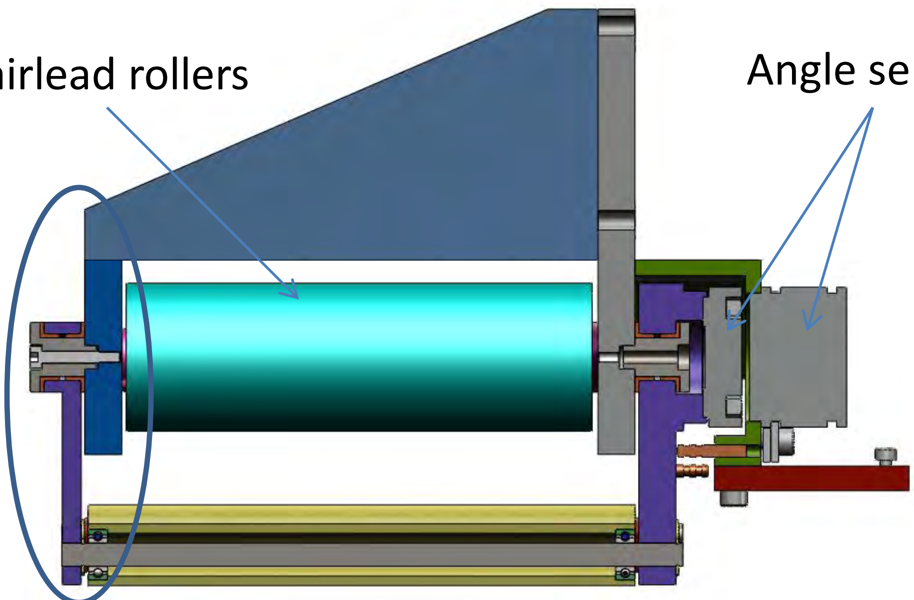
M_{Ly} = 137 Nm when B = 877 N

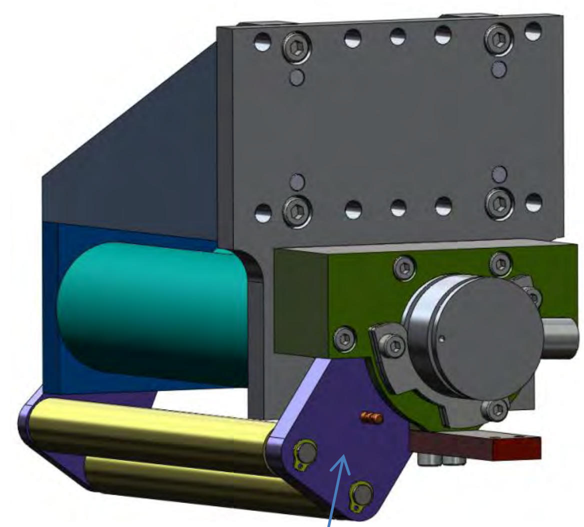
Level Wind –Fairlead assembly

- Cable can be installed by removing two screws
- Cable angle sensed with a sealed magnetic position sensor
- Sensor arm is spring loaded to return to “zero-angle” position

Fairlead rollers

Angle sensor



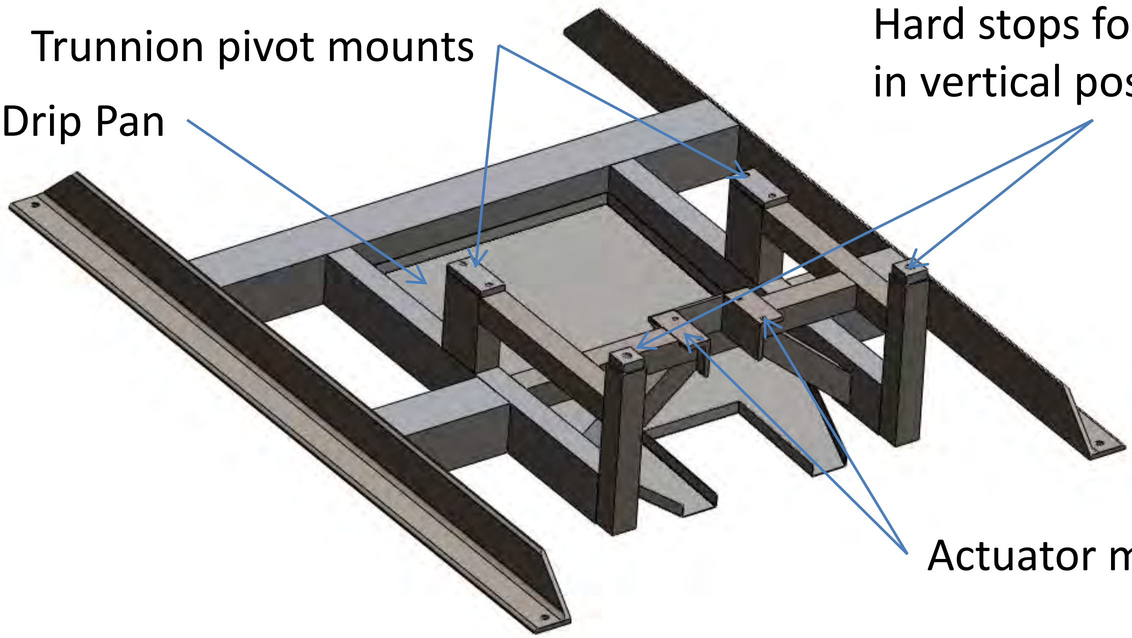


End plate assembly removes with two screws for installing the cable

Angle sense arm with rollers

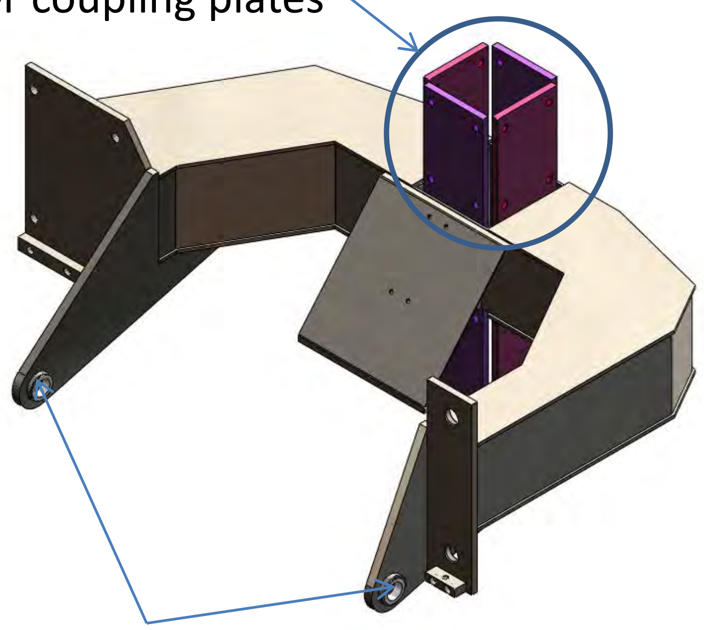
Tower Base

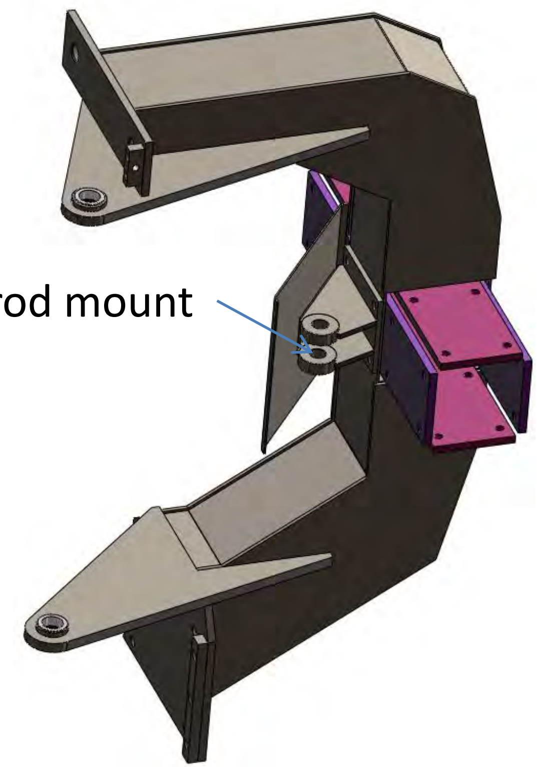
- Welded frame provides mounting points for the trunnion and tower actuator
  - 1.6m L x 1.3m W
- Adjustable stops for parking the tower in the vertical position
- Load analysis in progress



Trunnion

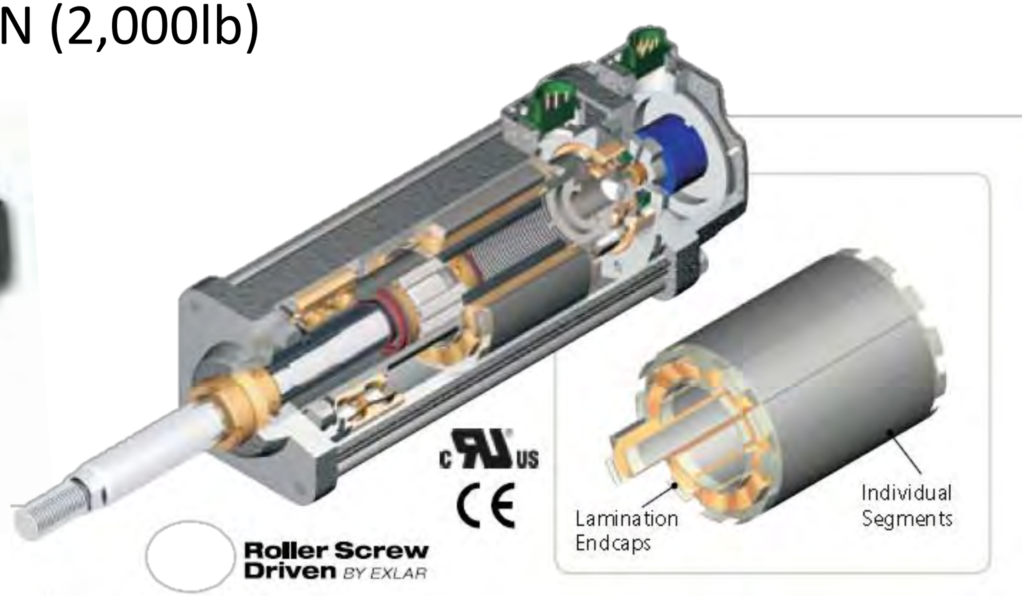
- Sheet metal weldment provides mounting points for the tower and winch components
- Stainless Steel and aluminum construction
- Load analysis yet to be completed



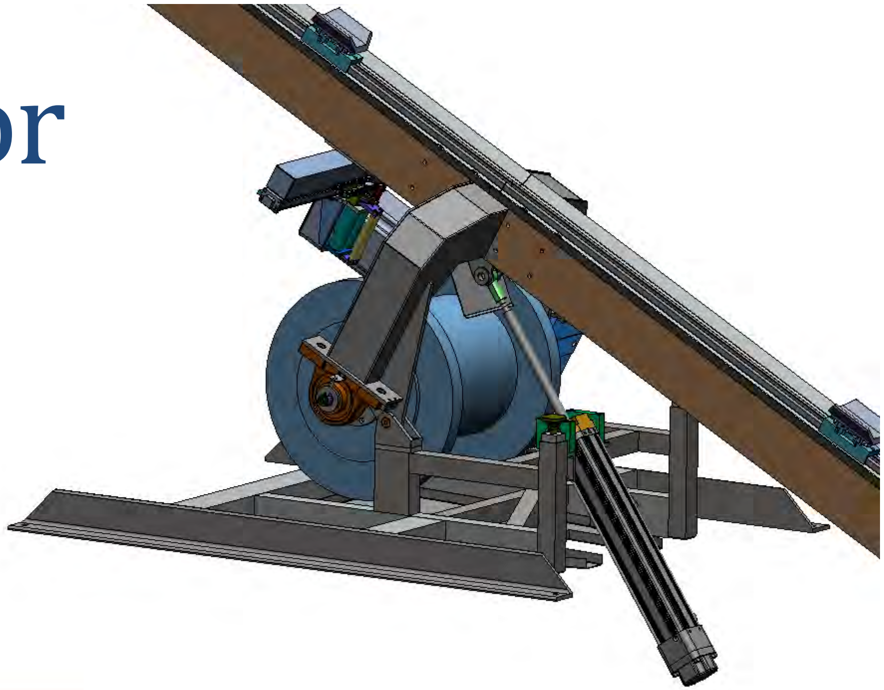


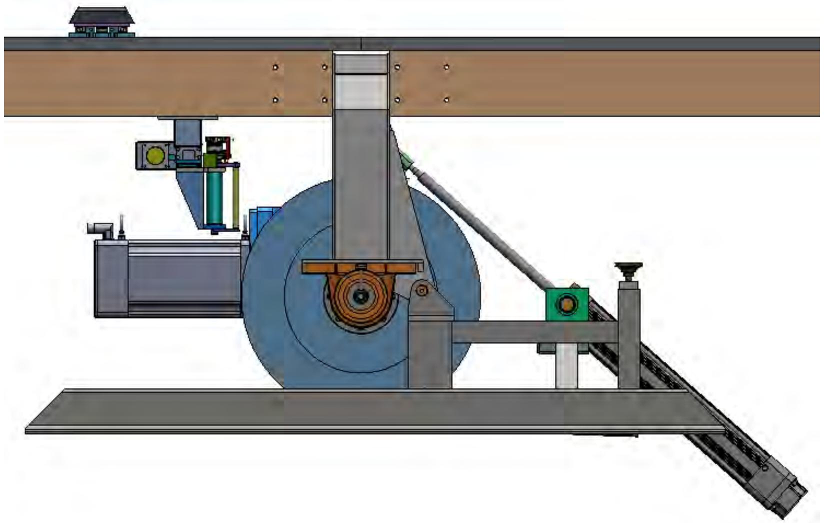
Tower Actuator

- Electric actuator made by Exlar
- Integral motor, fail safe brake, and position feedback system
- 18” of travel, provides 93° of movement
- 99mm square x 0.71m
- 17.6kN (3,966lb) continuous force rating
- Required thrust is 8.9kN (2,000lb)

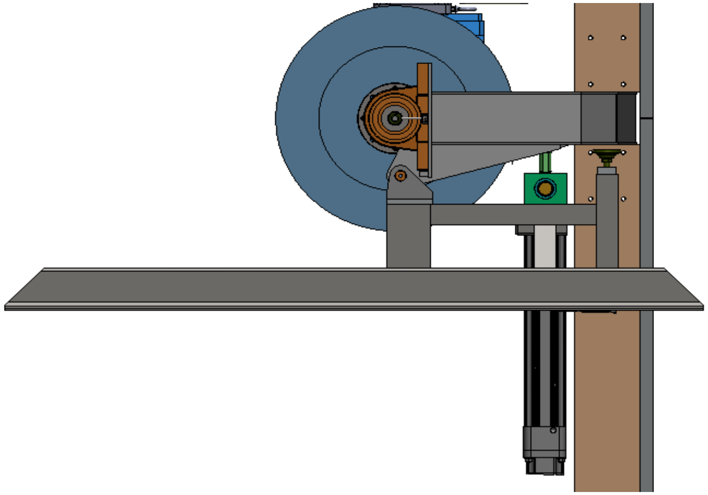


Tower Actuator





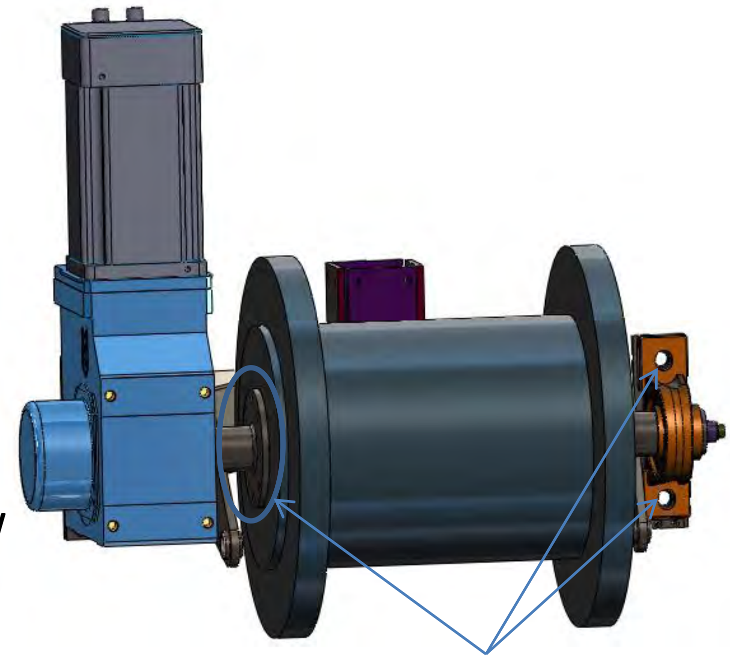
Tower horizontal

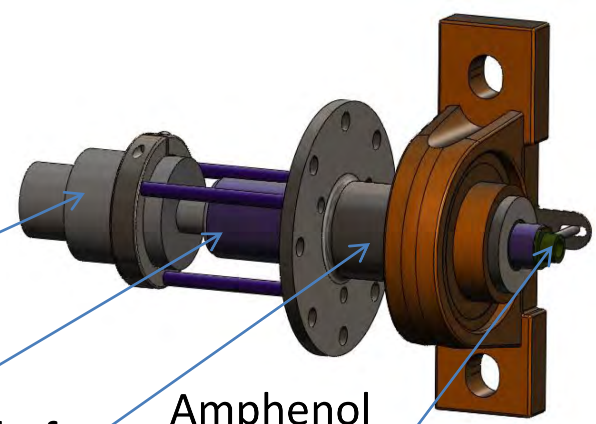


Tower Vertical

Winch

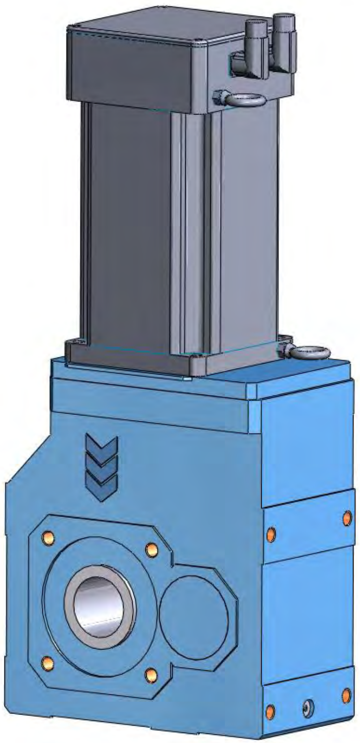
- Removable aluminum drum
  - 1,600m capacity
  - 81 wraps wide x 17 layers
  - 550mm (21.85”) Ø x 508mm(20”) W
  - Lebus grooved core
  - Being manufactured by Sound Ocean Systems, Inc.
- Internal 4-channel slip ring
  - Amphenol connector on end of stub shaft
  - Assembly stays with the drum when removed

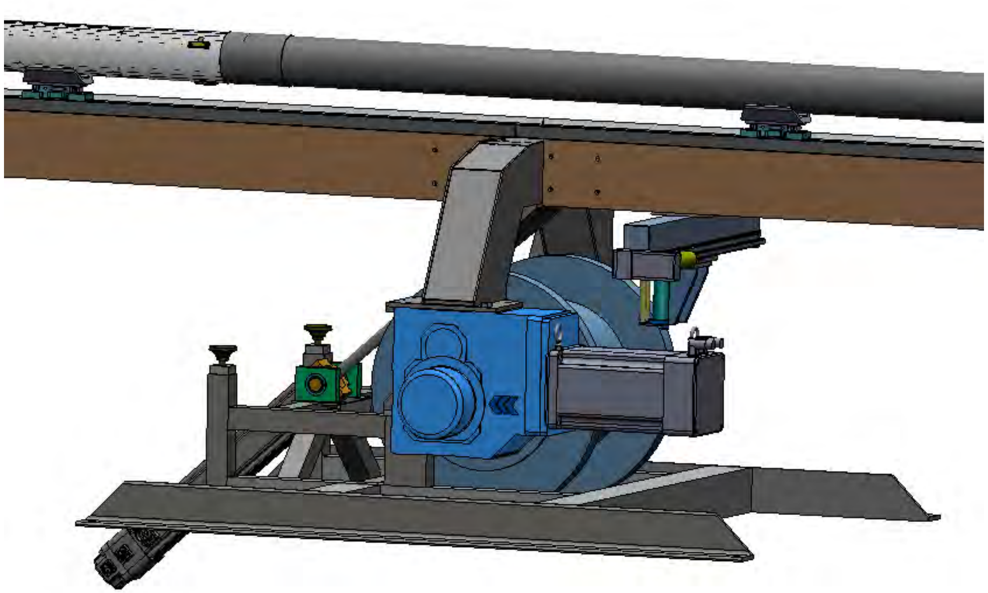




Winch Drive

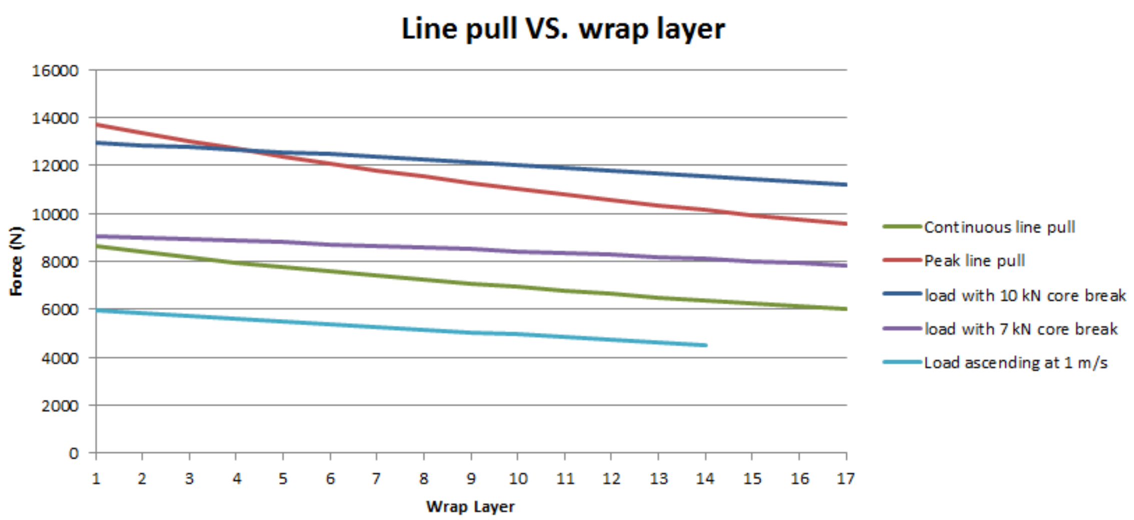
- Helical bevel gear reducer from Watt Drive
  - 56.38:1 ratio
  - Hollow shaft output with shrink disk
- 5.5 kW 8-pole servo motor from Exlar
  - 1-3000rpm speed range
  - Built-in failsafe break





Winch Drive

- Output torque: 1.7kNm
  - 6,007 – 8,615N continuous line pull
- Peak starting torque: 2.7kNm
  - 9,571 – 13,726N peak pull for core break
- Minimum line speed of 0.3 - 0.4 mm/s
- Maximum line speed of 1.0 – 1.4 m/s
- 230/460V 3-phase

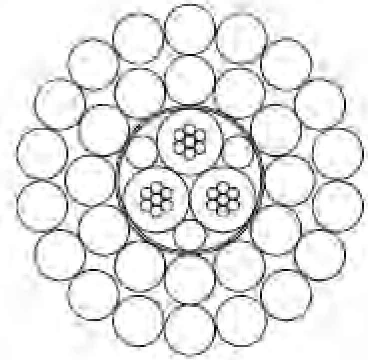


Winch Cable

- Manufactured by Rochester Wire & Cable
- FEP (Teflon) wire insulation
  - Compatible with Isopar-K and Estisol 140
- Two conductors and jacket being used for the drill motor
- One conductor for the anti-torque slip sensor
- A 1,615m cable has been received

DATALINE®

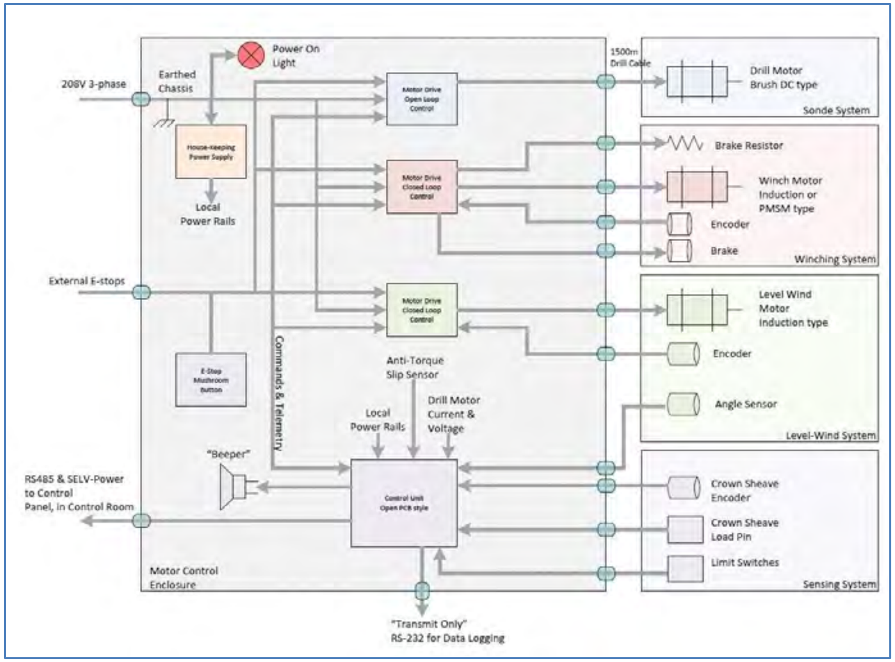
Description	mm	Inch
CONDUCTORS (3) #24 AWG, 7/0.008" (0.2 mm^2) Soft Bare Copper	0.61	0.024
INSULATION 0.012" (0.29 mm) Wall FEP	1.17	0.046
CORE 3 insulated cdrs twisted with high temperature fillers as necessary. Voids filled with free-stripping semiconductive material. Semiconductive tape over core.	2.51	0.099
ARMOR: Special GIPS Wire		
Inner: 12/0.031" (0.79 mm)	4.09	0.161
Outer: 18/0.031" (0.79 mm)	5.66	0.223



CABLE CHARACTERISTICS (Nominal Values @20°C)	Metric	English
PHYSICAL		
Overall Dimensions	5.66 mm	0.223 in
Weight in Air	137 kg/km	92 lb/kft
Weight in Freshwater	116 kg/km	78 lb/kft
Temperature Rating, normal	246°C	475°F
intermittent	260°C	500°F
MECHANICAL		
Breaking Strength	24.5 kN	5,500 lbf
Bend Diameter	30 cm	12 in
Elongation (approximate)	0.58 m/km/kN	2.6 ft/kft/klbf
ELECTRICAL		
Voltage Rating	600 Vdc	600 Vdc
Insulation Resistance @ 500 Vdc	15,000 MΩ-km	50,000 MΩ-kft
dc Resistance		
cdr	94.0 Ω/km	8.7 Ω/kft
armor	14.8 Ω/km	4.5 Ω/kft
Capacitance (cdr - armor)	167 pF/m	51 pF/ft
Velocity of Propagation @ 1 MHz	69 %	69 %

Winch and Drill Control

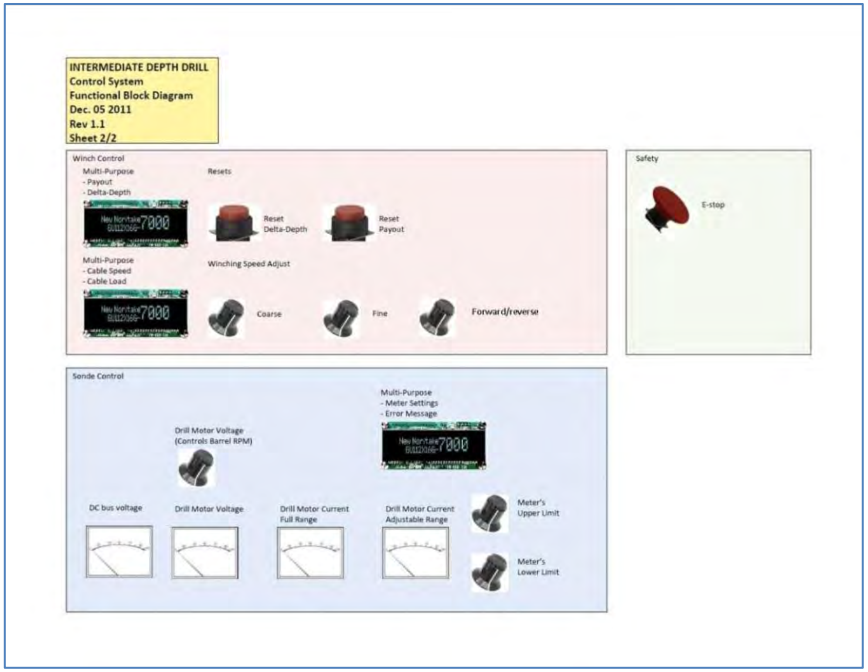
- “Plug and run” control
  - Does not require an external computer to operate
- Motor control components will be in a “warm” enclosure
- The level wind control will be “stand alone”
  - Drive will mount on the level wind
- RS-232 output for data logging



Control enclosure block diagram

Winch and Drill Control

- Drill control
  - Supply up to 600V DC at the surface
  - Step-down power supply in the motor section
- Control pendant
  - Will be separate from the motor control enclosure
  - Cold rated components

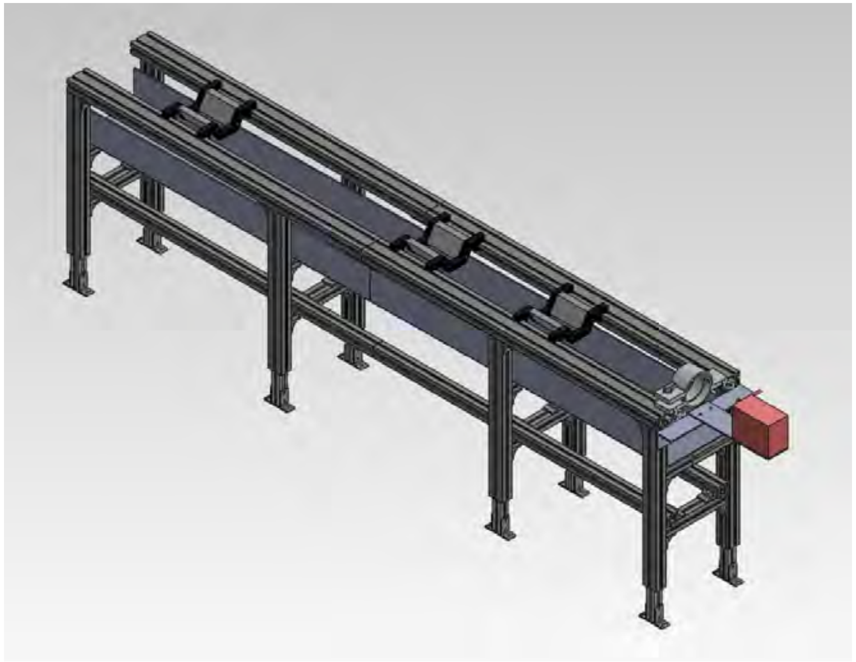


Control Pendant block diagram

Support Systems

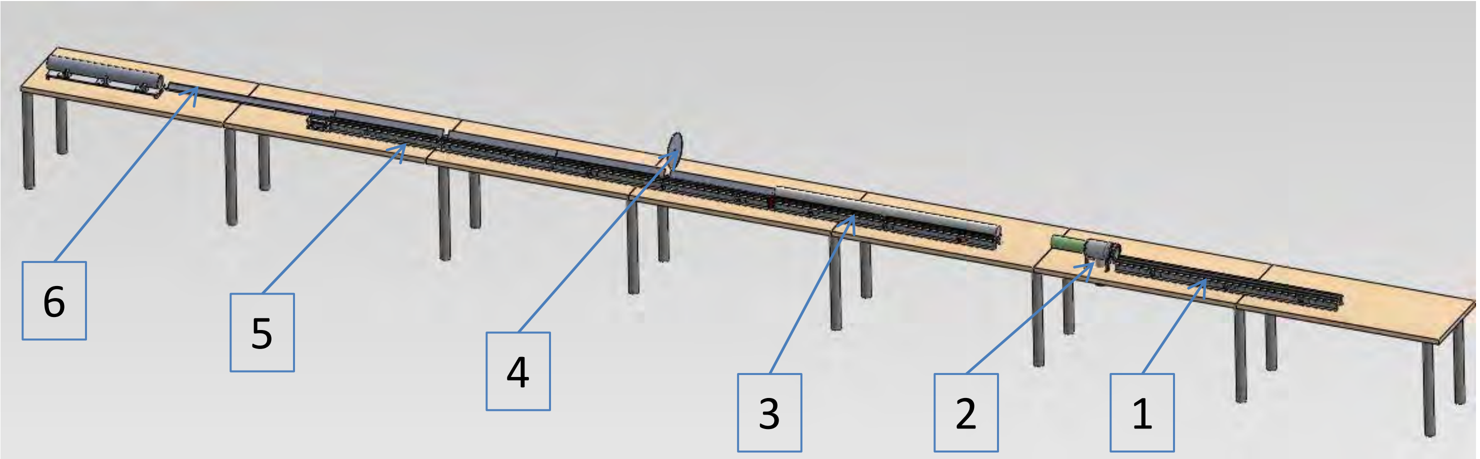
Core Barrel Pull-out Table

- Height adjustable
- Moveable barrel rests
- Barrel pull-out system
  - Hand crank winch
- Easily cleanable collecting trays



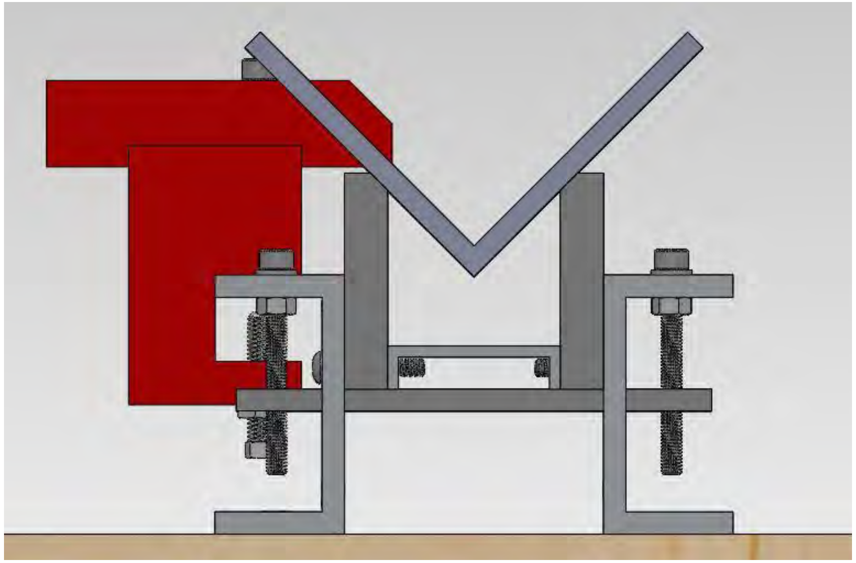
Core Processing

1) Core Push-out Station
2) FED Vacuum System
3) Core Measurement Station
4) Circular Saw
5) Core Processing Station
6) Core Packing Station



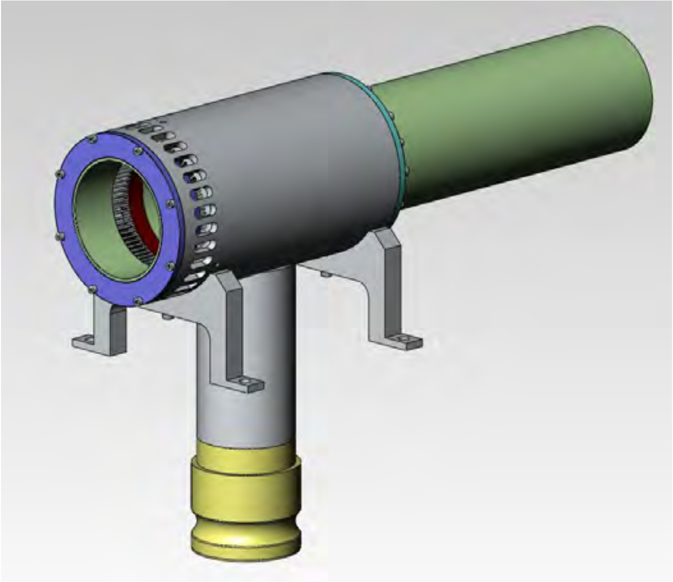
Core Processing (rail system)

- Adjustable height system
- C-channel construction
- 2m section length
- C-clamp for tray positioning



Core Processing (FED)

- Based on DISC Drill FED system
- Reduced size (98mm diameter)
- Netting deployment tube
  - Netting will be used with brittle ice
- New mounting system



Core Processing (Saw)

- Circular Chop Saw
  - 12’’ blade
  - 2.0-2.2 mm kerf

14” chop saw at WAIS Divide

Centrifuge

- Specifications
  - Drum volume 19 liters
  - 6 minute cycle time
  - Footprint 29.5”x36.9”
  - Optional Crane Support
  - Separately Mounted Control Unit
  - 440lb
- The volume of the chips chamber is 15.5L

Fluid Handling System

- Based on current DISC Drill Fluid System
- Smaller Fluid Tank (440 L)
  - Removable lid
- Drum pumps for moving fluid
- 1'' ID Low temp hose
- Simplified Control System
- Replaced acrylic hydrometer parts with polycarbonate

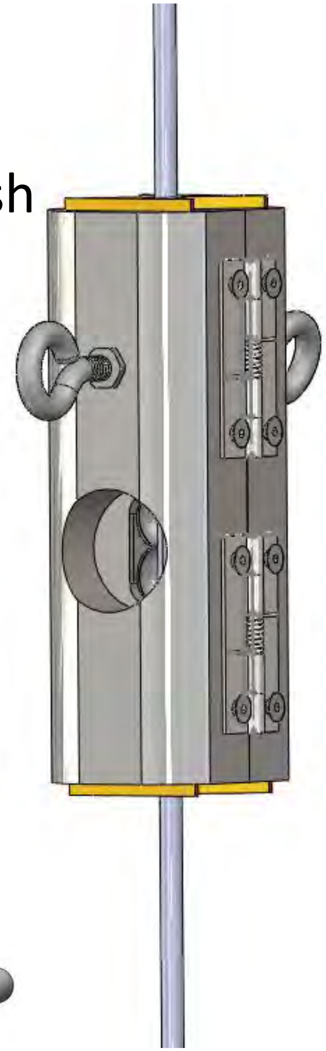
DISC Drill Fluid Handling System

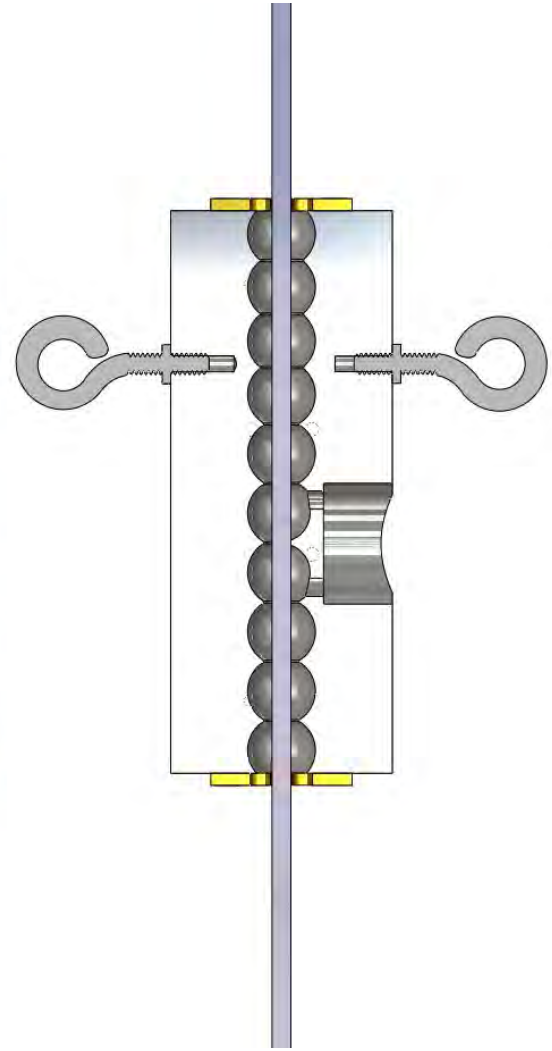
Vacuums

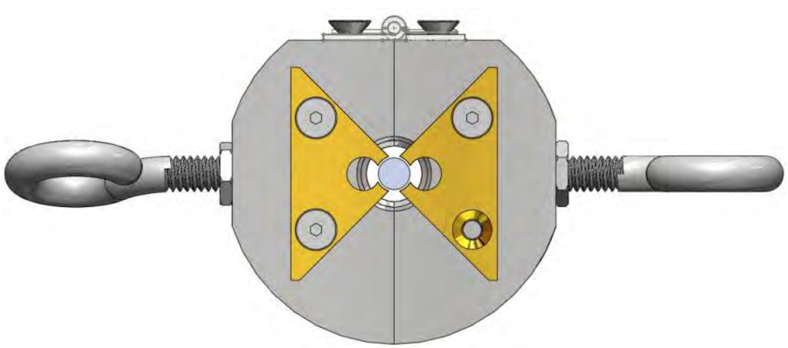
- Explosion proof
- 12.5 gal size
- 1.5 inch hose
- Same vacuums used at WAIS Divide
- For use with the FED and cable cleaner

Cable Vacuum

- Modified version of the Danish cable vacuum
- Field proven design
- Clam-shell opening for easy installation and removal from the cable
- Bronze cable guides







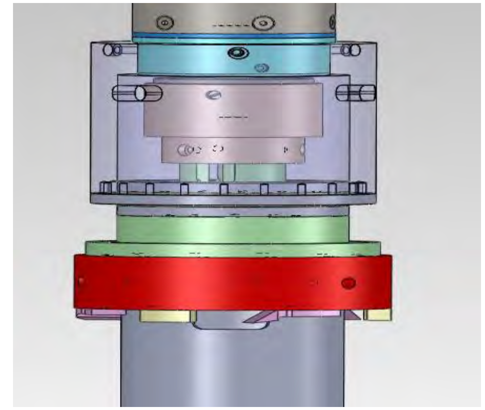
Pilot Hole System

- Polyethylene casing
  - 219mm (8.625”) OD x 192mm (7.549”) ID
  - 3m (10’) long sections
  - ~22.7 Kg (50lb) per section
  - Sealed thread together connections
  - Will need ~40 sections for South Pole
    - 907 Kg (2,000lb) total weight

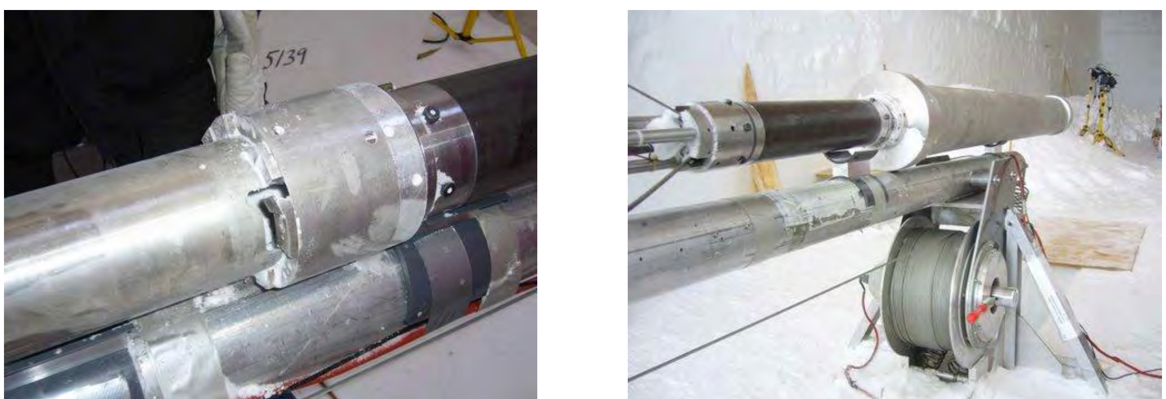
DISC Drill casing

Installing the DISC Drill casing

Pilot Hole System



- Reamers
  - Two step reamer to enlarge the hole from 126mm to 229mm
  - Includes a slewing ring bearing support to prevent bending moments from damaging the motor shaft

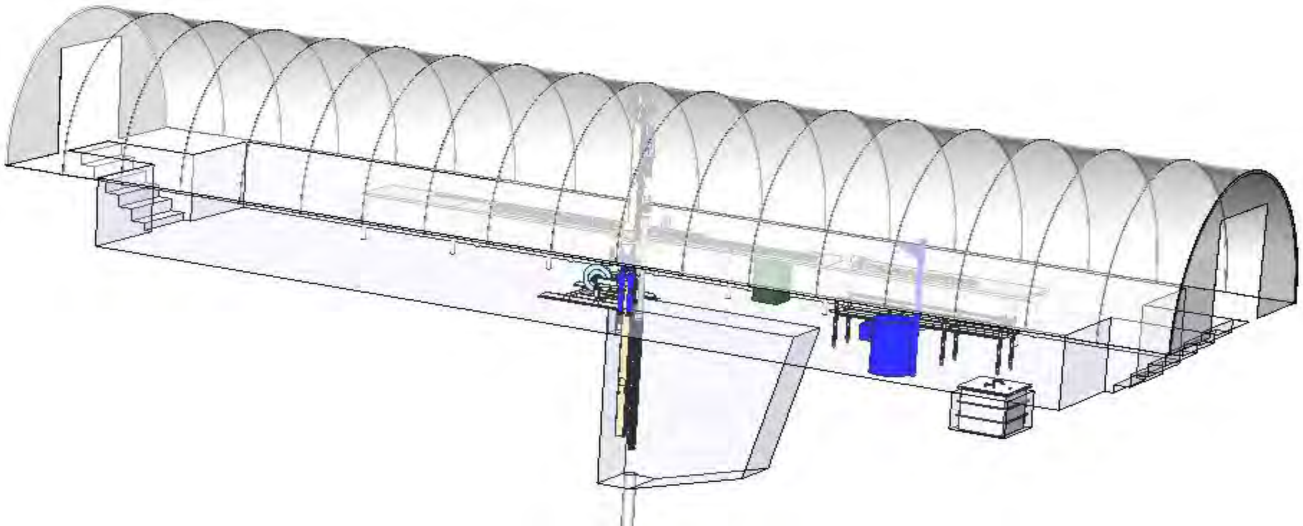


Danish reamers being used with the HT drill

Structures

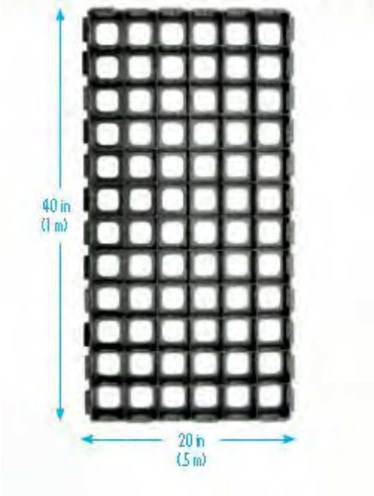
- Drill Tent
  - 4.9m (16ft) x 22.0m (72ft) x 2.8m (9ft) high un-insulated Weatherport
  - Working area will be lowered 1.5m below the surface
  - Building and point of use ventilation
- Generator Tent
  - 3.0m (10ft) x 4.9m (16ft) un-insulated Weatherport

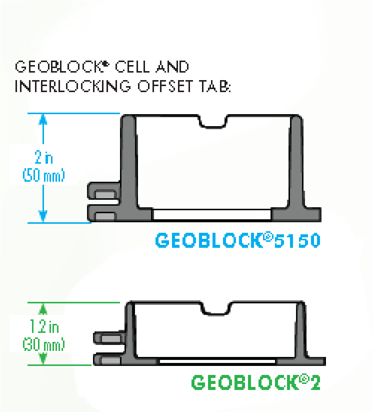
Similar Weatherport in use at NEEM



Structures - flooring

- GEOBLOCK porous pavement system
  - Polyethylene grating
  - 4kg (9lb) per piece
  - Inert to drilling fluids
- Being used by the RICE project





GEOBLOCK in use on the RICE project

Power System

- Modular multi-generator system
- Transportable by Twin Otter airplane
- 12kW average load, Peak load under 20kW (at sea level)
- De-rating for the altitude at South Pole (3,000m) will increase the power requirement to 27kW
- Generators will not be linked
  - Load balancing will be done manually

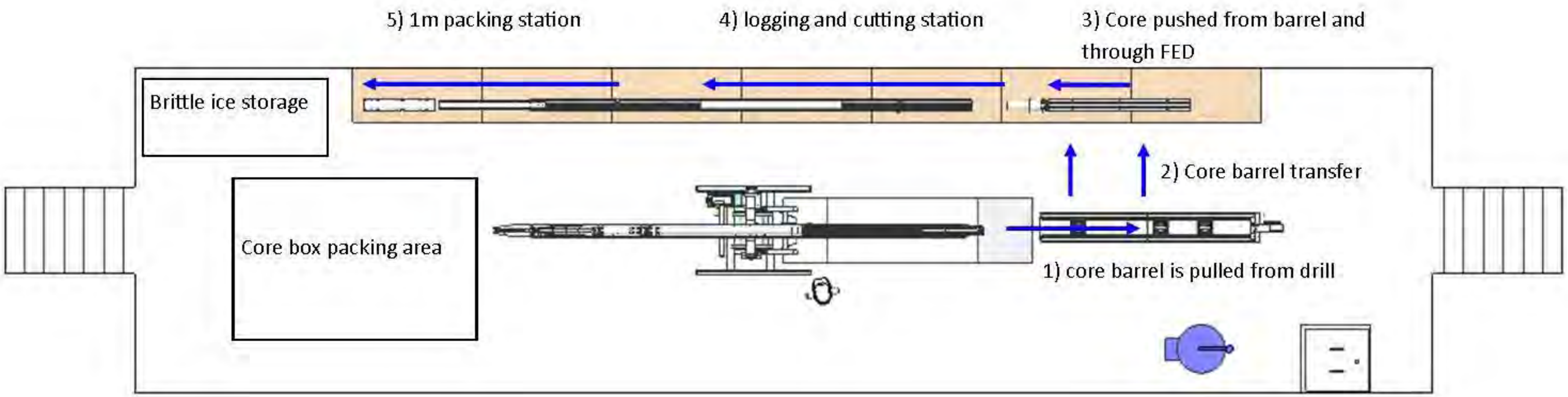
Drilling Fluid

- Two single part fluids are being considered
  - Isopar-K
  - Estisol 140
- Testing in process on samples
  - Viscosity vs. temperature
- Danes recommend using Estisol 140
- Will need 132 drums for 1,500m deep hole
  - Assumptions:
    - Fluid level maintained at 75m
    - 30% loss rate
    - 200l per drum

Safety

- FMEA
- PPE
- Safety Plan including confined space procedure
- Drip pans to contain drilling fluid
- Slot hand rails
- Ventilation
  - Drill Tent
  - Slot
  - Centrifuge
  - Vacuum systems
- Centrifuge controls remotely mounted
- E-stop system

Core Processing Flow

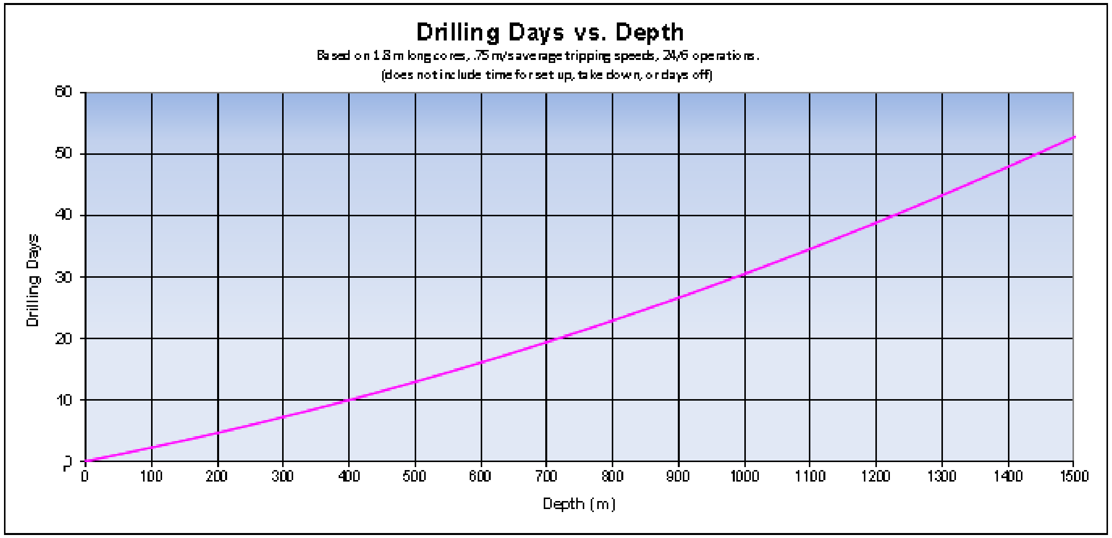


- How to handle brittle ice?
  - Cut and pack as with ductile
  - Short duration 2m buffer, than cut and pack in tubes
  - Trench off of drill tent for over winter storage of 2m cores
  - Drill two 1m cores in one drill run
    - Has not been tried with this type of drill

Drilling Plan

24/6 schedule: 3 persons per shift

- Dry drilling to ~135m
  - Drilling will start from the bottom of the slot
- Ream hole to ~125m
- Set casing
- Wet drilling



Discussion