IDD System Engineering Design Review

IDD Project Timeline

Milestone Description	Expected Completion Date
Approval of Intermediate Drill Conceptual Design	05/31/11
Submission of IDPO-IDDO FFY 2012 Annual Plan to NSF	08/31/11
Begin Detailed Design of the Drill Based on Conceptual Design	10/01/11
Submission of Formal Conceptual Design Document to IDPO for Approval	11/30/11
IDD System Design Verification Review	07/26/12
IDD System Science Review	10/17/12
Complete System Design	12/31/12
IDD – Full System Engineering Design Review	03/29/13
Complete Fabrication of the Drill	09/30/13
Draft of Testing, Operating, and Maintenance Documentation	12/31/13
Integration of Drill System (including integration test)	03/31/14
Complete Field Testing	06/15/14
Review of Field Test and Needed Improvements	06/25/14
Complete Improvements and Modifications after Testing	08/31/14
Finalize Safety, Operating, and Maintenance Documentation	09/30/14

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.

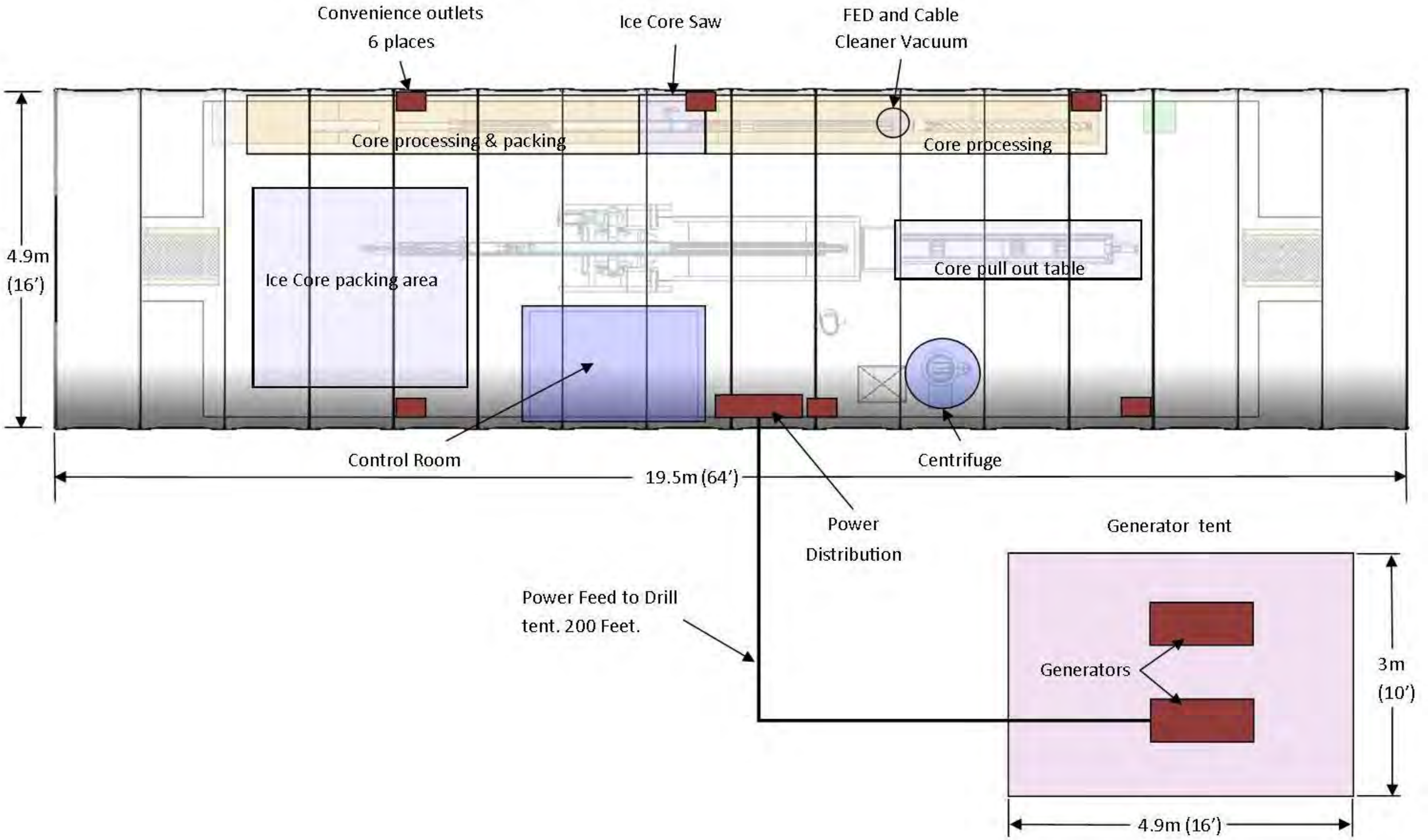
6.8.1 Keep logistical needs and expenses at the minimal reasonable level.

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

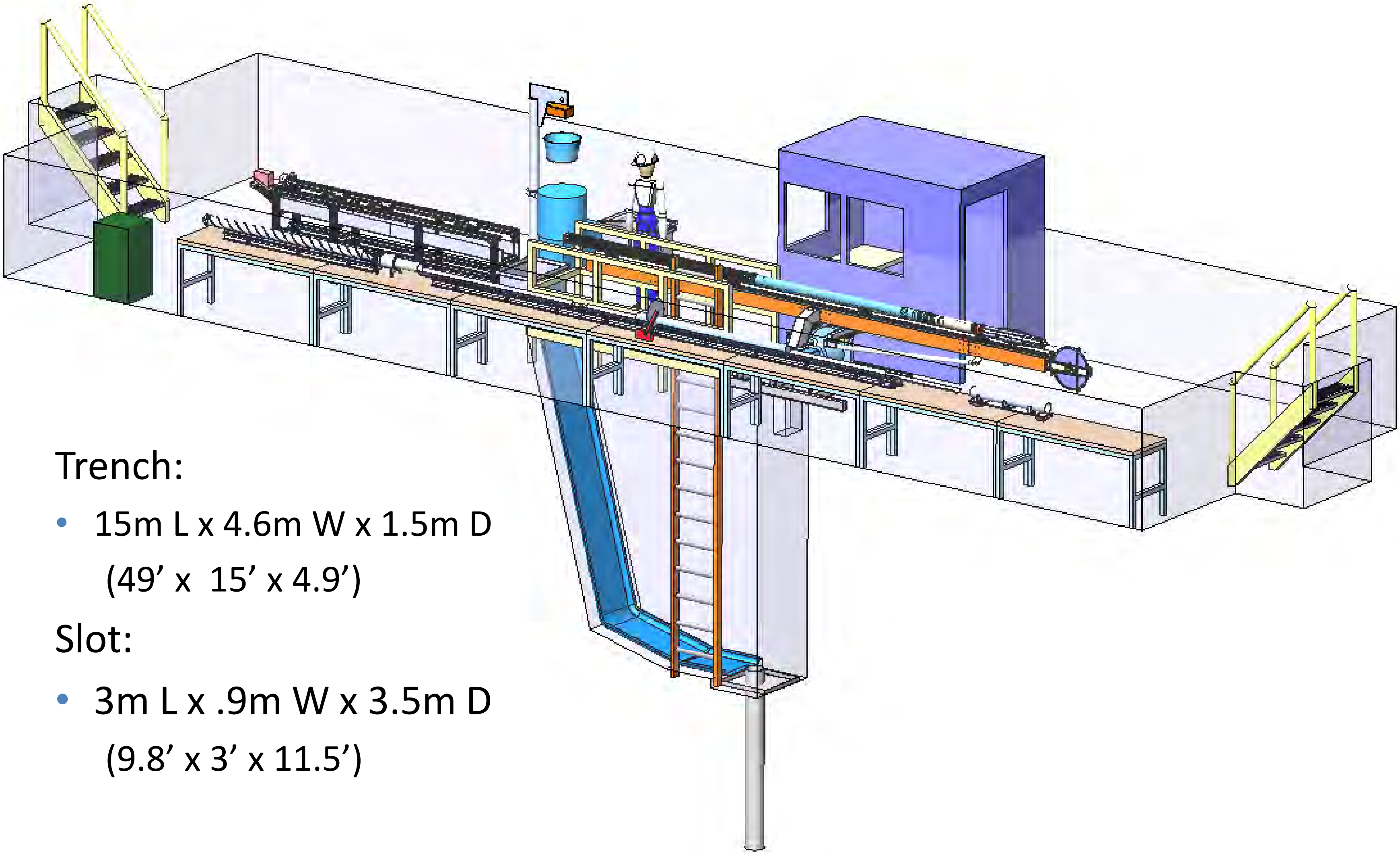
6.8.3 Design the system for rapid set-up and check out, and subsequent removal at the end of the season.

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 site Layout



Trench:

- 15m L x 4.6m W x 1.5m D
  (49’ x 15’ x 4.9’)

Slot:

- 3m L x .9m W x 3.5m D
  (9.8’ x 3’ x 11.5’)

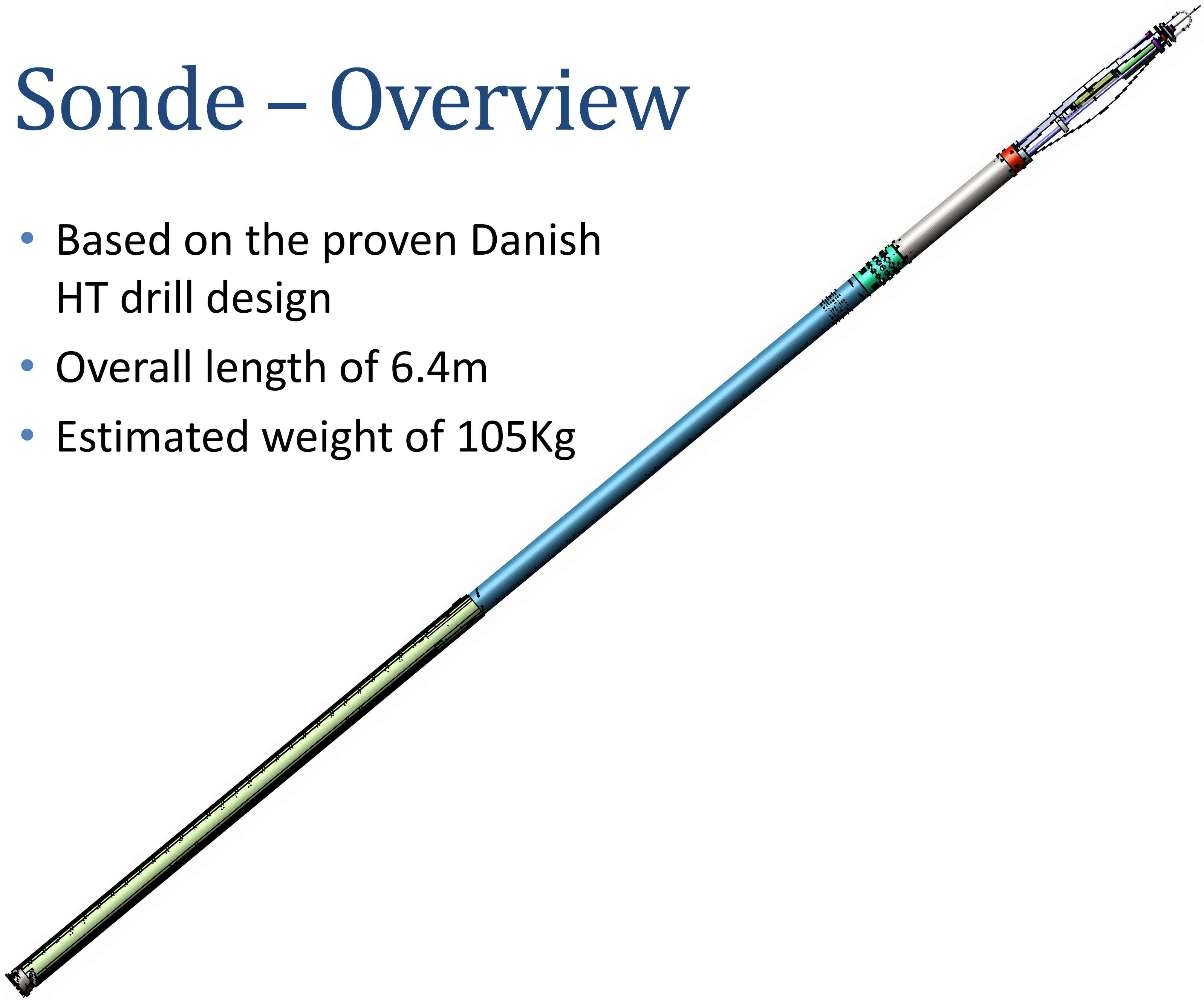
Drill System Design

- 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 10kN

Sonde

Sonde – Overview

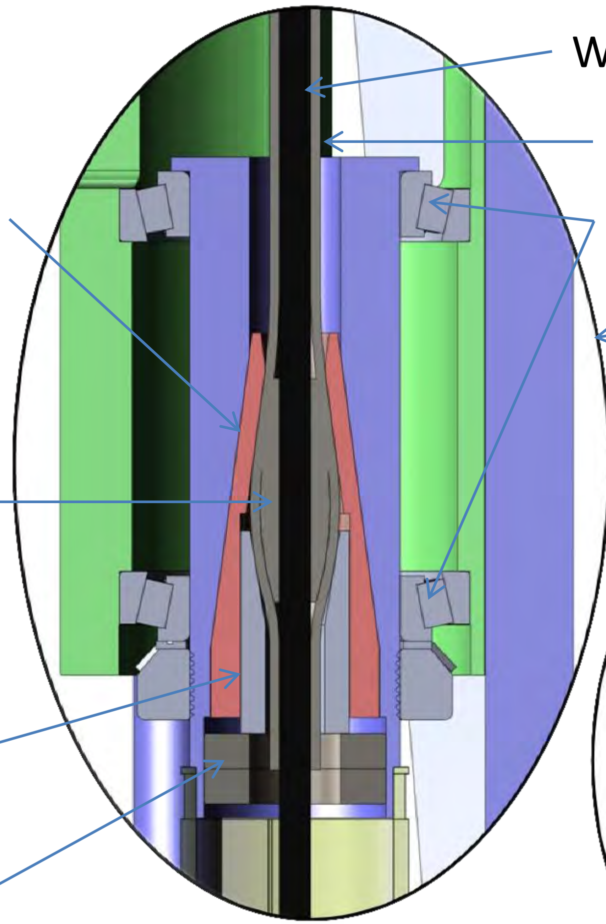
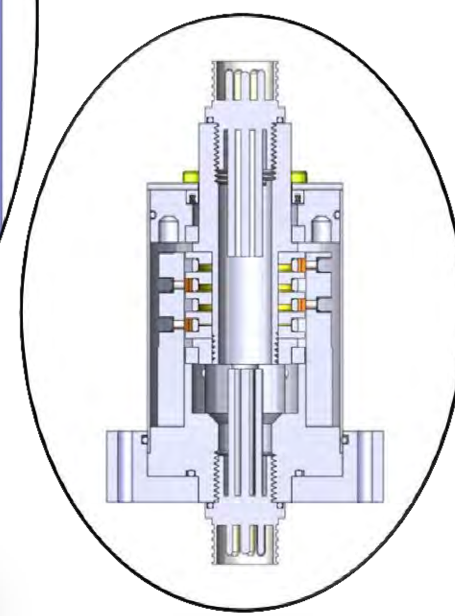
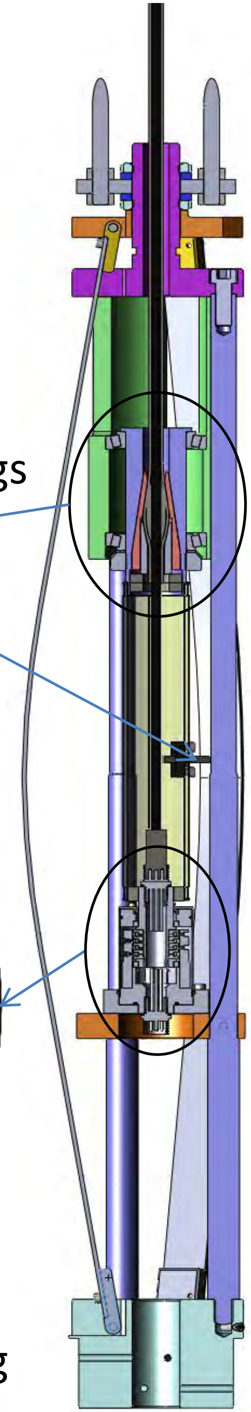
- Based on the proven Danish HT drill design
- Overall length of 6.4m
- Estimated weight of 105Kg



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
- 4-pin SeaCon MINI-CON connectors
  - 10,000psi open face pressure rating
- Anti-Torque slip sensor
- Top recovery loop
- Single adjustment moves all three blades

Sonde – Anti-Torque

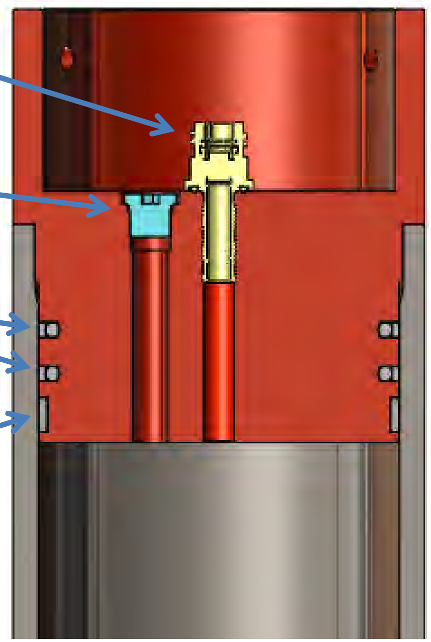




Section view of Slip Ring

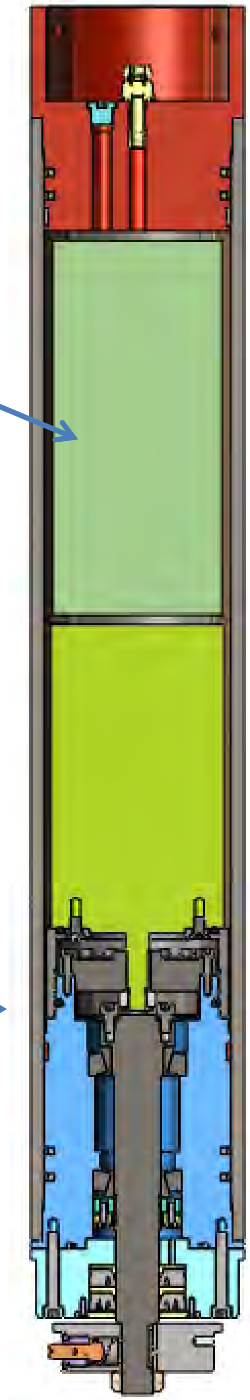
Sonde – Motor Section

- Permanent magnet brushed DC motor
  - Manufactured by Minnesota Electric Technology (MET)
  - 500w (0.68hp)
  - 280V
  - 5400rpm
- Harmonic Drive speed reducer
  - 80:1 ratio
- Internal motor power supply with current limiting protection
- Minimum pressure rating of 4,000psi
- Tapered roller bearings carry the core break force
  - Static load capacity of 38kN
- 65 to 68rpm cutter speed
- 4-pin SeaCon MINI-CON connectors
  - 10,000 psi open face pressure rating

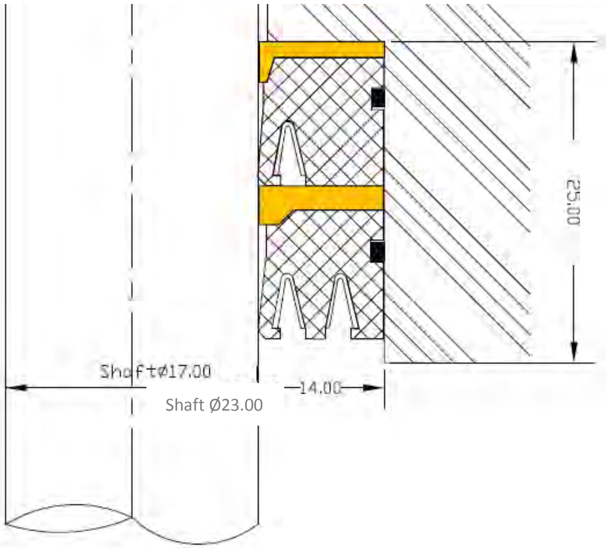
Sonde – Motor Section



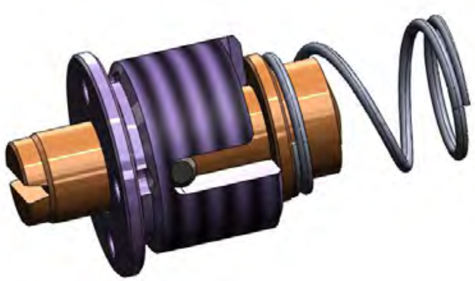
Top Plug



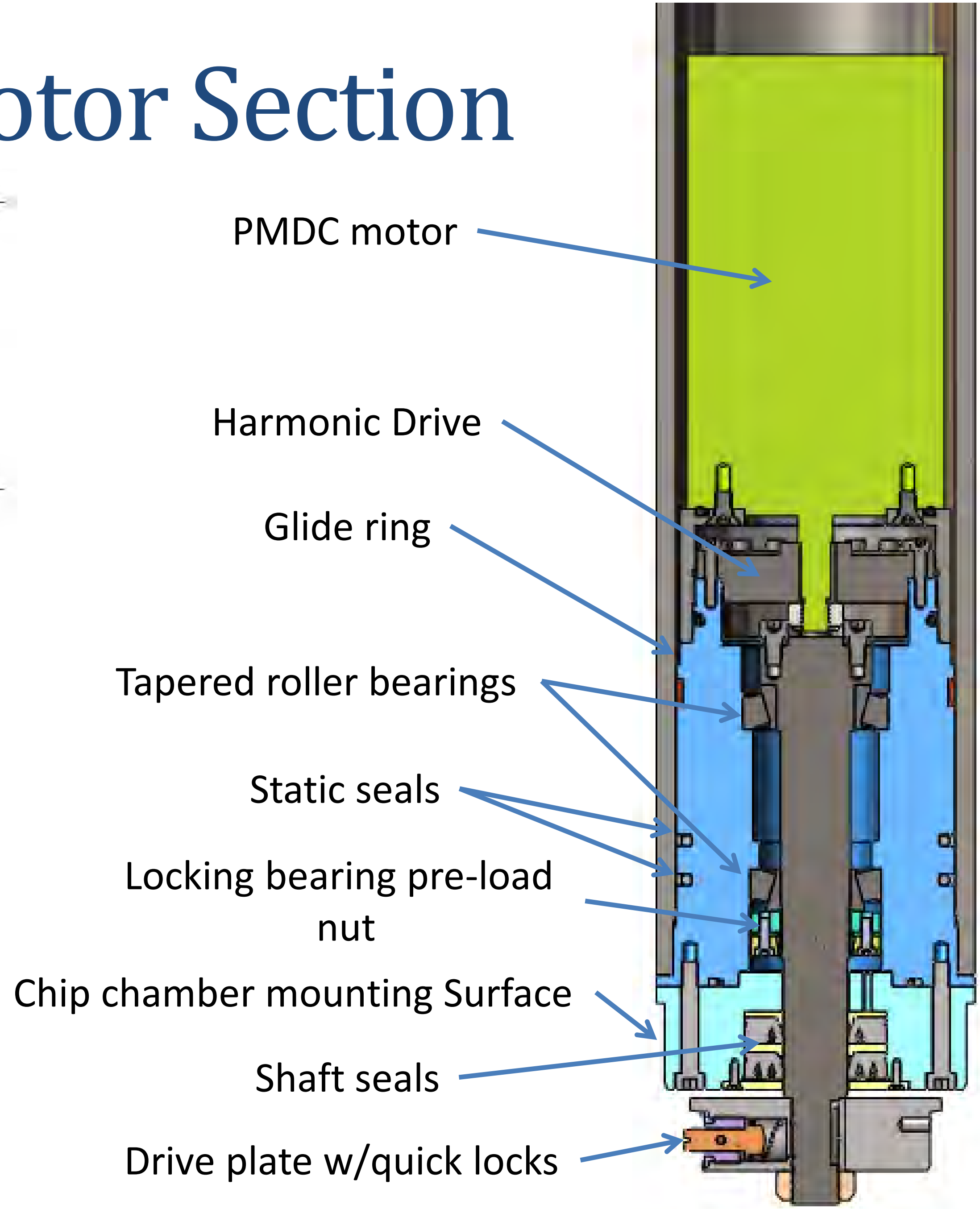
Sonde – Motor Section



Shaft seal detail



Drive plate quick locks

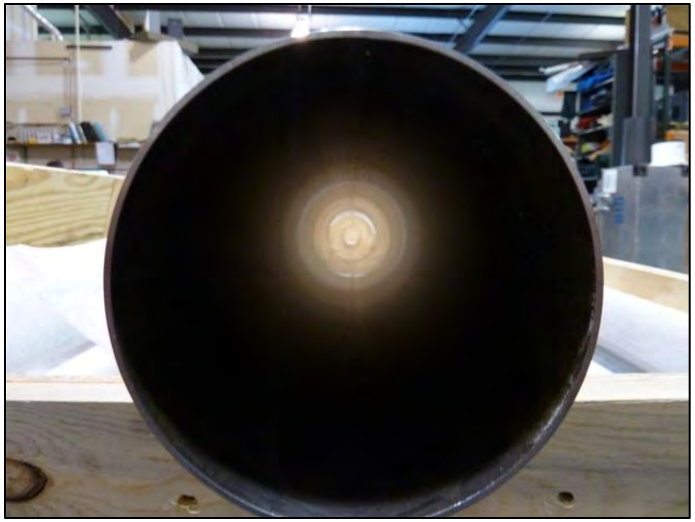


Sonde – Motor Section, Seals

- Static and shaft seal package designed by American High Performance Seals
- All seal materials are compatible with both Isopar K and Estisol 140

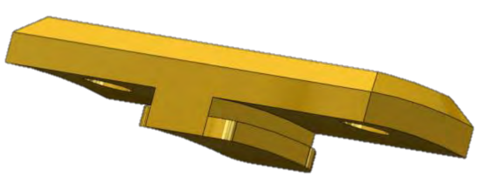
Barrel Tubing

- 304 series Stainless Steel
- Fusion welded seam
- 0.2mm/m straightness
- Vacuum annealed

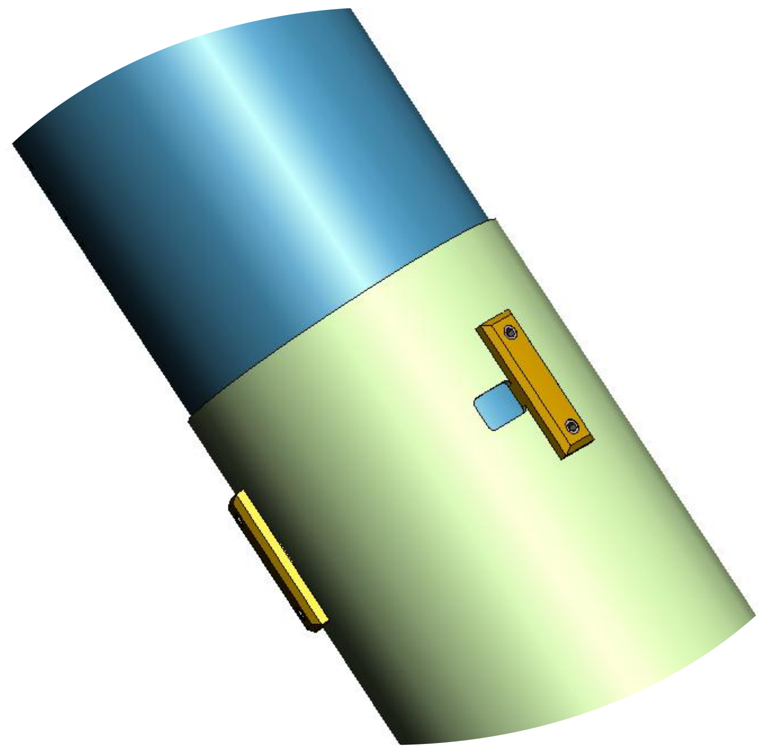


Sonde – Chips Chamber

- 114.3mm OD, 110.0mm ID
- Outer tube mounts to the chips chamber with three locking pieces
- Two barrel configurations
  - Solid tube
  - Tube with filter holes
    - 7,200 1.4mm Ø holes

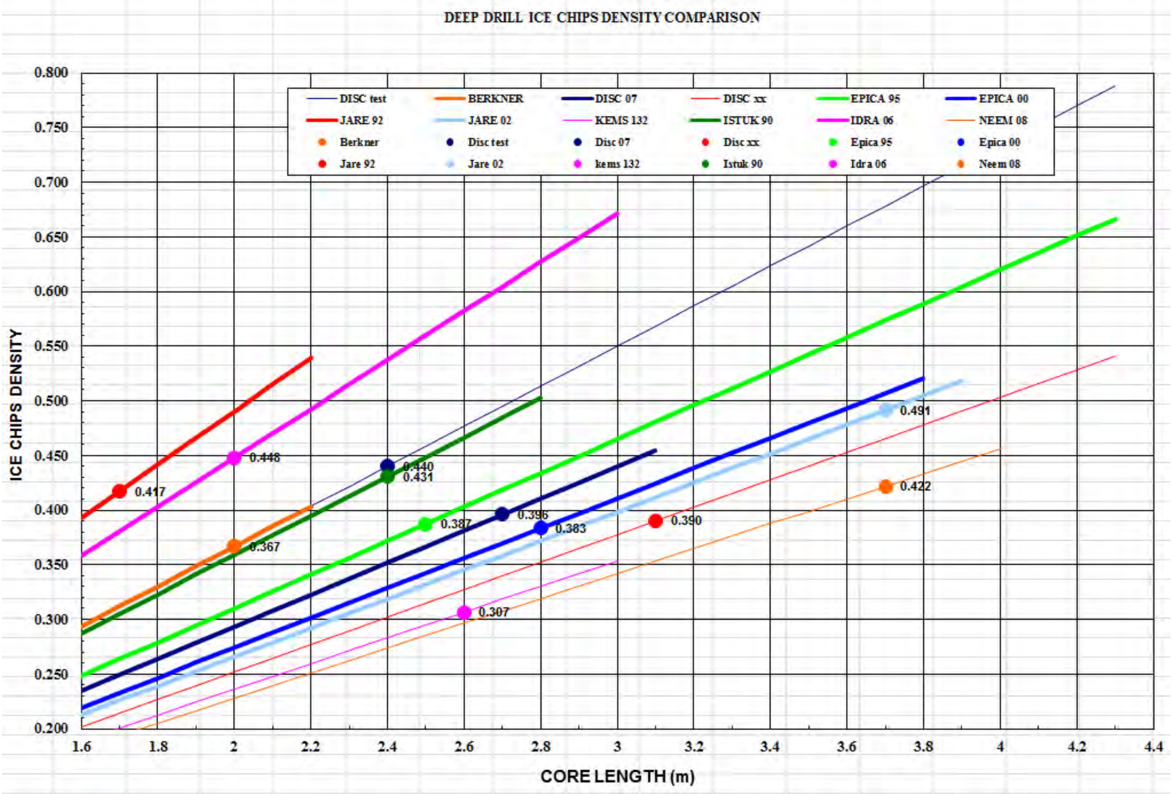


Barrel locking piece



Chips chamber

- 2.269m usable length for chips
  - 0.372 chips density with a 129.6mm Ø bore (wet drilling)
  - 0.305 chips density with a 126.0mm Ø bore (dry drilling)



Comparison done by Laurent Augustin

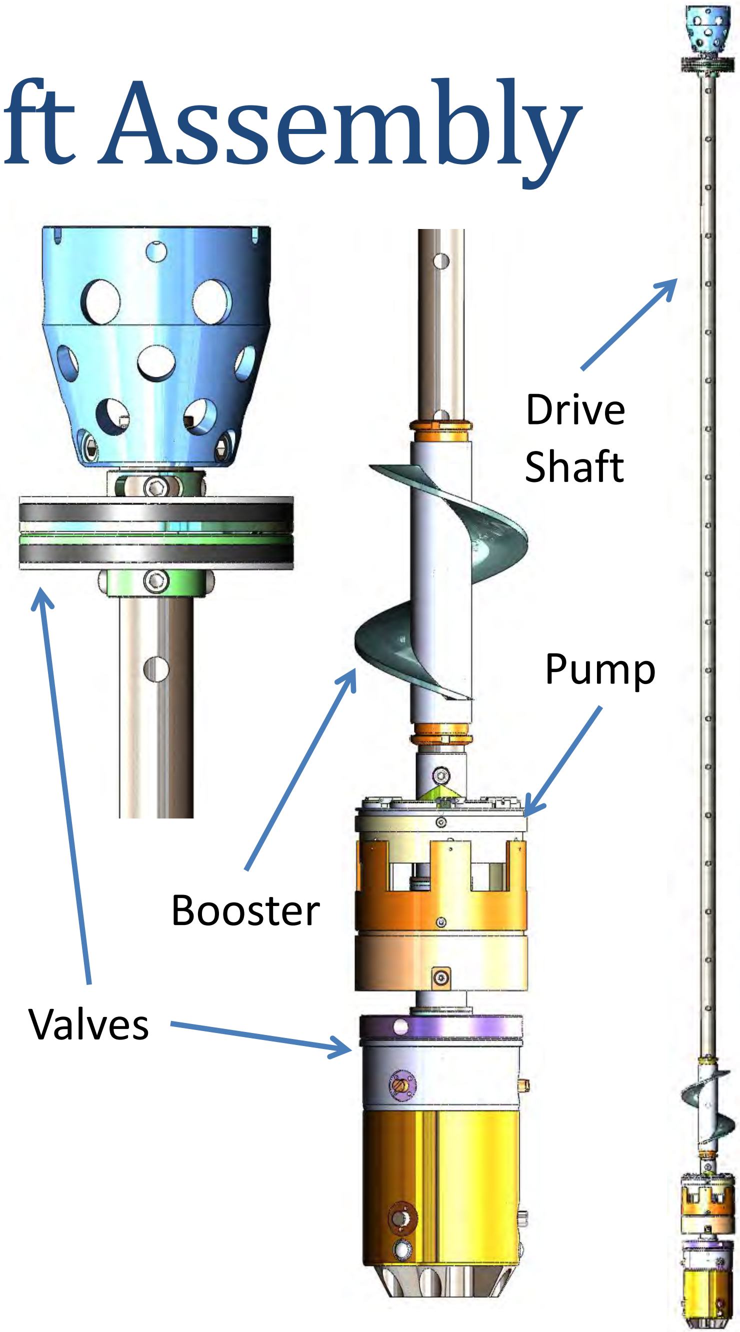
Sonde – Drive Shaft Assembly

Drive Shaft

- Couples the motor section to the core barrel
- Runs the booster, pump, and valves
- Two drive shaft configurations will be built
  - With filter holes (shown at right)
    - A filter sleeve with 0.3mm openings will cover the shaft
  - Solid shaft

Boosters

- Aid in chip transport and packing
- Collet type mounting permits mounting at any point along drive shaft



Sonde - Drive Shaft Assembly

Valves

- Valves at the top and bottom of the chips chamber open during descent to reduce fluid drag
- Open by turning the drive shaft CCW

Piston Pump

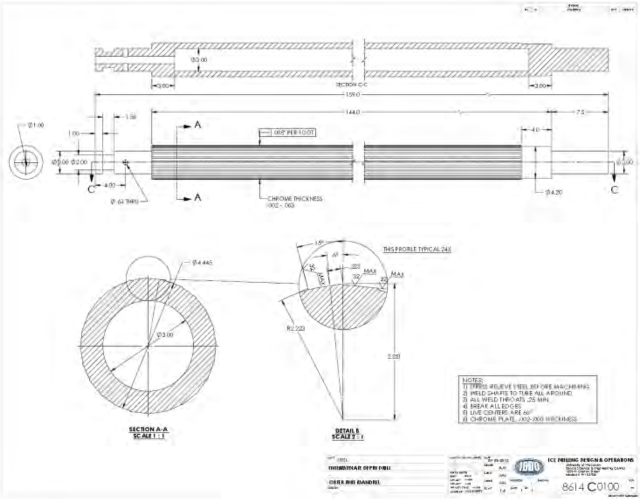
- Direct copy of the Danish unit
- Used for wet drilling for improved fluid circulation

Valve assembly

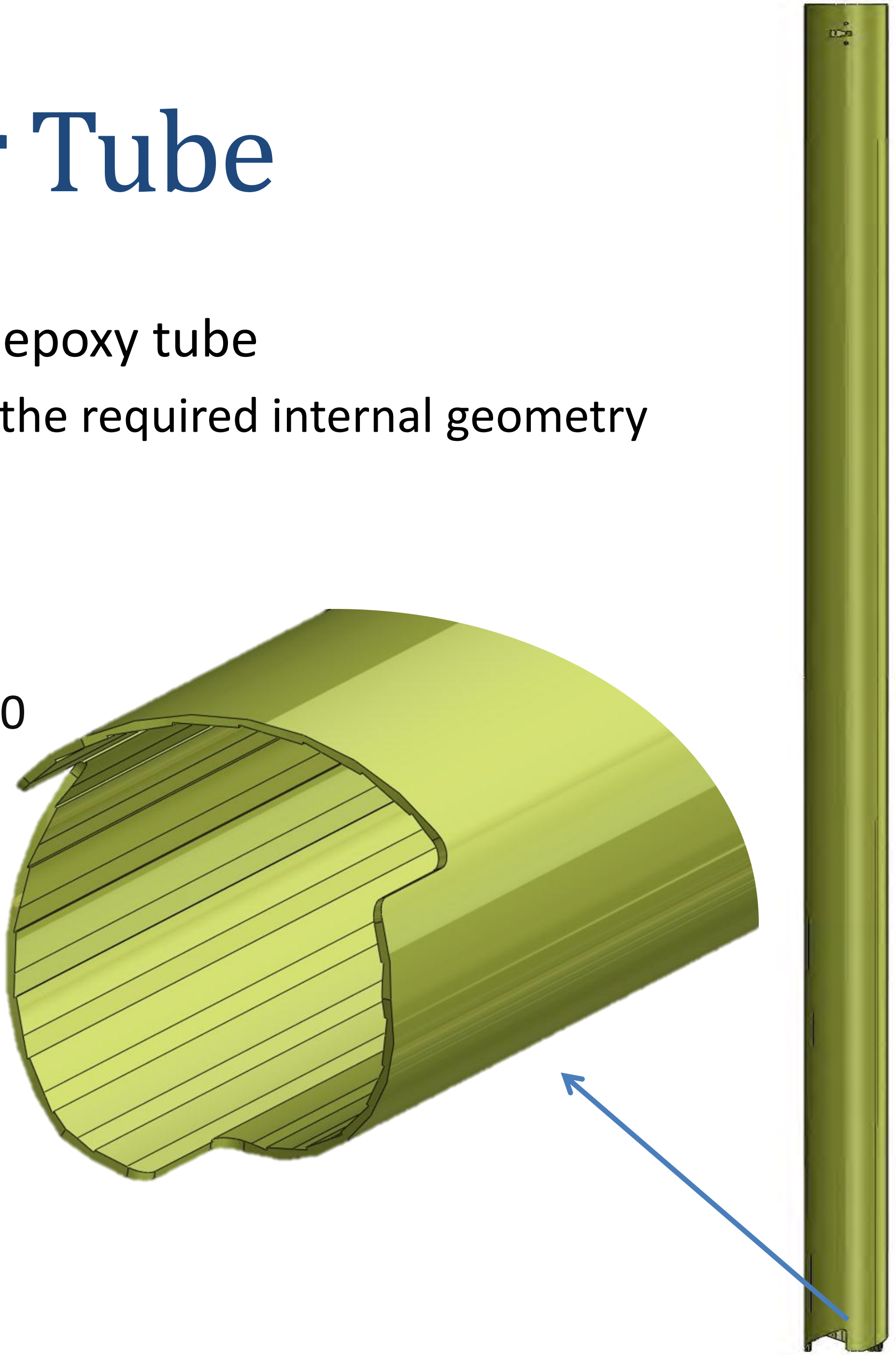
Pump assembly

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 -0.00

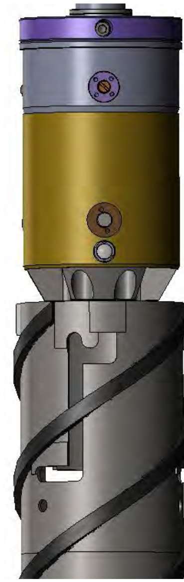


Tube winding mandrel

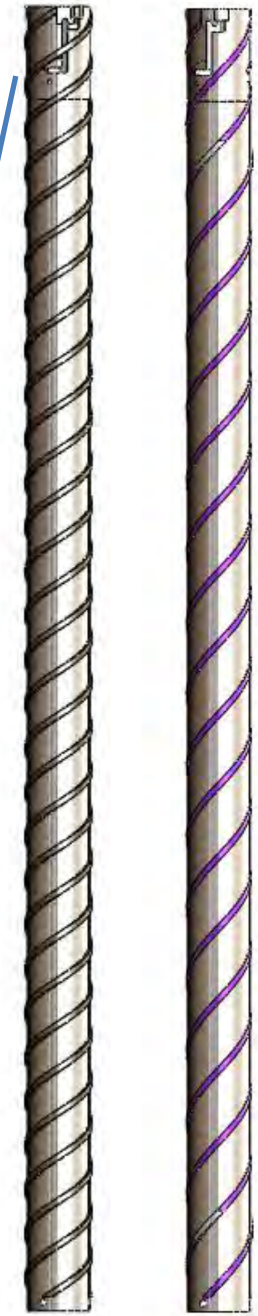


Sonde – Core Barrel

- 304 Stainless Steel core barrel tube
  - 104mm OD, 100mm ID
  - Fusion welded tube
  - 2.1m long core capacity
  - 0.02mm/m straightness
- Two barrel configurations
  - Full height polyethylene flights for dry drilling
    - 200mm pitch
  - Partial-height aluminum flights for wet drilling
    - 369mm pitch
- Bayonet coupling with “Super Banger”



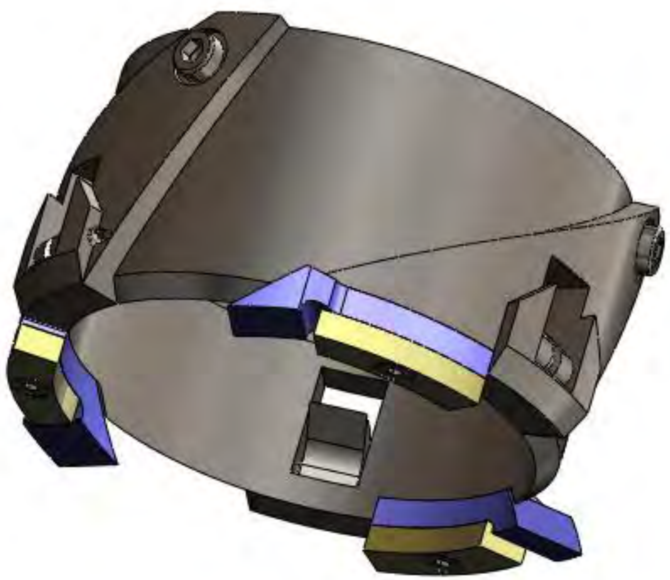
“Super Banger”

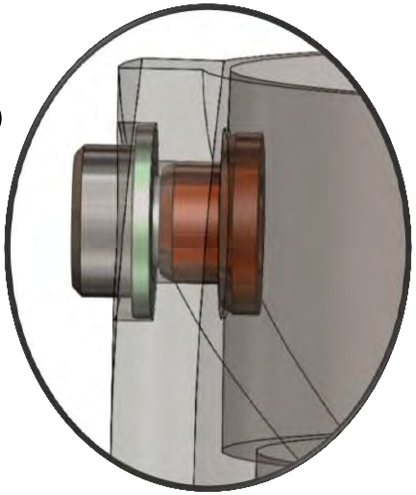


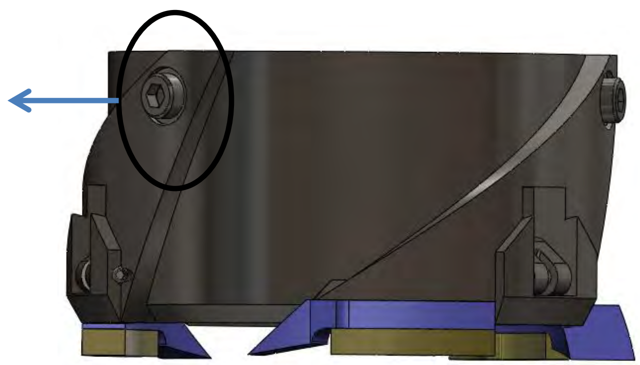
Dry Wet

Sonde – Cutter Head

- Copy of 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
- Head is “pinned” to core barrel
- Shoes for 1mm to 5mm per tooth penetration rates





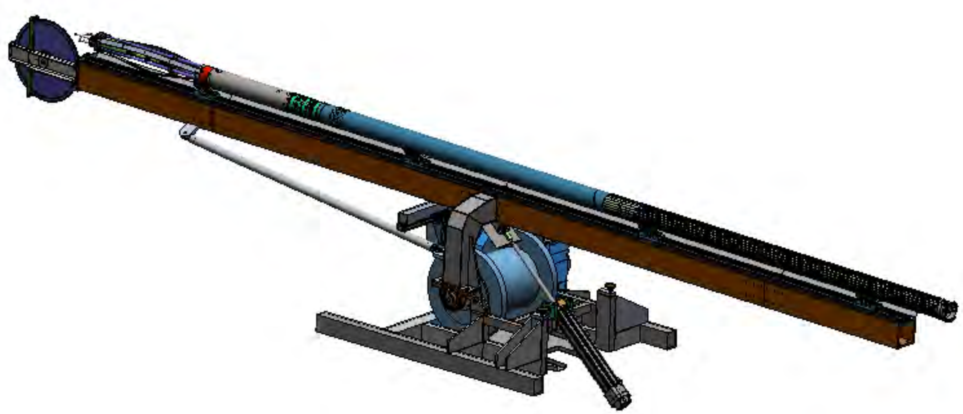


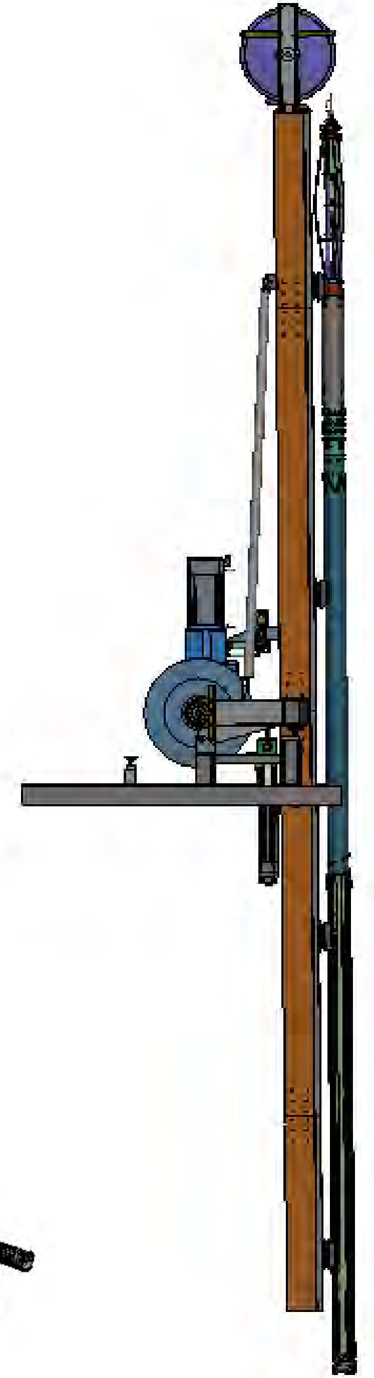
Head mounting system

Tilting Tower and Winch

Tower

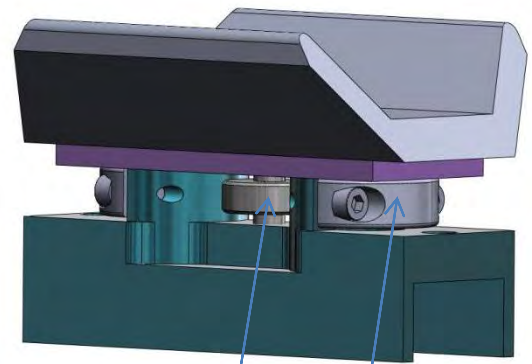
- Tilting Tower and Winch features
  - Drill remains stationary as the tower tilts
  - Permits removal of the drum without rigging
- Square aluminum tube
  - 152.4mm square with a 12.7mm wall thickness
- Modular bolt-together 1m and 2m long sections
- Stainless steel drip pans
- Sized to work with reamers up to 280mm Ø
- Worst-Case Tower Loading:
  - Core Break: 15kN Peak Line Pull
  - Tripping Peak Load: 6kN
  - Horizontal Load: Sonde + 300lb incidental load





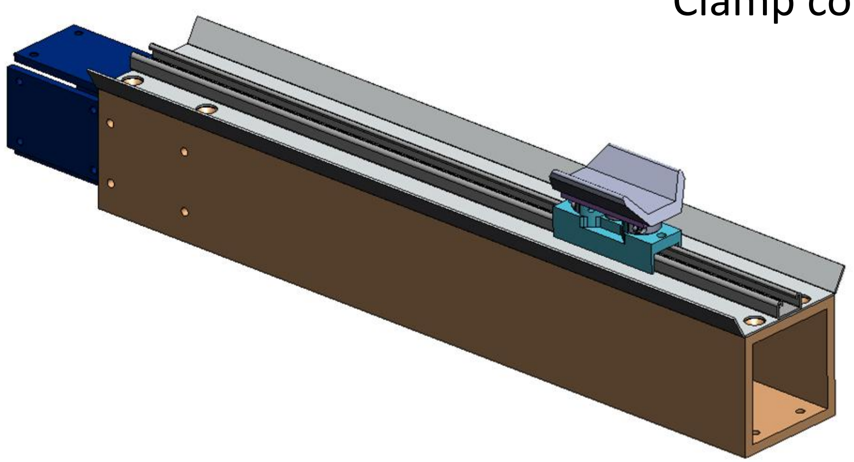
Tower – Drill Supports

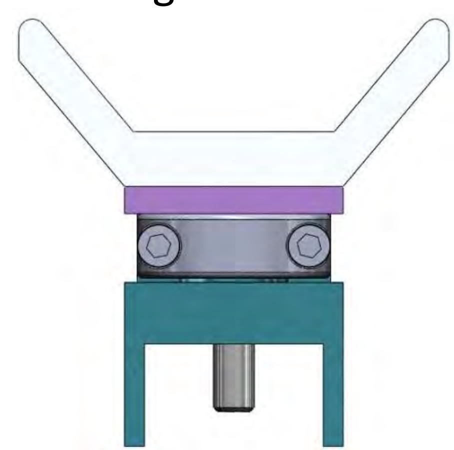
- Mount on a rail running the length of the tower
- Can be positioned at any place on the rail
- 0.75” (19mm) of height adjustment
- Drill working height with tower horizontal is 1.0m (39.4”)



Height adjustment knob

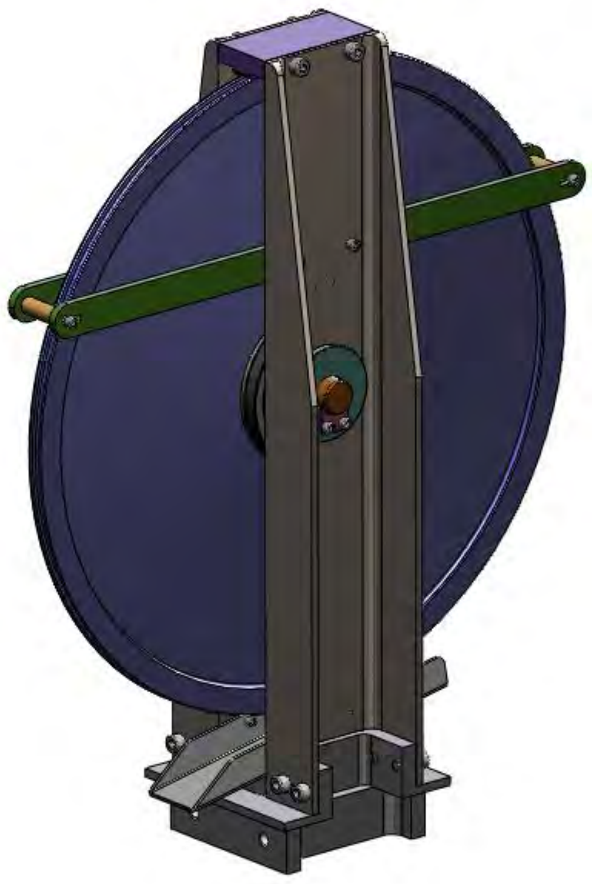
Clamp collars fix rest height



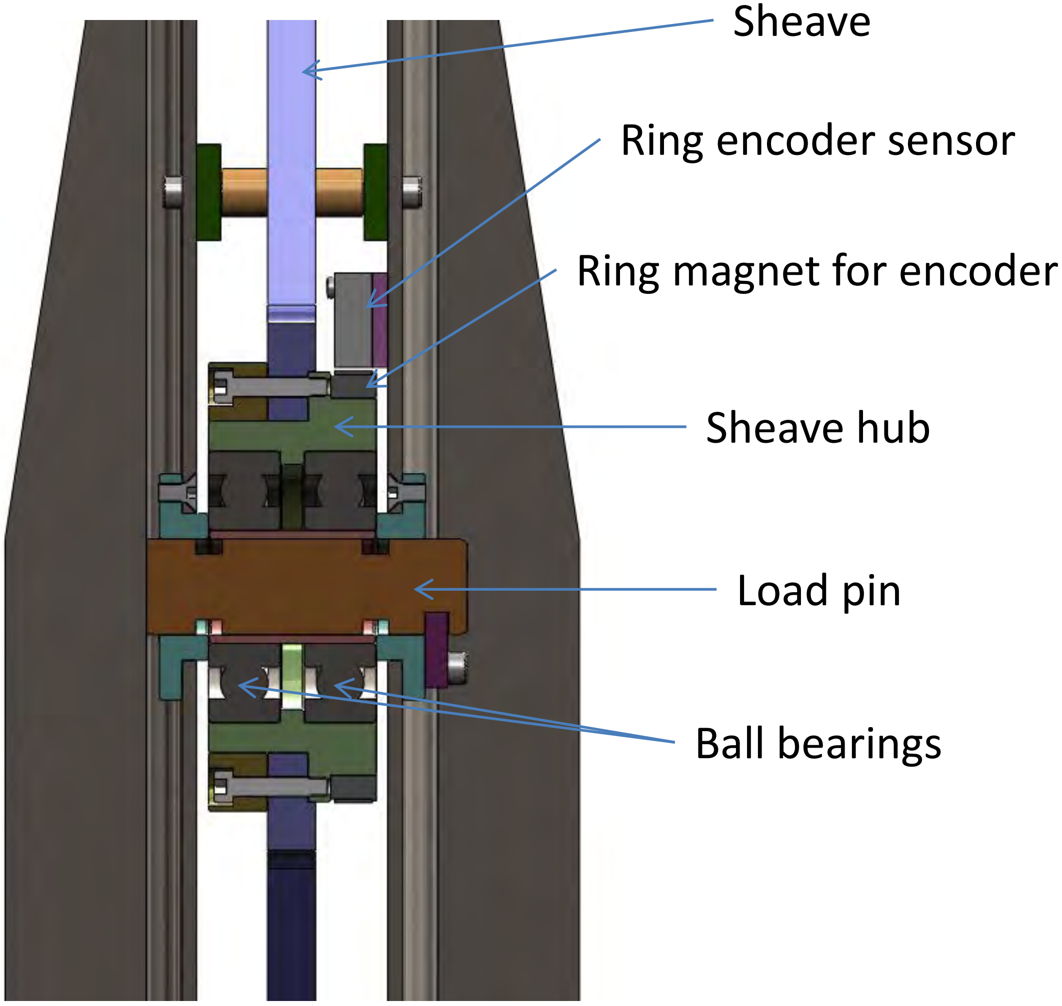


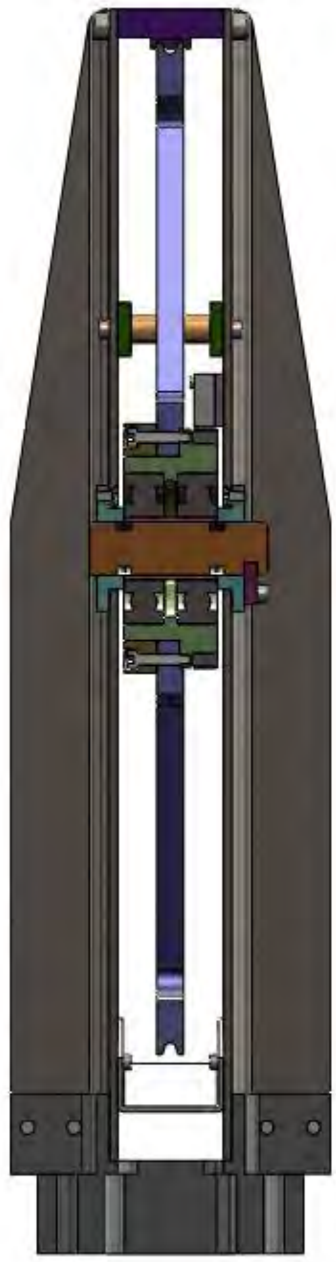
Crown Sheave

- Max tension 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



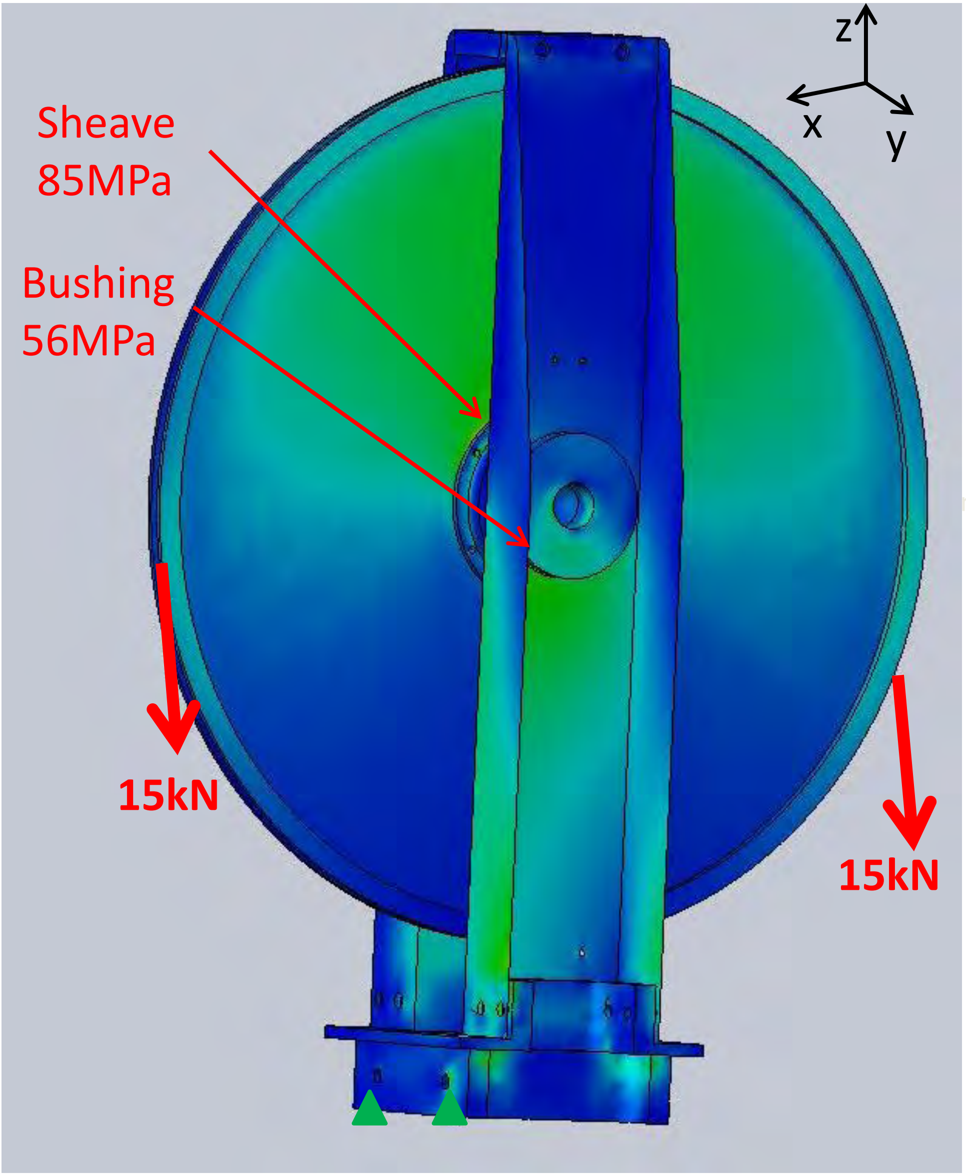


Crown Sheave Stress Analysis

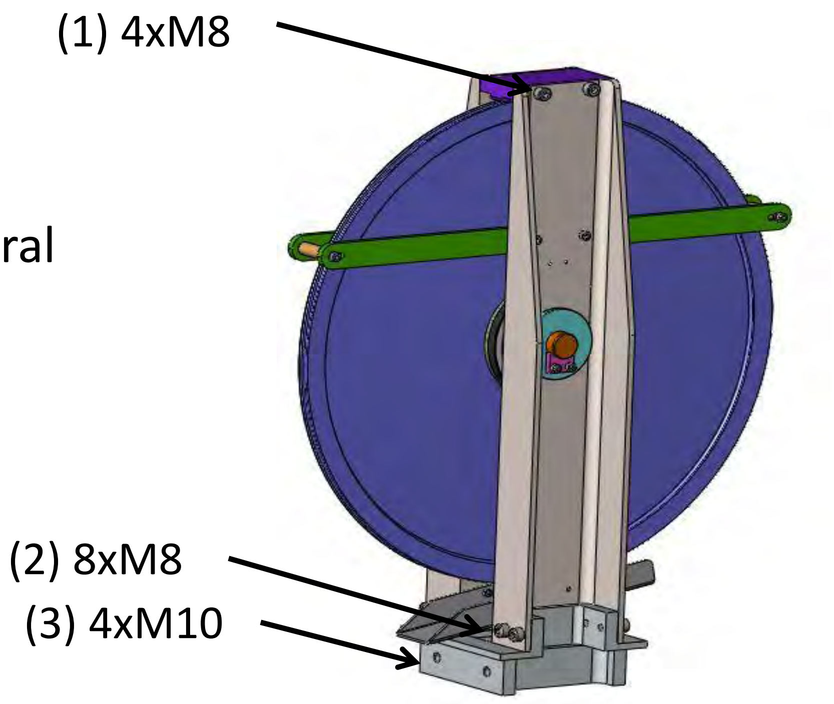
<u>Sheave Design:</u>
•6061 T6 Machined Aluminum Sheave
•6061 T6 Machined Aluminum Base
•6061 T6 4"x2" U-channel Side Supports
•304 SS Hub
•Class 12.9 Metric Screws

<u>Loading Conditions:</u>
•Modeled to max winch line pull 15kN
•4° off-vertical load to winch x-direction
•4° tower misalignment x and y-directions
•Fixed at base mounting holes
•See Figure

<u>Sheave Assembly Summary</u>:
• Solid sheave showed reduced stress
• Improved bushing
• Max Deflection: 2.0mm at sheave
• 3.2x Sheave Safety Factor
• 3.7x Side Supports Safety Factor



Analysis Results: Bolted Joints



Bolted Joints Sheave

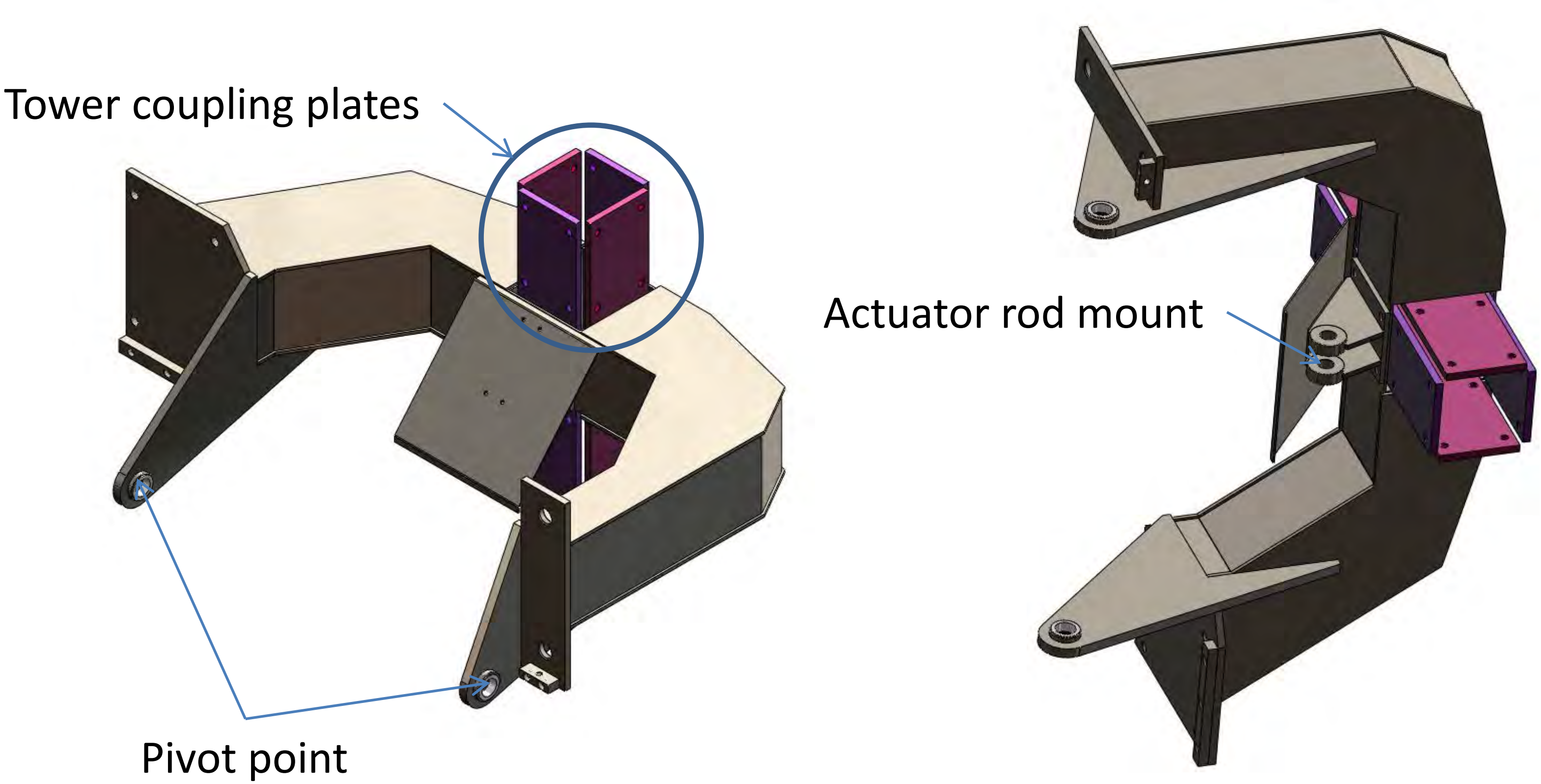
<u>Joint Design:</u>

- Core Break:
  - load carried primarily by structural members
- Cantilever:
  - 300lbs incidental load
  - safety factor 3.1
  - see table below

Bolted Joints Sheave Assembly				
Desc	Material	Value (Mpa)	Limit	Safety Factor
(1) Bolt Shear	Alloy Steel	36	900	25.0
(1) Tear-out Upright	Al 6061 T6	44	386	8.8
(2) Bolt Shear	Alloy Steel	100	900	9.0
(2) Tear-out Upright	Al 6061 T6	125	386	3.1
(3) Bolt Shear	Alloy Steel	129	900	7.0
(3) Tear Out Sq Tube	Al 6061 T6	60	386	6.4

Trunnion

- 304 stainless steel sheet metal weldment
- Mounting points for the tower and winch components
- Galvanized alloy steel coupling plates



Tower Sub-Assembly Analysis: Core Break

Design:

•Square Tube: 6061 T6, 6" x 0.5" Wall

•Trunnion Weldment: 304 Stainless Steel

•Struts: Ø2"x0.25" Wall, Al 6061-T6

Loading Conditions, Core Break:

•Modeled to max winch line pull 15kN

•Gravity applied

•4° off-vertical load to winch x-direction

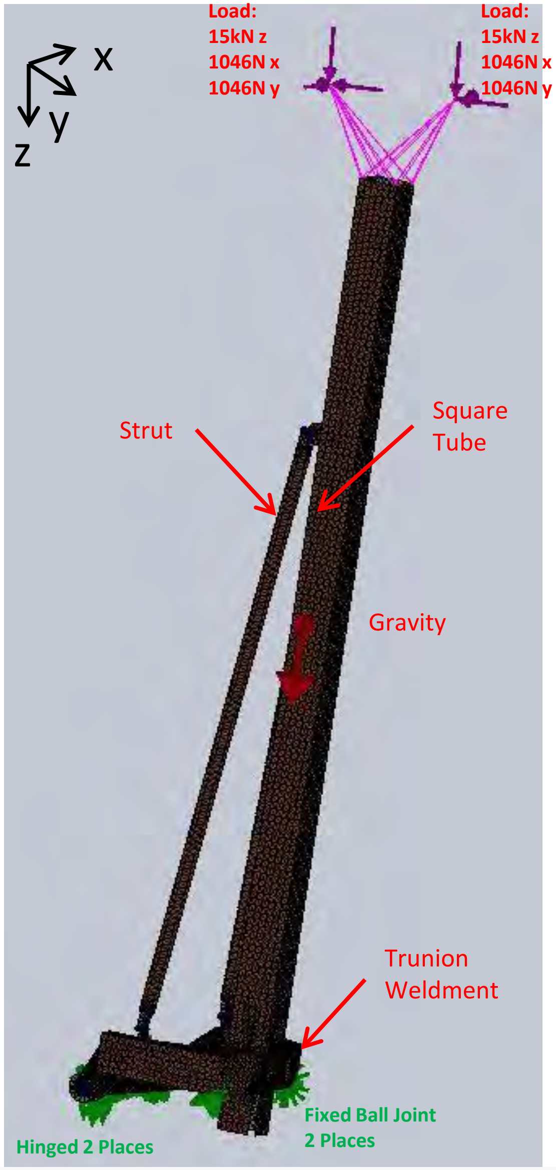
•4° tower misalignment x and y-directions

•Fixed ball joint at trunnion stops

•Hinged at base

•No-slip assumed at bolted joints

•See figure at right



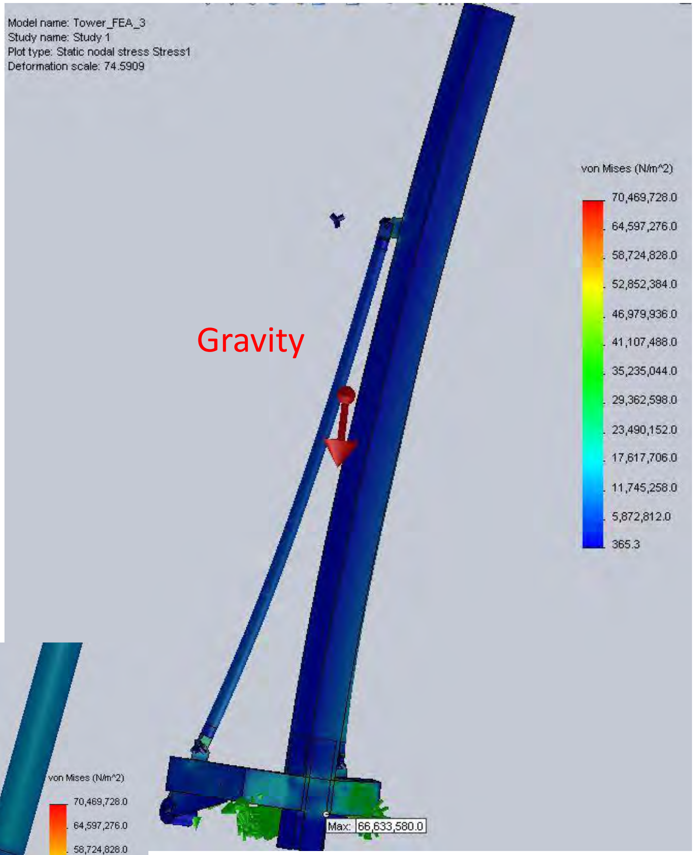
FEA Model Tower Sub-Assembly

Lower Tube not Modeled

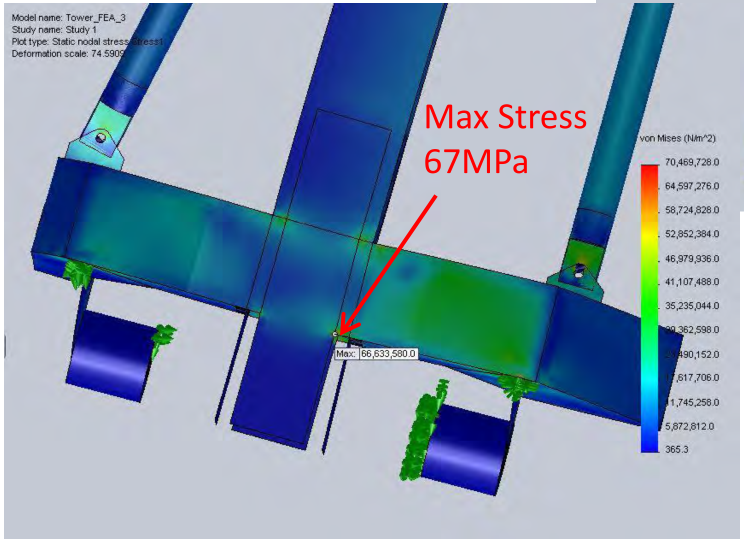
Tower Sub-Assembly Analysis Results: Core Break

<u>FEA Results:</u>
•Max Deflection: 4.7mm
•Max Stress: 67MPa at trunnion

<u>Summary</u>:
- Trunnion Safety Factor 3.6x at max line pull
- All other components have larger SF
•Struts offer increased stability and adjustment



FEA Model Stress



FEA Model Stress at Trunnion

Analysis Results: Buckling

Buckling:

- **Worst case loading is at core break**
- **Hand calculations performed of buckling for both struts and tower**
- **Loads shown relative to calculated buckling limit in table below**

Buckling Sq Tube

Buckling Limit	F=3.14^2*EI/(kL)^2	K=2 free 1 end
Area Moment Rnd Tube	I=3.14*(D^4-d^4)/64	K=1 pined 2 ends
Area Moment Sq Tube	I=(L^4-l^4)/12	K=0.7 fixed 1 end

	Sq	Wall	I	E	K	L	Actual Load*	Load Limit	SF
	in	in	in4	psi	--	in	lbs	lbs	--
Tower	6	0.5	56.00	10000000	2	118	6742	99134	14.7

*based on FEA results at 15kN Cable Tension

Buckling Strut

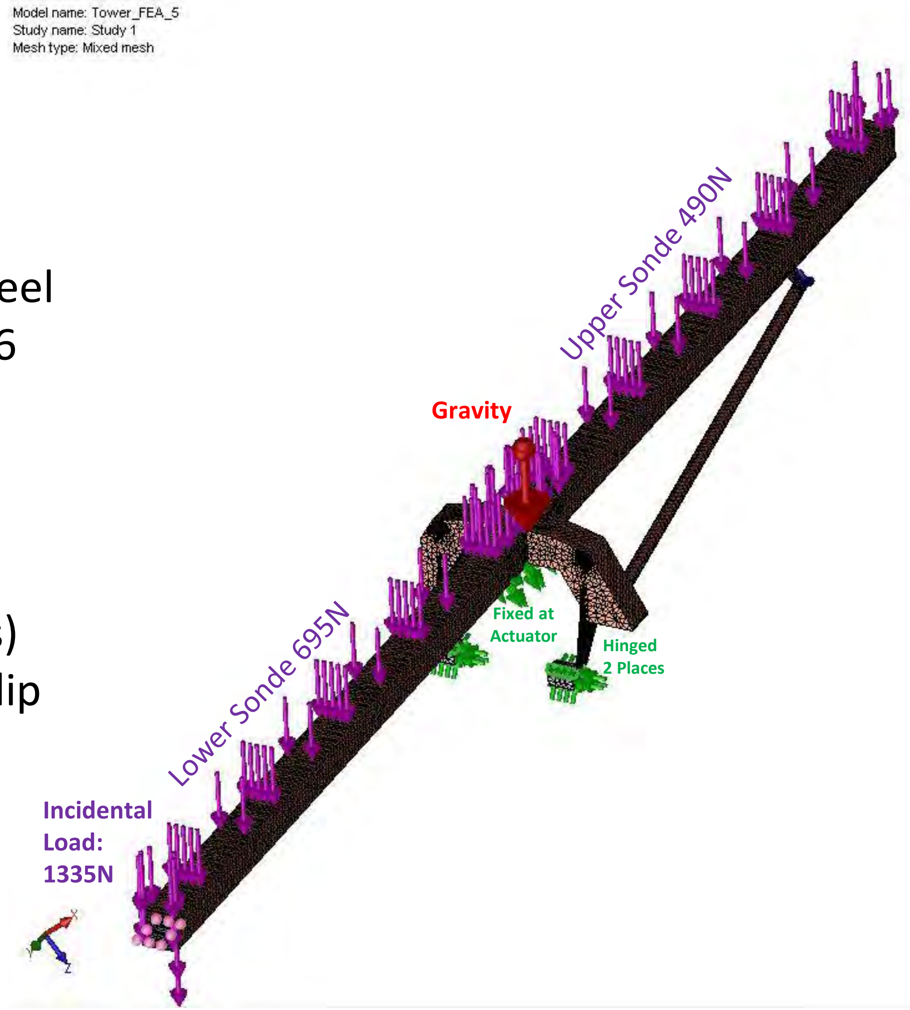
	Matl	OD	ID	I	E	K	L	Actual Load*	Load Limit	SF
	--	in	in	in4	psi	--	in	lbs	lbs	--
Strut	AL6061T6	2	1.5	0.54	10000000	1	82	2119	7869	3.7

*based on FEA results at 15kN Cable Tension

Tower Sub-Assembly Analysis : Horizontal

Design:
- Square Tube: 6061 T6, 6” x 0.5” wall
- Trunnion Weldment: 304 stainless steel
- Struts: Ø2.00”x0.25” Wall, Al 6061-T6

Tower Loading Conditions:
- Fixed constraint at actuator
- Hinged at trunnion
- Load Sonde Weight + 1335N (300lbs)
- Bolted joints assumed bonded; no slip



FEA Model Tower Cantilever

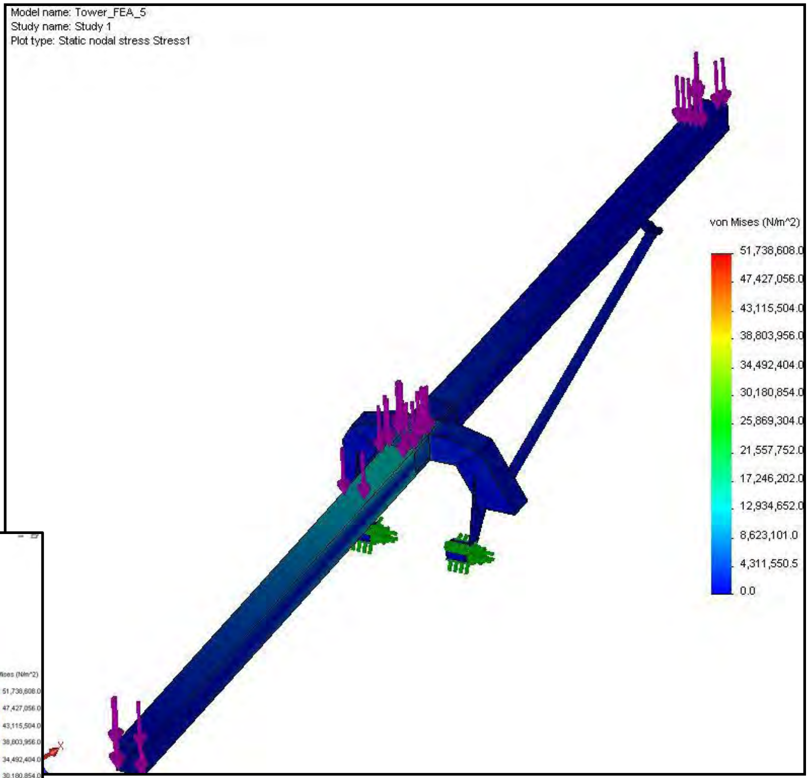
Analysis Results: Tower Sub-Assembly Horizontal

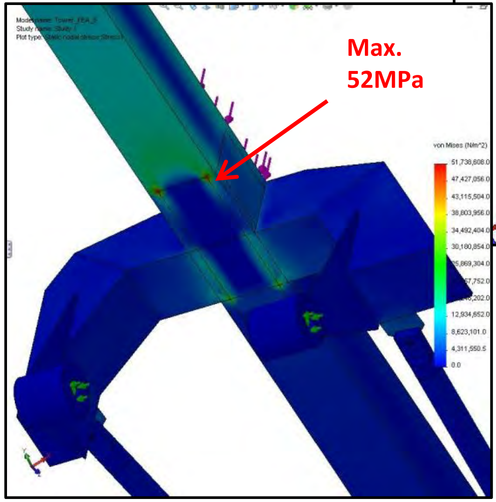
<u>FEA Results:</u>

- Max Deflection: 10mm
- Max Stress: 52Mpa at trunnion
- Yield Strength Al 6061 T6: 275 MPa

<u>Summary</u>:

- Trunnion Safety Factor: 5.3x
- All other components have larger SF





FEA Model Tower Max Stress Horizontal

Analysis Results: Bolted Joint

<u>FEA Results:</u>

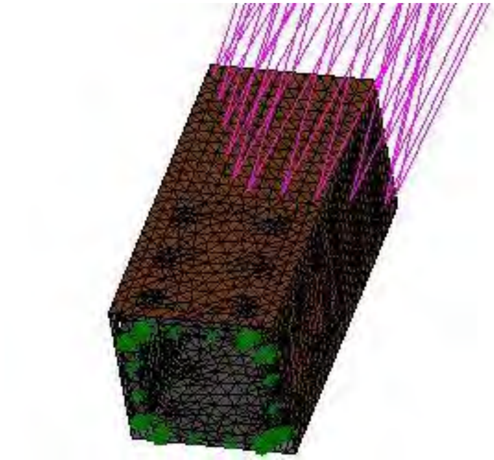
- Detailed look at bolt loads
- Worst-case loading in core break
- Max load/plate: 34kN (No Slip)
- Max pin shear: 8.9kN

<u>Joint Design:</u>

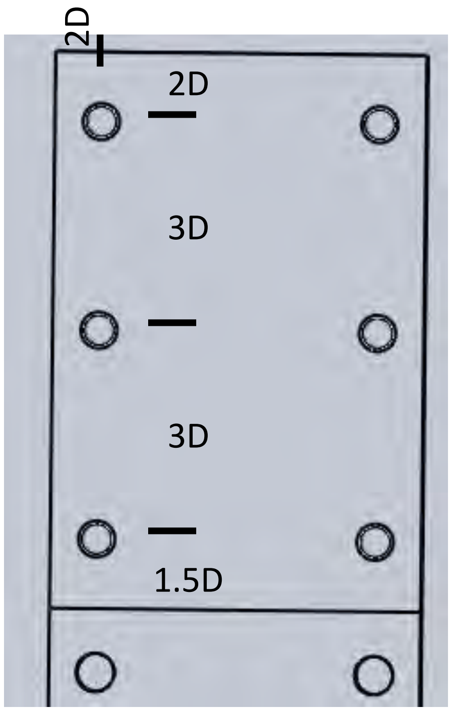
- 3/8” Galvanized steel coupling plate
- Loading based on detailed FEA results
- No slip at trunnion
- 6xM6 screws each side

Coupling Plate at Trunnion

Desc	Material	Value (Mpa)	Limit (Mpa)	Safety Factor
Thread Engagement	Steel Plate	334	568	1.7
Bolt Tension	Alloy Steel	500	1200	2.4
Bolt Shear	Alloy Steel	409	900	2.2
Tear-out Coupling	Steel Plate	50	568	11.4
Tear Out Sq Tube	Al 6061 T6	44	386	8.7
No Slip Condition	--	34kN	67kN	2.0



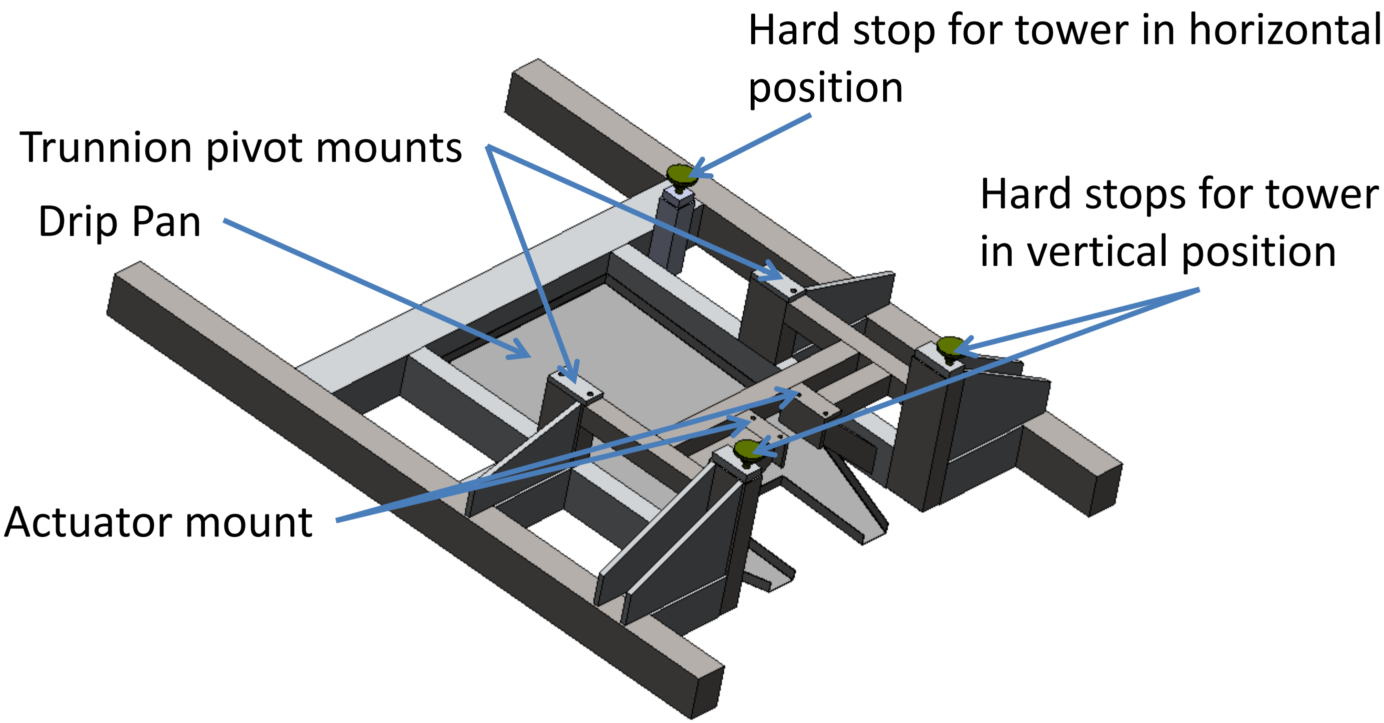
Detailed FEA Model: Bolted Joint



Bolt Pattern

Tower Base

- Welded aluminum 6061 T6 frame
- 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



Tower Base

Model Details:

•6061 T6 Aluminum Tubes

•Butt joints bonded to simulate welds with cross-section of base material

Loading Conditions, Core Break:

•Modeled to max winch line pull 15kN cable tension (See load calcs excel file)

•Fixed at mount points to joists

•See figure at right

FEA Results:

•Max Deflection: 0.5mm

•Max Stress: 51MPa

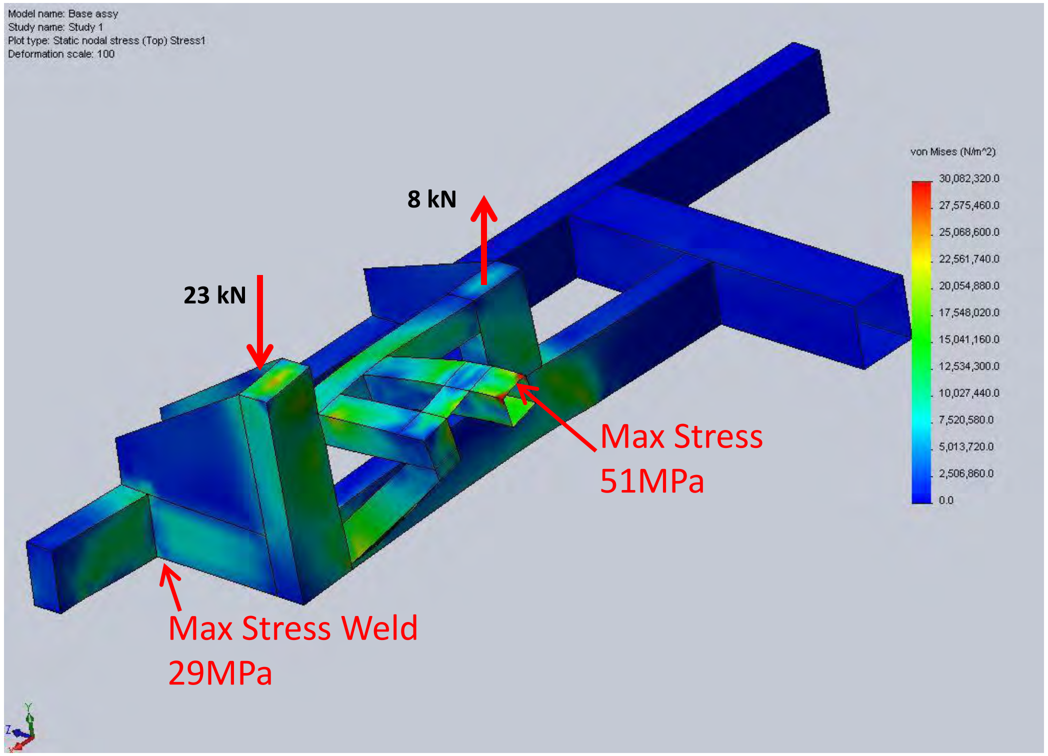
•Max Stress at Weld: 29MPa

•Yield Limit at Weld: ~60MPa

•Yield Limit T6: 275MPa

Summary:

•Safety Factor 2.0x at max line pull

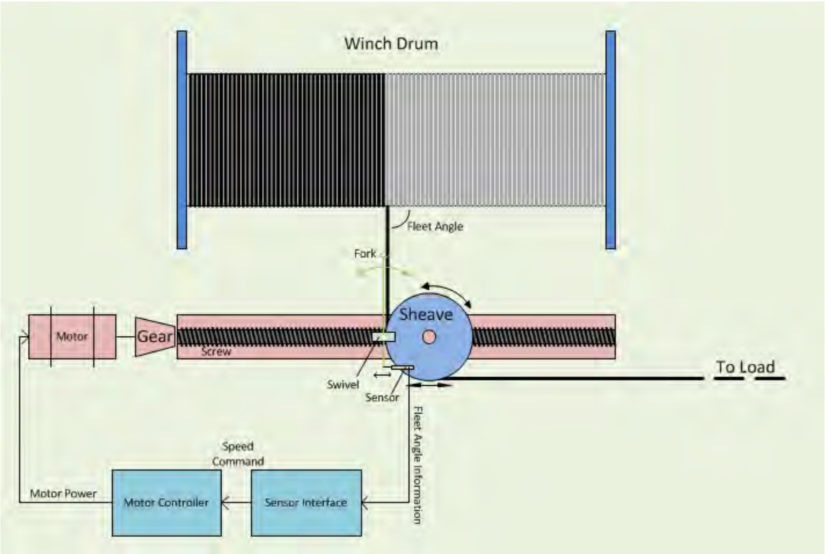


FEA Revised Model Results with Actuator Load

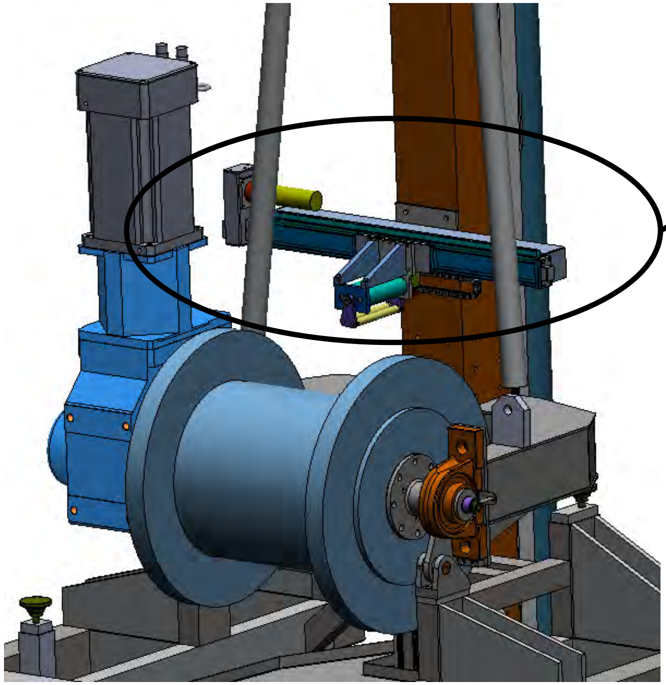
Modeled Symmetric Half

Level Wind

- Use design from DISC
- Measure Fleet angle
- Adjusts level wind speed continuously



DISC Drill Level Wind Schematic

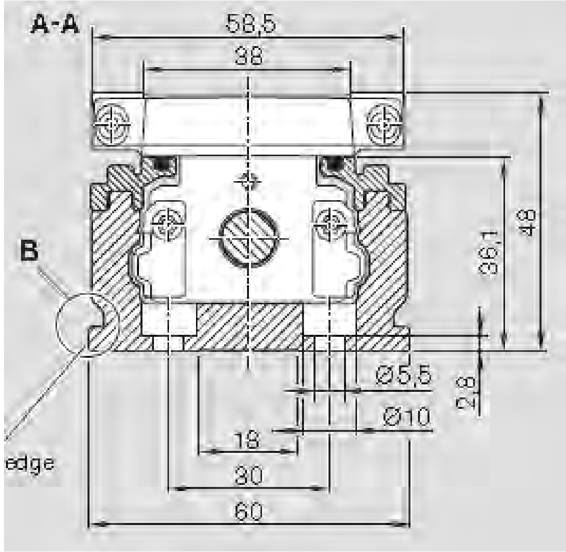


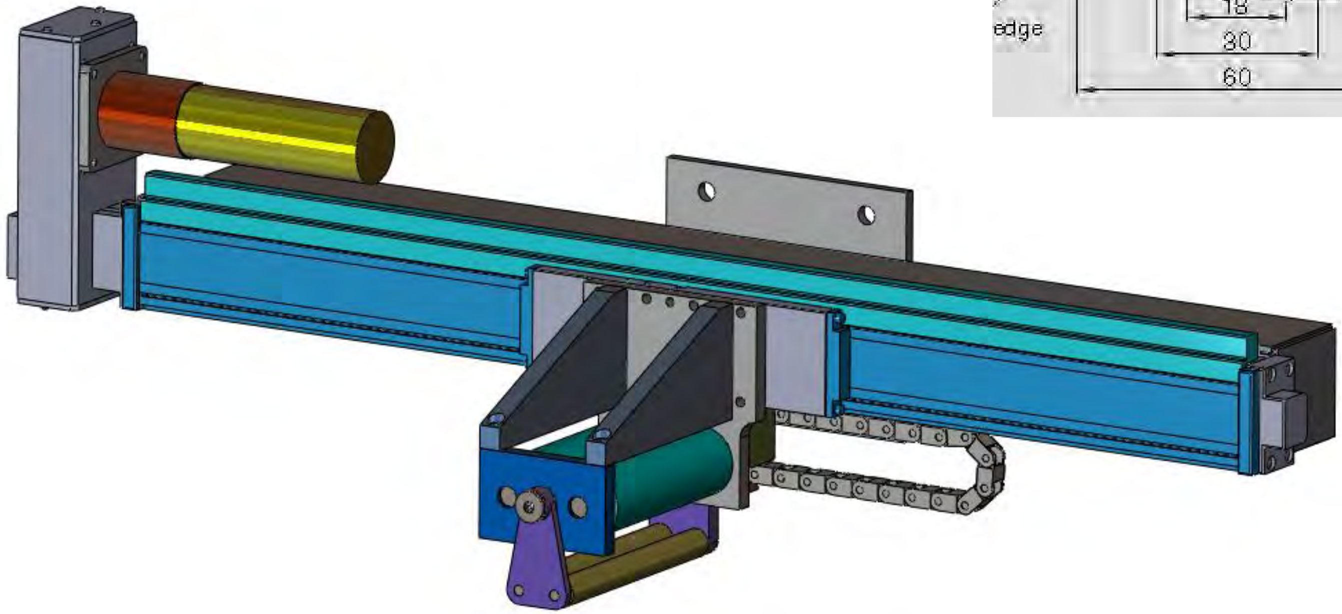
IDD Level Wind:

- Uses rollers to guide cable
- Magnetic angle sensor
- Adjusts level wind speed continuously
- Conceptually identical to proven DISC design

Level Wind

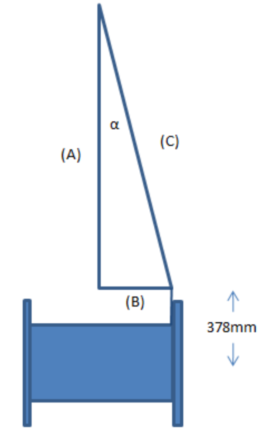
- Bosch Rexroth linear slide
  - Ball screw drive with ball rail system
  - Magnetically sealed cover strip
  - Built-in reed contact limit switches
  - 485mm travel





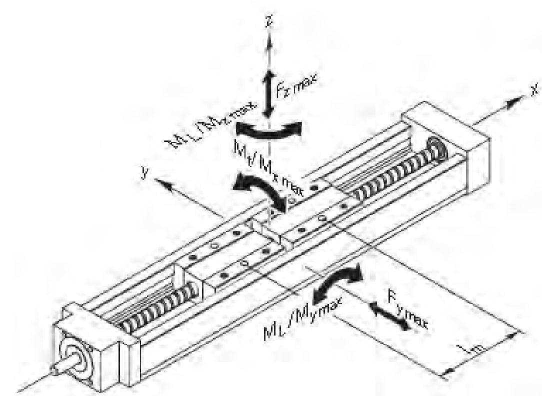
Level Wind

- Travel speed of 5mm/s with a line speed of 1.4m/s
- Drive
  - Maxon 40mm Ø Brush DC motor with failsafe brake
  - 150W
  - 26:1 Planetary gearhead
  - Continuous torque rating is 57% greater than required at room temp
  - Rated for operation to -40°C
- IDDO built control
  - Based on the proven DISC Drill system
  - Self contained control that mounts with the level wind



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



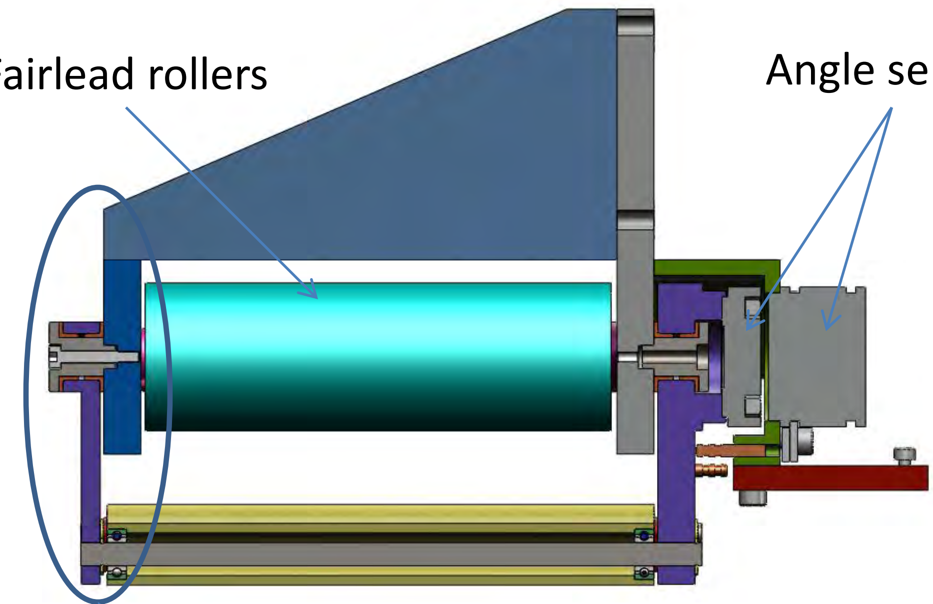
M_L is rated to 541 Nm

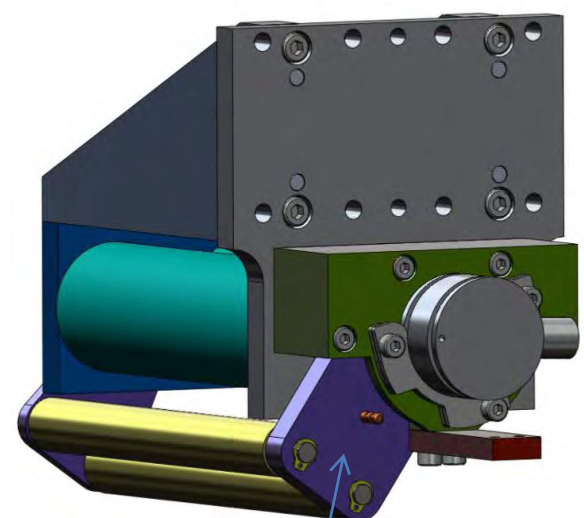
M_{Ly} = 63 Nm when B = 403 N

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

Level Wind –Fairlead assembly

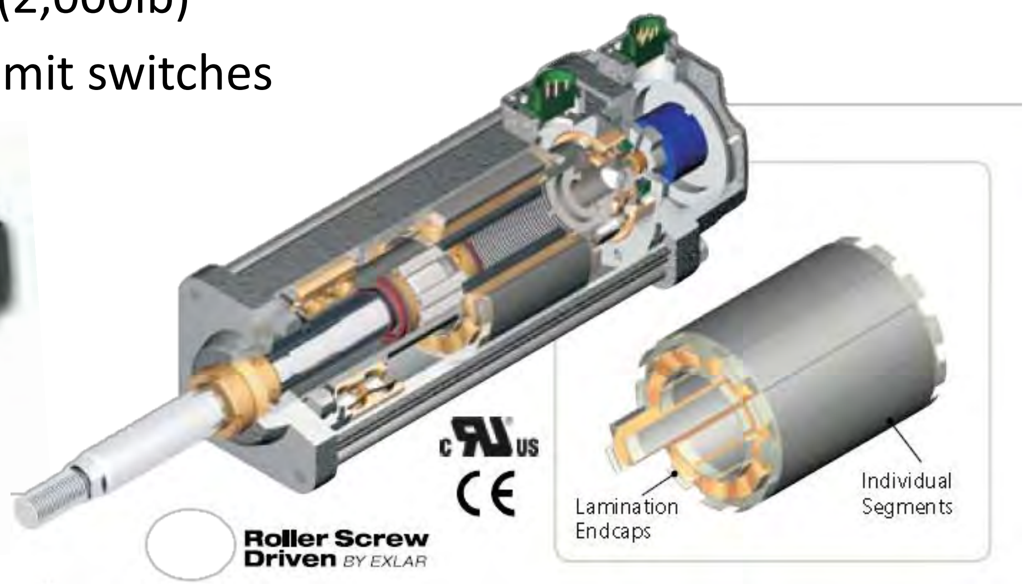
- Cable can be installed by removing two screws
- Cable angle sensed with a sealed magnetic position sensor
- Sensor arm is spring loaded to return to “zero-angle” position





Tower Actuator

- Electric actuator made by Exlar
- Integral permanent magnet servo 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)
- External proximity type limit switches

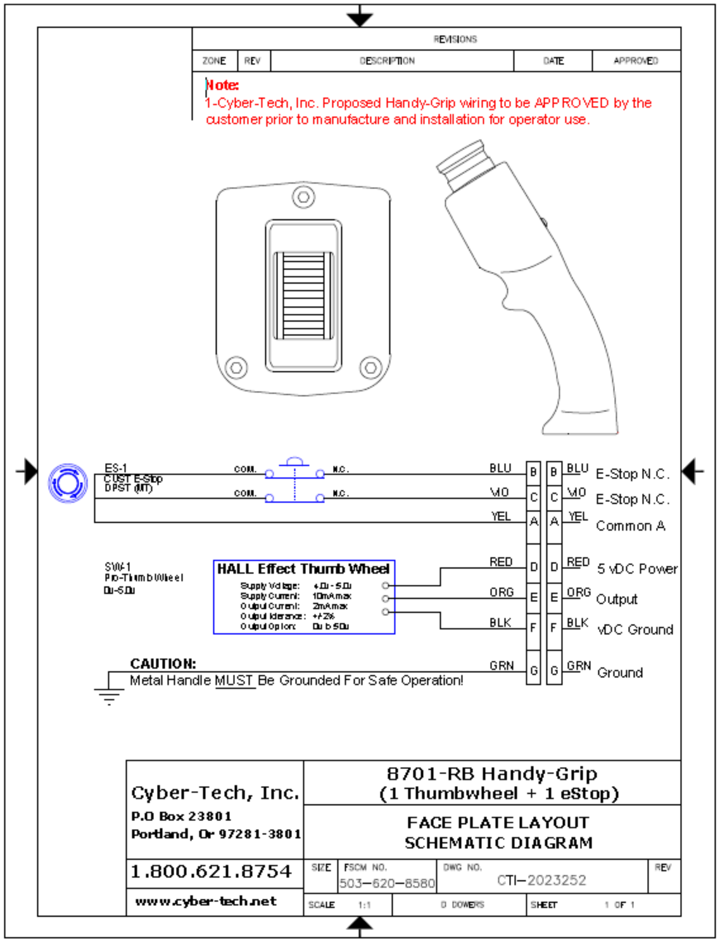


Tower Actuator

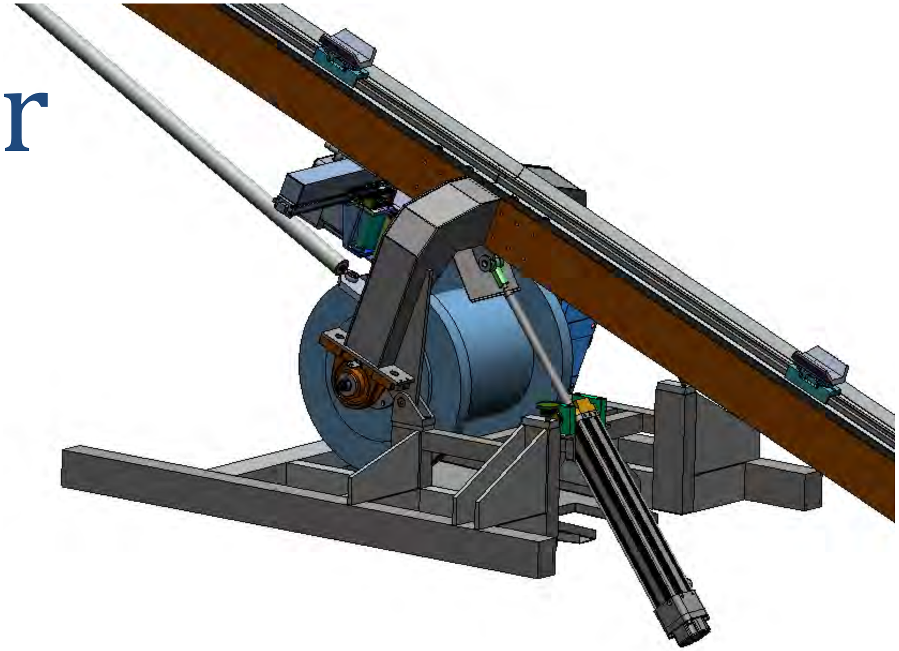
- Controlled with a wired pendant
  - Proportional speed Thumb Wheel on pendant face
  - E-stop on top of pendant
  - Components rated to -40°c

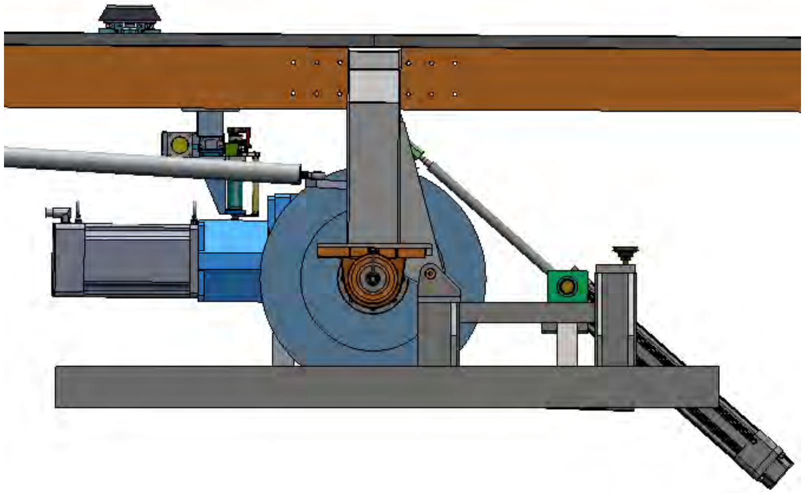
Basic pendant model

Thumb wheel

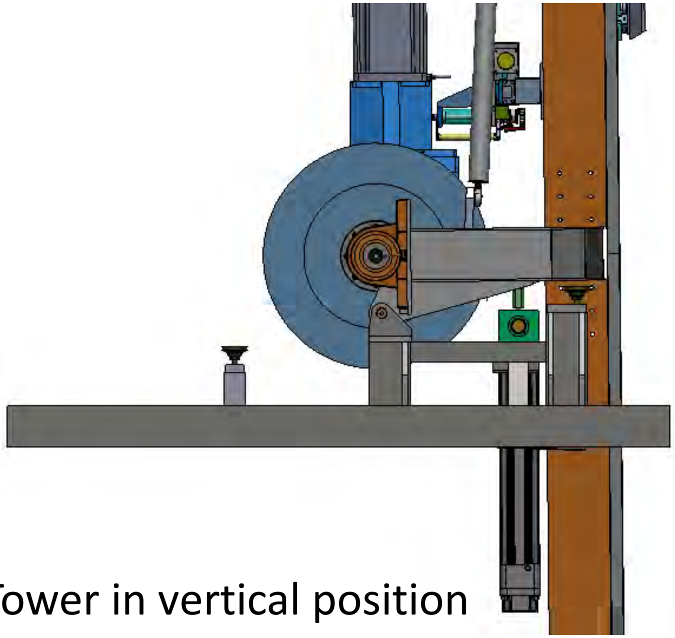


Tower Actuator





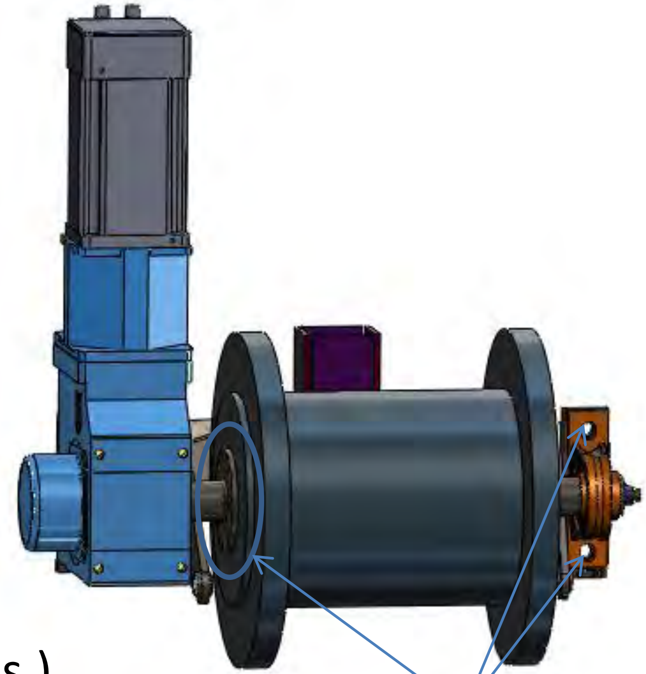
Tower in horizontal position

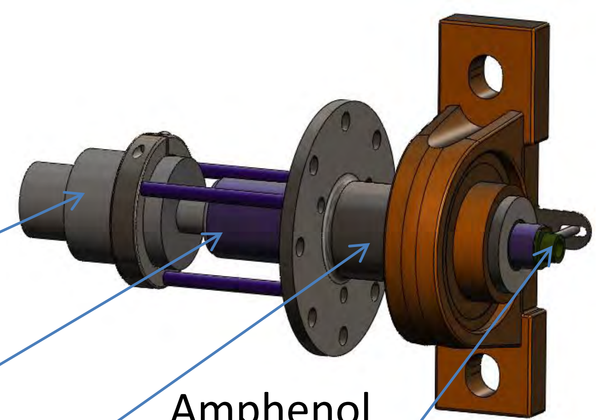


Tower in vertical position

Winch

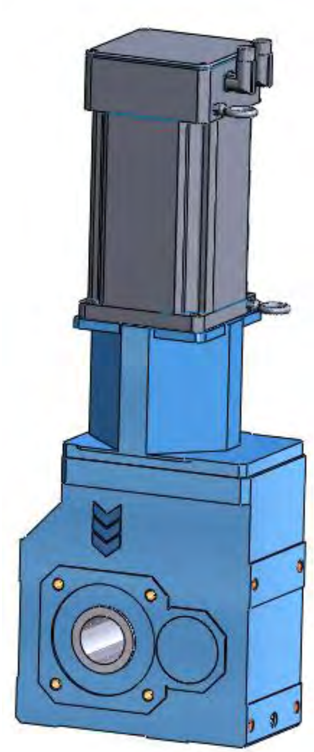
- Removable aluminum drum
  - 1,600m capacity
  - 81 wraps wide x 17 layers
  - 550mm (21.85”) Ø x 508mm(20”) W
  - Lebus grooved core
  - Drum and cable weigh 296 kg (652 lbs.)
    - Drum alone is 82kg (180 lbs.)
    - Cable alone is 214 kg (472 lbs.)
- Internal 4-channel slip ring
  - Amphenol connector on end of stub shaft
  - Assembly stays with the drum when removed

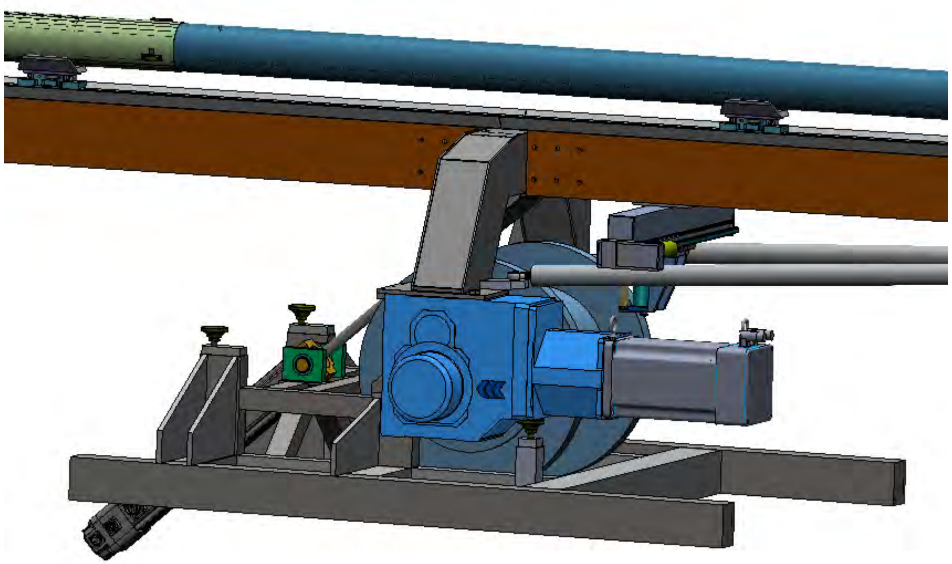




Winch Drive

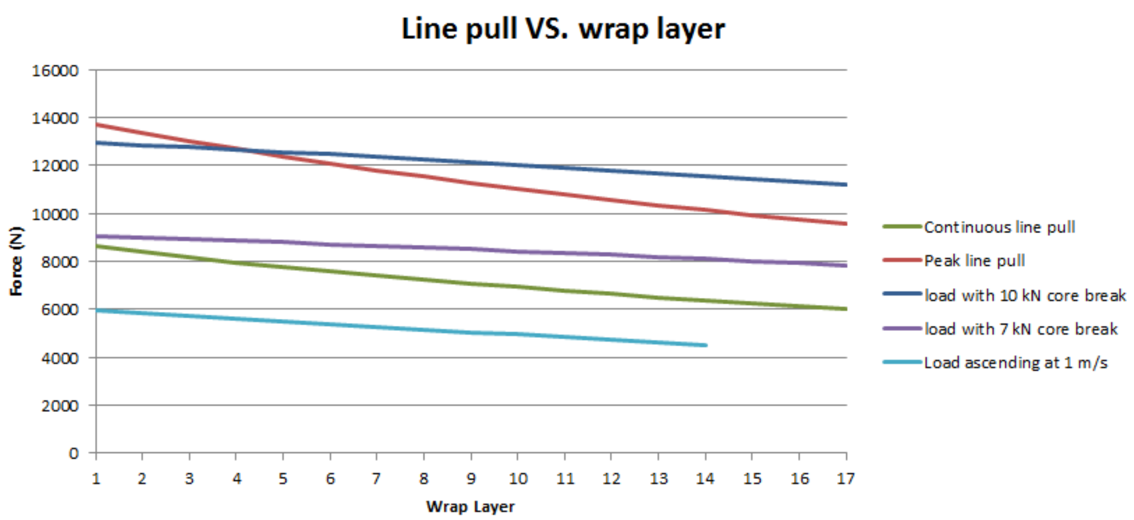
- Helical bevel gear reducer from Watt Drive
  - 56.38:1 ratio
  - Hollow shaft output with shrink disk
- 5.5 kW 8-pole permanent magnet servo motor from Exlar
  - 1-3000rpm speed range
  - Built-in failsafe break



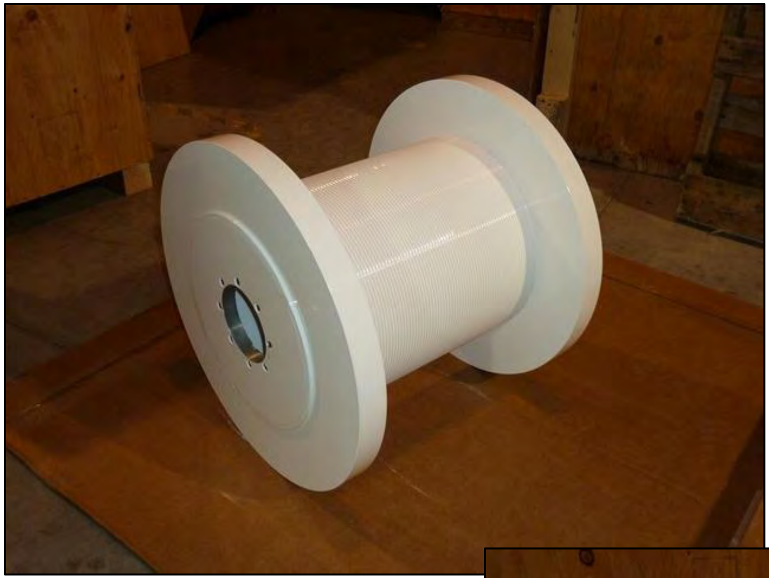


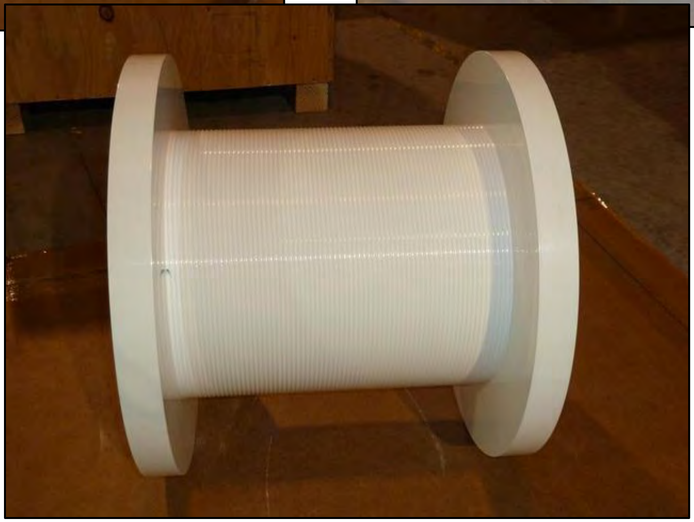
Winch Drive

- Output torque: 1.7kNm
  - 6.0 – 8.6kN continuous line pull
- Peak starting torque: 2.7kNm
  - 9.6 – 13.7kN peak pull for core break
- Minimum line speed of 0.3 - 0.4mm/s
- Maximum line speed of 1.0 – 1.4m/s
- 230/460V 3-phase



Winch Components



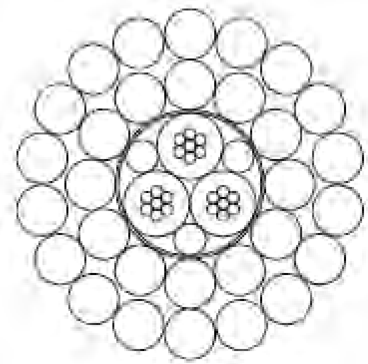


Winch Cable

- Manufactured by Rochester Wire & Cable
- FEP (Teflon) wire insulation
  - Compatible with Isopar K and Estisol 140
- Two conductors and armor 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 mm²) 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



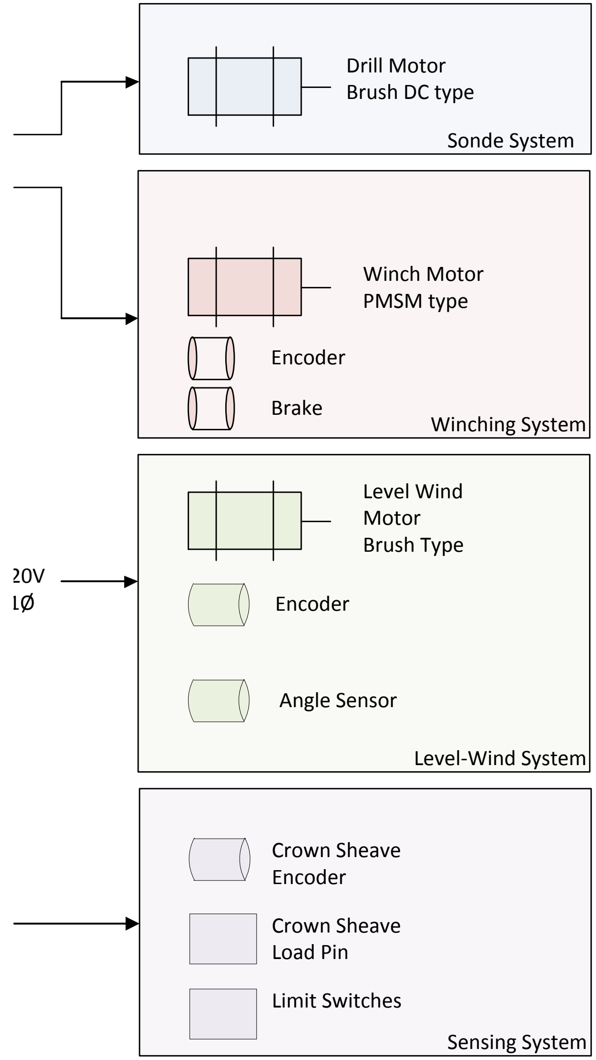
CABLE CHARACTERISTICS
(Nominal Values @20°C)

	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 %

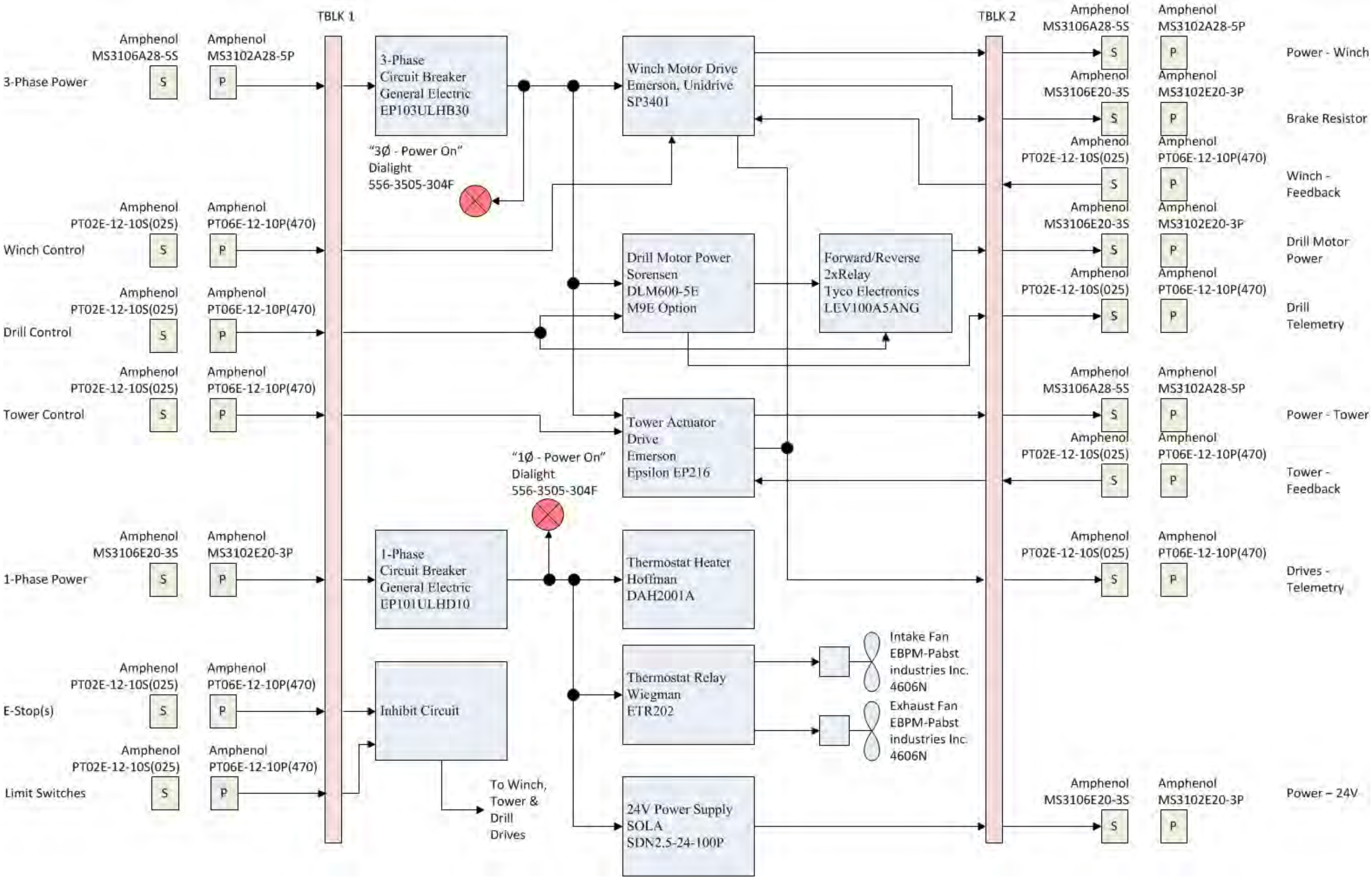
Control System

Winch and Drill Control

Overview:

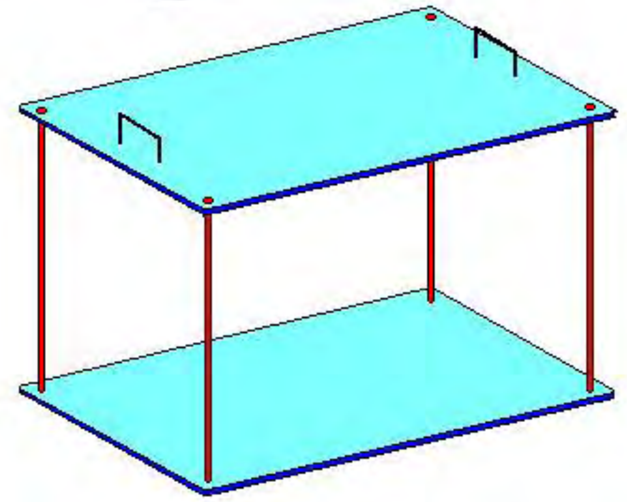


Main Control Unit

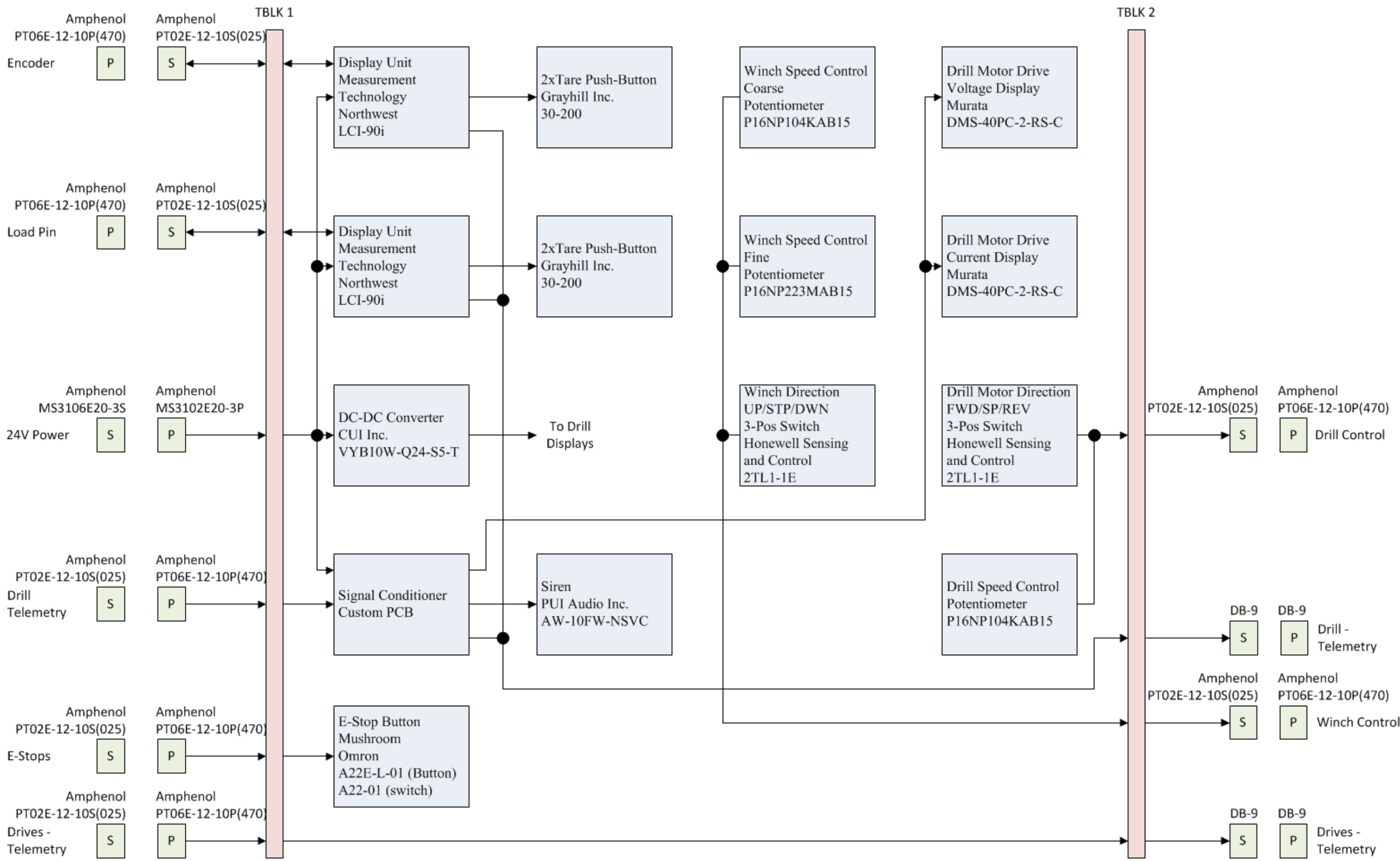


Main Control Unit, Enclosure

- Simple aluminum "trunk" type enclosure for easy handling
- Electronics Assembly designed as an "insert" that can be inserted and removed from the enclosure easily
- 31.5" L x 23.6" W x 24.0" H Electronics mount to the insert's two metal plates



Control Station



Control System

LCI – 90i Line control Instrument

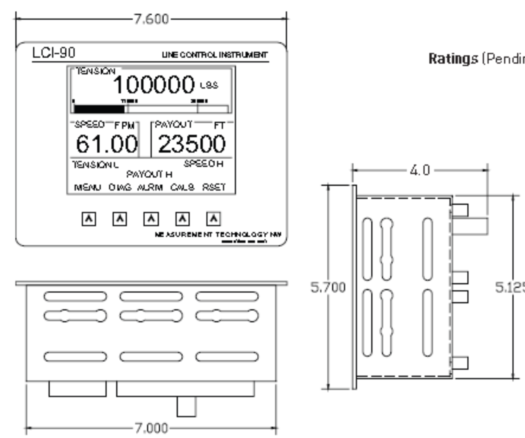
LCI-90*i* Line Control Instrument

Operator Interface Features

- Full programmability via English language menus
- Six alarms, independently linked to any parameter
- Configurable parameter position, scale, and units
- Three modes of analog sensor calibration
- Network configurable
- On-screen diagnostics
- Configuration security
- RS-485, RS-232, USB and Ethernet ports
- On-board CF disk for internal data logging

General Specifications

Display	320x240 graphic, EL (Optional color TFT) Readable in all conditions
Enclosure Size	H 5.7" x W 7.6" x D 5.0"
Operating Temperature	-40°C to 75°C standard
Environmental	Waterproof front panel Watertight rear enclosure or console available
Power	0.75 Amp @ 9-36VDC Isolated, surge protected



NOTES:
1: Unit fits into 7.15" x 5.25" cutout
2: All units in inches

Instrument Specifications

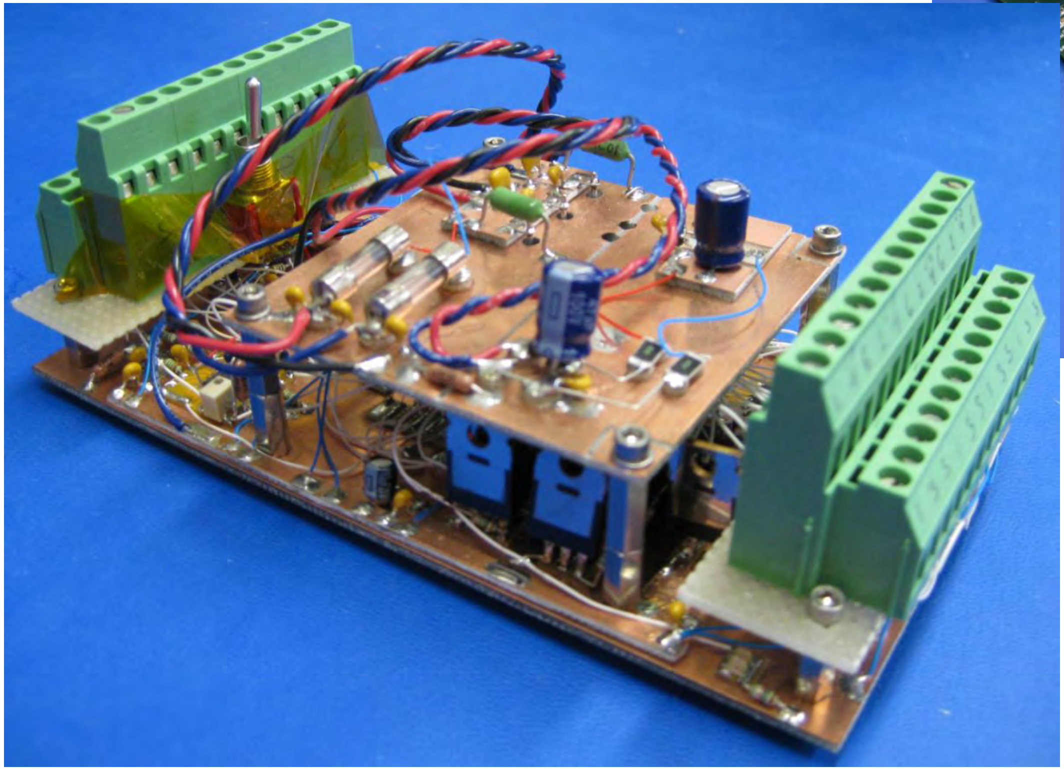
Analog Input	4 channels 4-20 mA, 0-5VDC, 0-10VDC, ± 5VDC, ± 20 mV, ± 100 mV
Sensor Excitation	Regulated +5/+12/+24VDC, 0.5 A NAMUR sensor interface
Analog Output	4 channels 4-20 mA, 0-10VDC, 0-5VDC ± 5VDC
Count Input	4 channels Quadrature x1, x2, x4 Count/Direction Up/Down counter 10kHz Bandwidth
Digital Output	4 channels, isolated SPDT dry contact: 125VAC 60VDC@1 Amp
Digital Input	4 channels 0-60VDC, Trigger level: 2.5VDC
Serial Communication	RS-485, isolated, half-duplex RS-232, non-isolated Ethernet, 10 Base-T TCP/UDP
Alarms	Tension, Payout, and Speed High and low setpoints (any parameter) Accessible via front panel menu interface
Ratings (Pending)	Nonincendive for Class I, II, III Div. 2, Groups A, B, C and D; AEx NC IIC Zone 2 & Ex nC IIC Zone 2; Indoors/Outdoors Type 4x

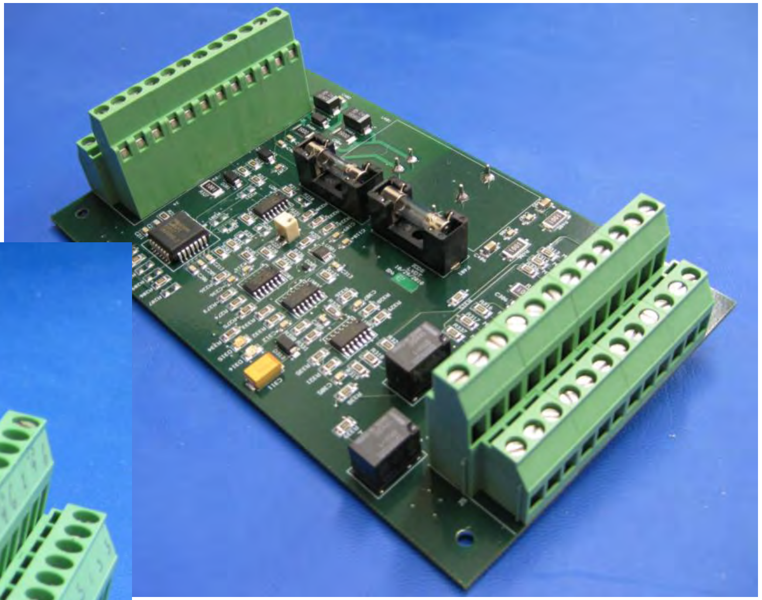
MEASUREMENT Technology NORTHWEST

4211-24th Avenue West, Seattle, WA 98199
Phone: 206-634-1308 / Fax: 206-634-1309
www.mtnw-usa.com

Level Wind Prototype

- Prototype Controller from DISC will be used for early testing

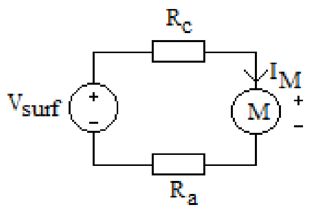




- IDD controller will include a power stage for motor control
- Both Voltage and current are controlled variables

Drill Motor Power Supply

- Ensures constant motor speed
- Enables use of smaller cable
- Increases power available to the drill motor
- Protects motor from over voltage
- Protects motor from over current
- Provides reduced risk of “sticking” the drill

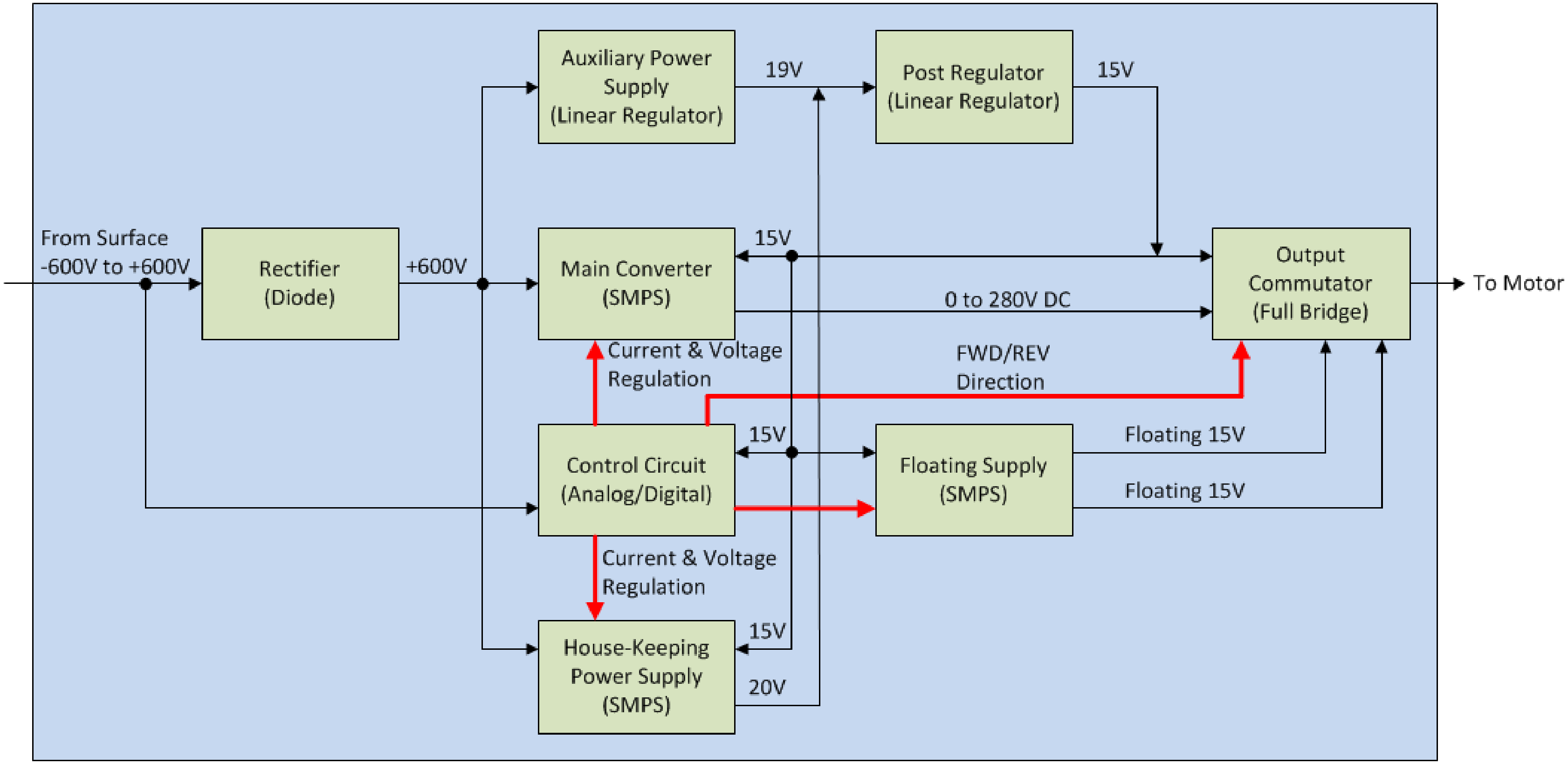


$$V_M = V_{surf} - I_M(R_c + R_a)$$

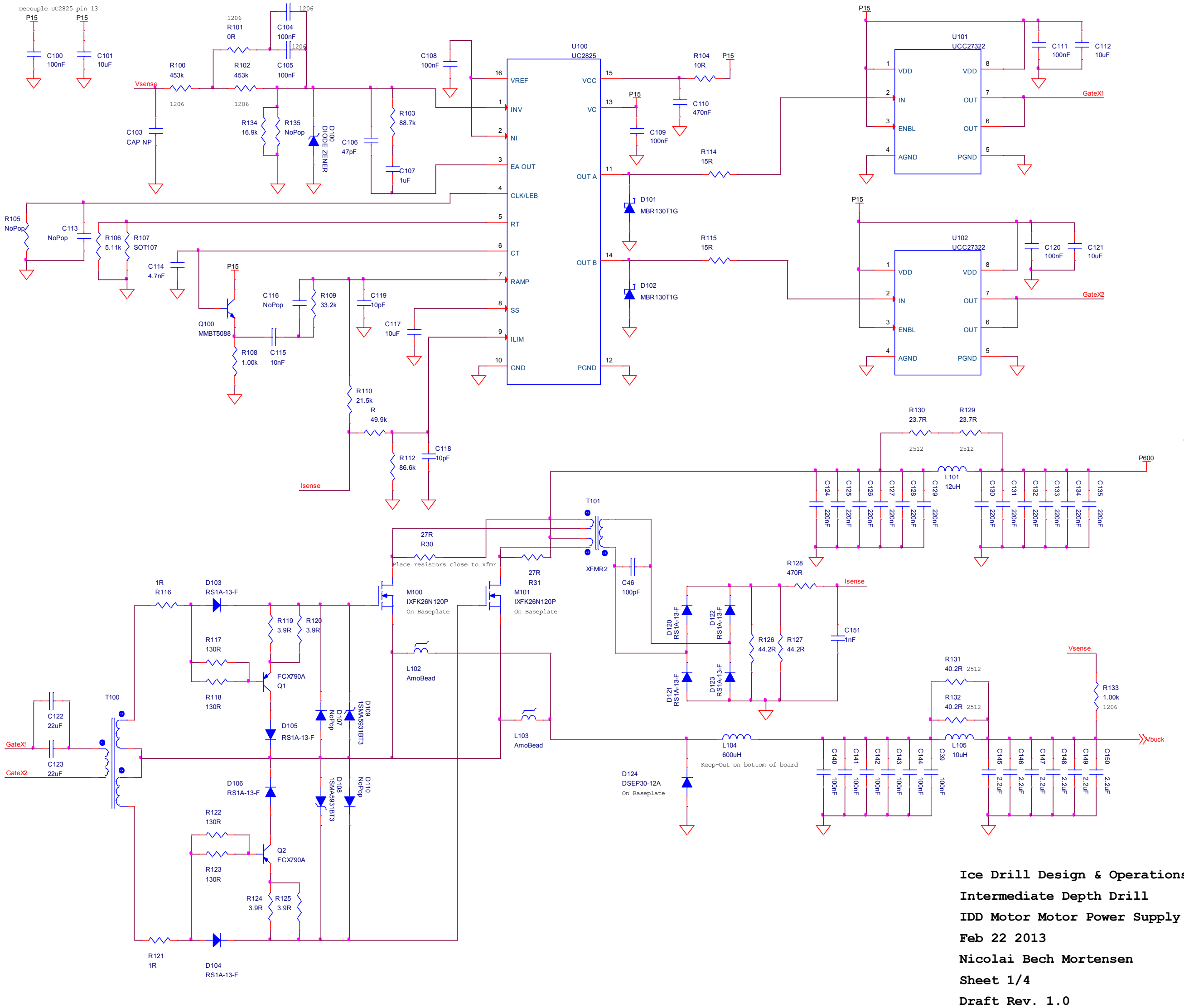
- With 300V at the surface, very little power is available at the drill
- Motor is rated to 280V which should not be exceeded “too much”
- Power supply inclusion permits the surface supply to be at 600V yielding over 500W of shaft power

Drill Motor Power Supply

- Single PCB design
- Modular design



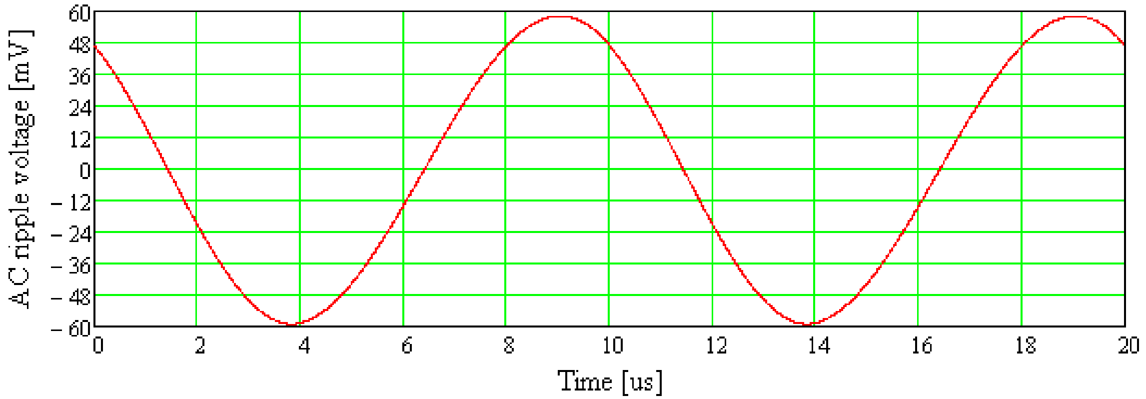
Drill Motor Power Supply



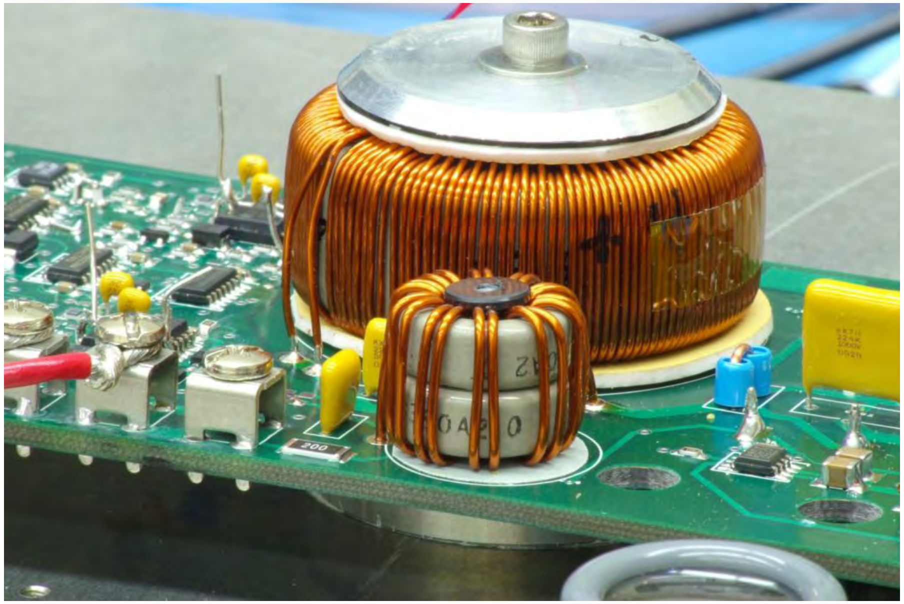
- Main converter based on DISC's Motor Power Supply "MPS"
- Buck converter topology with peak current control
- High Efficiency ~90%

Drill Motor Power Supply

- Produces "clean" DC voltage for the motor



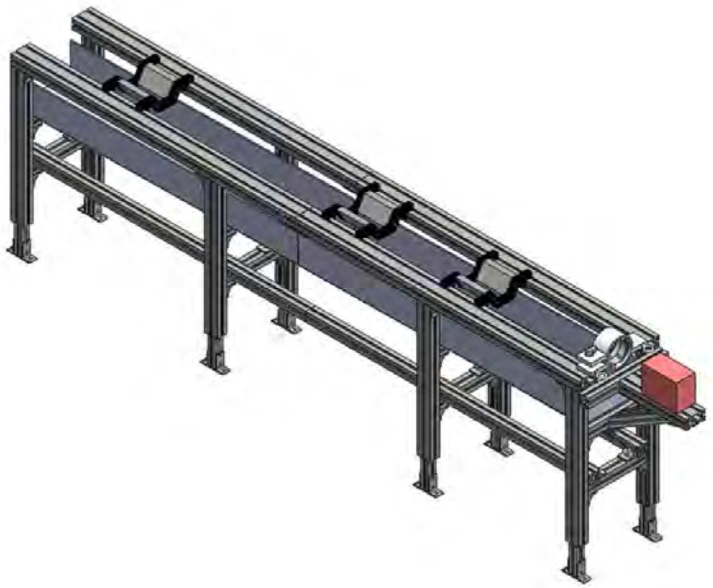
- Custom magnetics parts are transferable from DISC to IDD



Support Systems

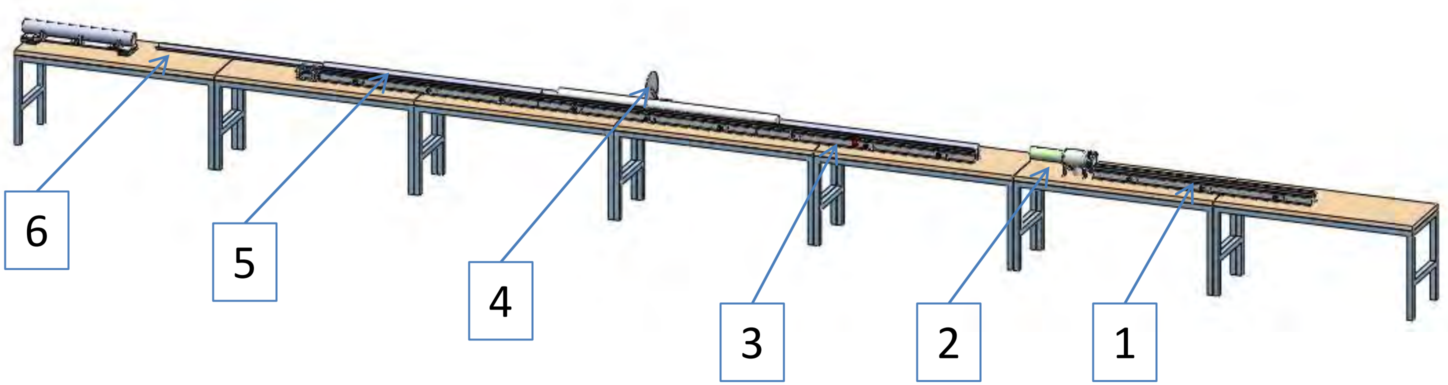
Core Barrel Pull-out Table

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



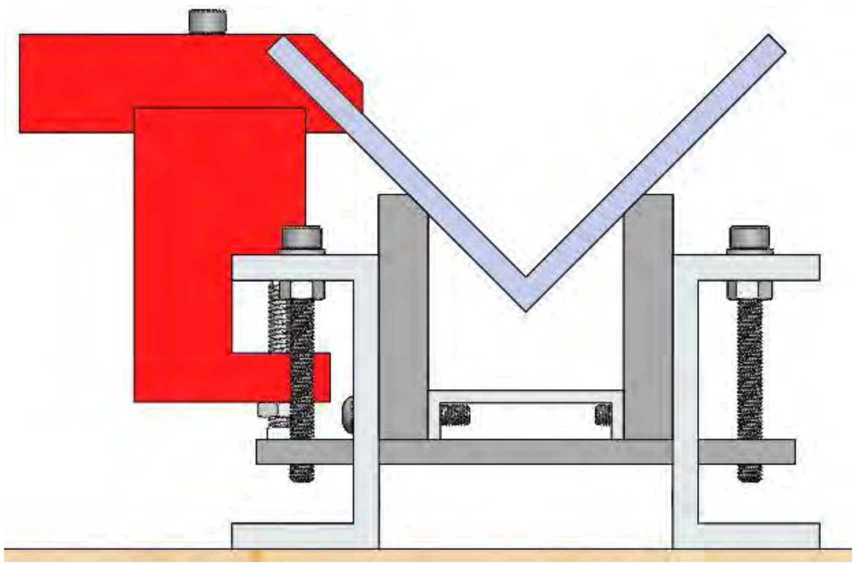
Core Processing

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



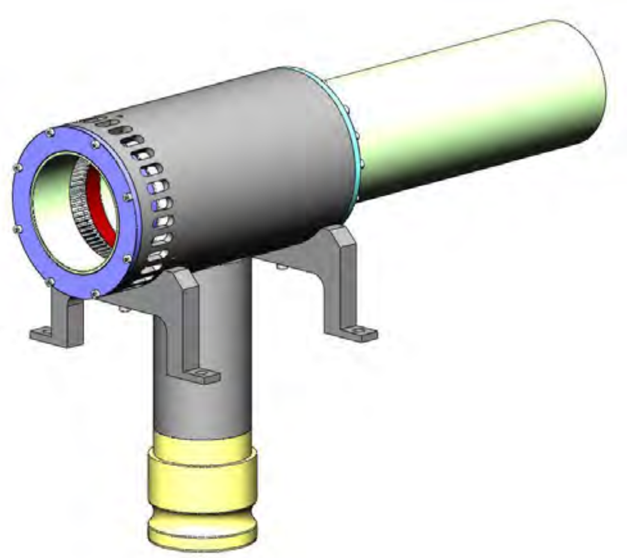
Core Processing (rail system)

- Adjustable height system
- C-channel construction
- 2m section length
- C-clamp style tray stop



Core Processing (FED)

- Based on DISC Drill FED system
- 98mm core diameter
- Netting deployment tube
  - Netting will be used with brittle ice



Core Processing (Saw)

- Circular Chop Saw
  - Reused from DISC
  - Good supply of 14” blades on hand
    - 2.4-2.6mm kerf
  - Optional 12’’ blade
    - 2.0-2.2mm kerf

14” chop saw at WAIS Divide

Centrifuge

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

Fluid Handling System

- Direct from barrels to borehole
- Drum pumps for moving fluid
- 1'' ID Low temp hose
- Fluid filter tank after centrifuge
- Gravity feed through filter screen to borehole

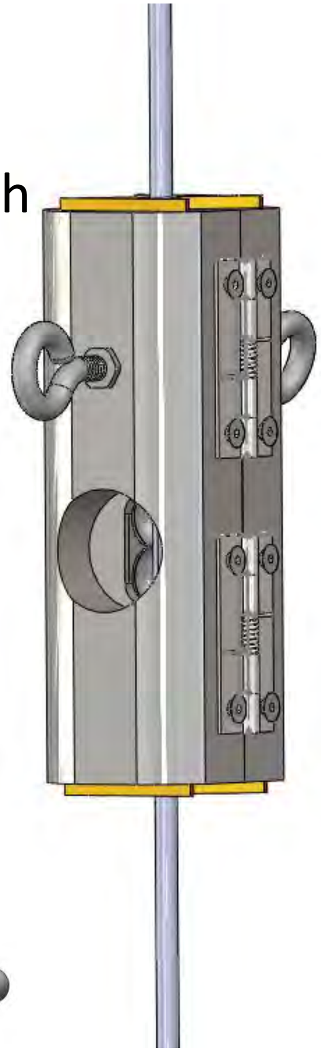
Fluid Filter Tank

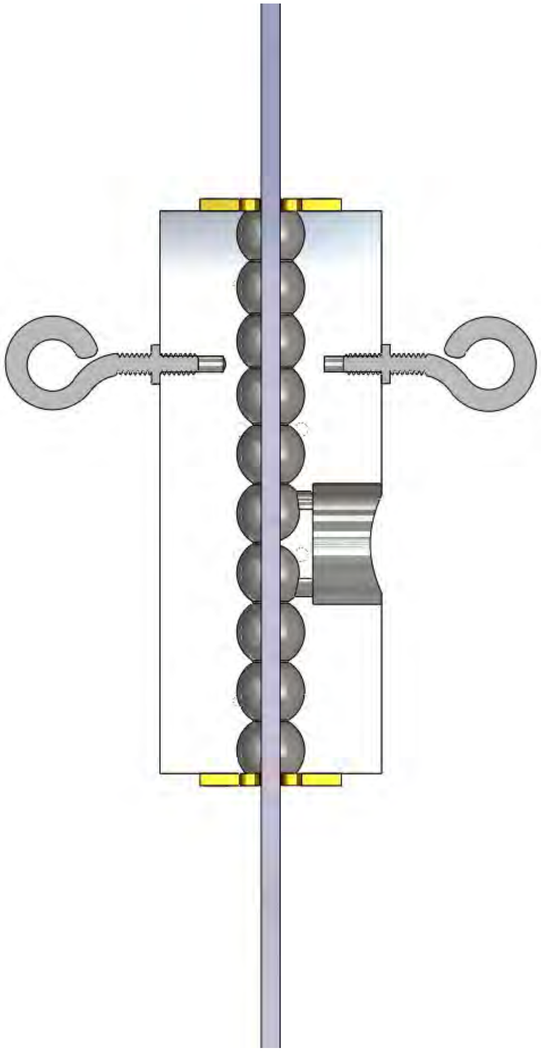
Vacuums

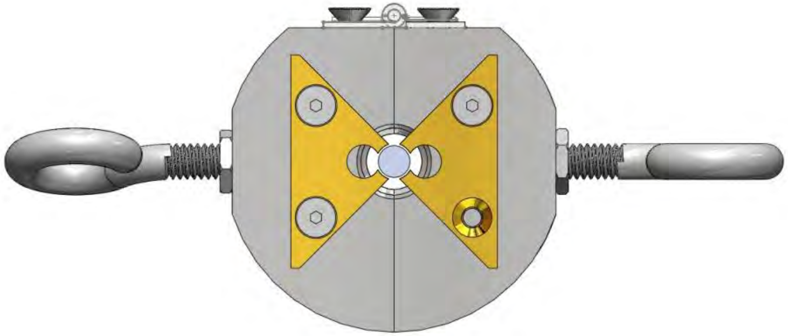
- Explosion proof
- 12.5 gal size
- 1.5” hose
- Same vacuums used at WAIS Divide
- For use with the FED and cable cleaner

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







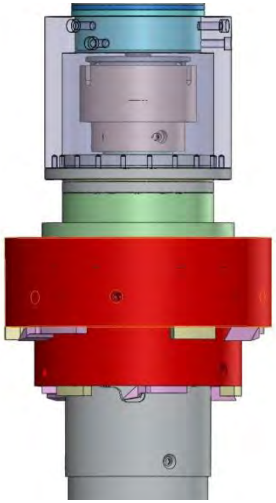
Pilot Hole System

- Polyethylene casing
  - 219mm (8.625") OD x 192mm (7.549") ID
  - 3m (10') long sections
  - ~22.7kg (50lb) per section
  - Sealed thread together connections
  - Will need ~40 sections for South Pole
    - 907kg (2,000lb) total weight
  - Installed using the drill tower

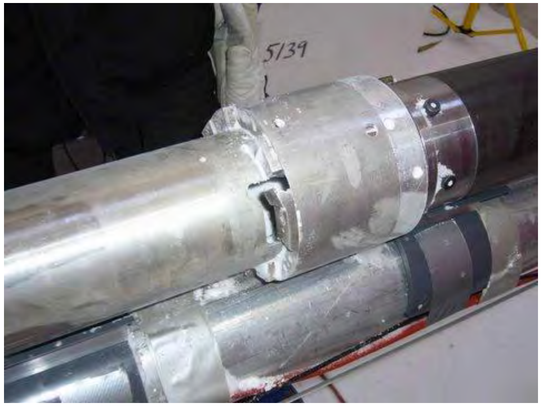
DISC Drill casing

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

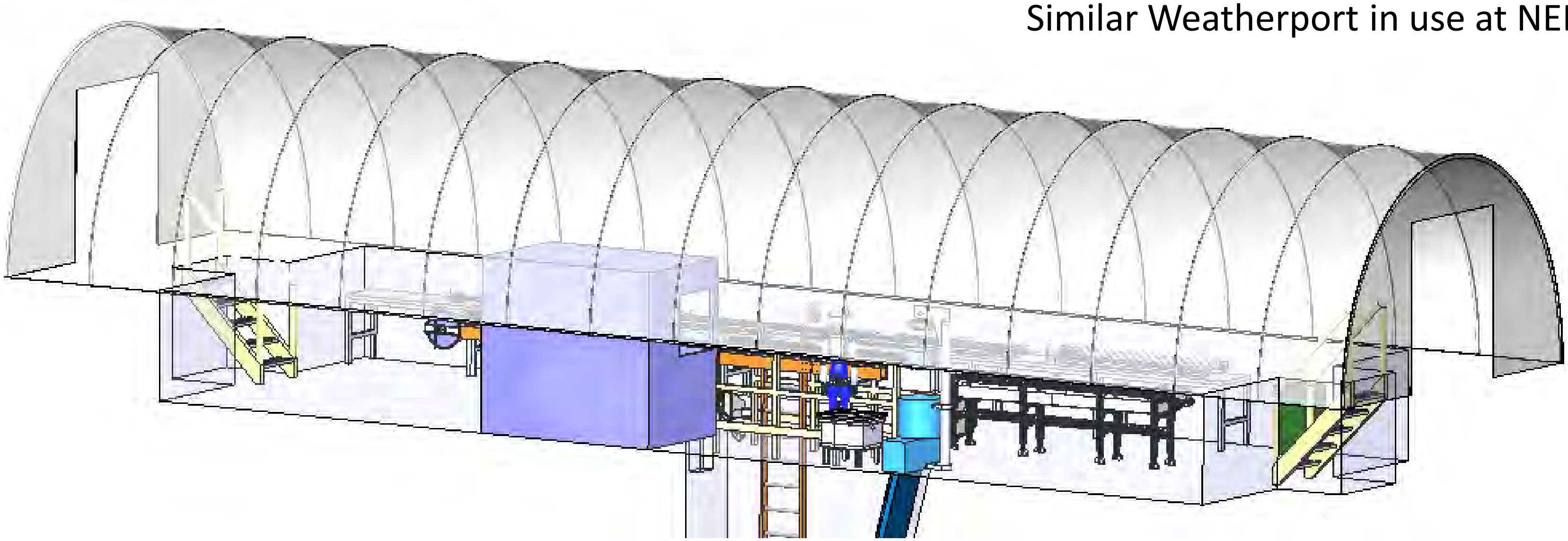


Danish reamers being used with the HT drill

Structures

- Drill Tent
  - 19.5m (64ft) x 4.9m (16ft) x 2.8m (9ft) high un-insulated Weatherport
  - Building and point of use ventilation
- Generator Tent
  - 4.9m (16ft) 3.0m (10ft) un-insulated Weatherport

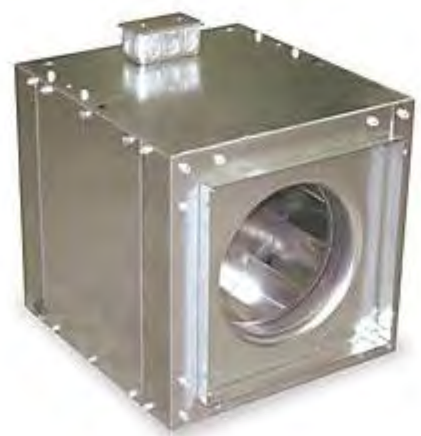
Similar Weatherport in use at NEEM



Ventilation

- The complete structure will have six exchanges per hour, per the WAIS arch design
- System will move 1200ft^3/min
- Exhaust from bottom of the slot, intake air at end wall of the arch
- Localized ventilation at the centrifuge and vacuums

Slot Ventilation Fan



Localized Centrifuge Ventilation

Multi-function Machine

Bobcat MT55 Mini Track loader

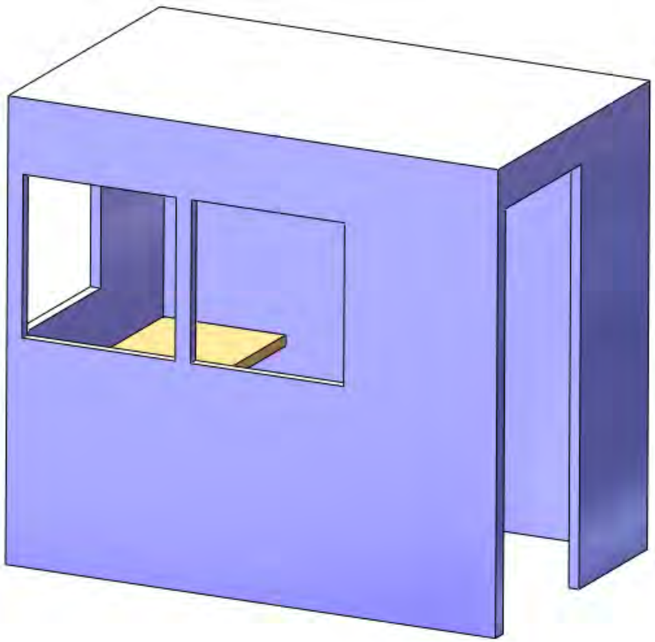
- Multi-purpose machine
  - Can run a snow blower as well as other attachments like a bucket and forks
- 3.6psi ground pressure with wide track kit
- 1,610lbs tipping load
- Machine weight is 2,600lbs
- 39” wide by 93” long

Zaugg snow blower

- Open end auger for slot cutting in hard snow and ice
- 16” diameter auger
- 47” cutting width

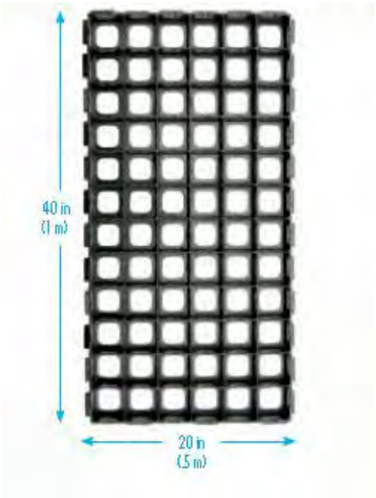
Control Room

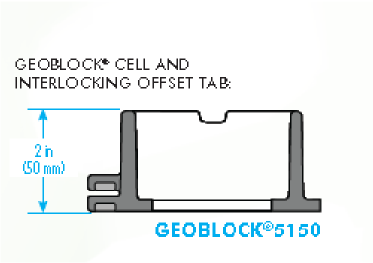
- Soft-side building
  - Insulated fabric walls and ceiling
- Insulated floor
- 2.4m (8ft) x 1.5m (5ft)
- Three thermopane windows
  - End window on side wall will open
  - Will provide operator with a good view of the entire drilling operation
- Hard side door
- Electric head with supplemental heating provided by winch motor break resistor



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

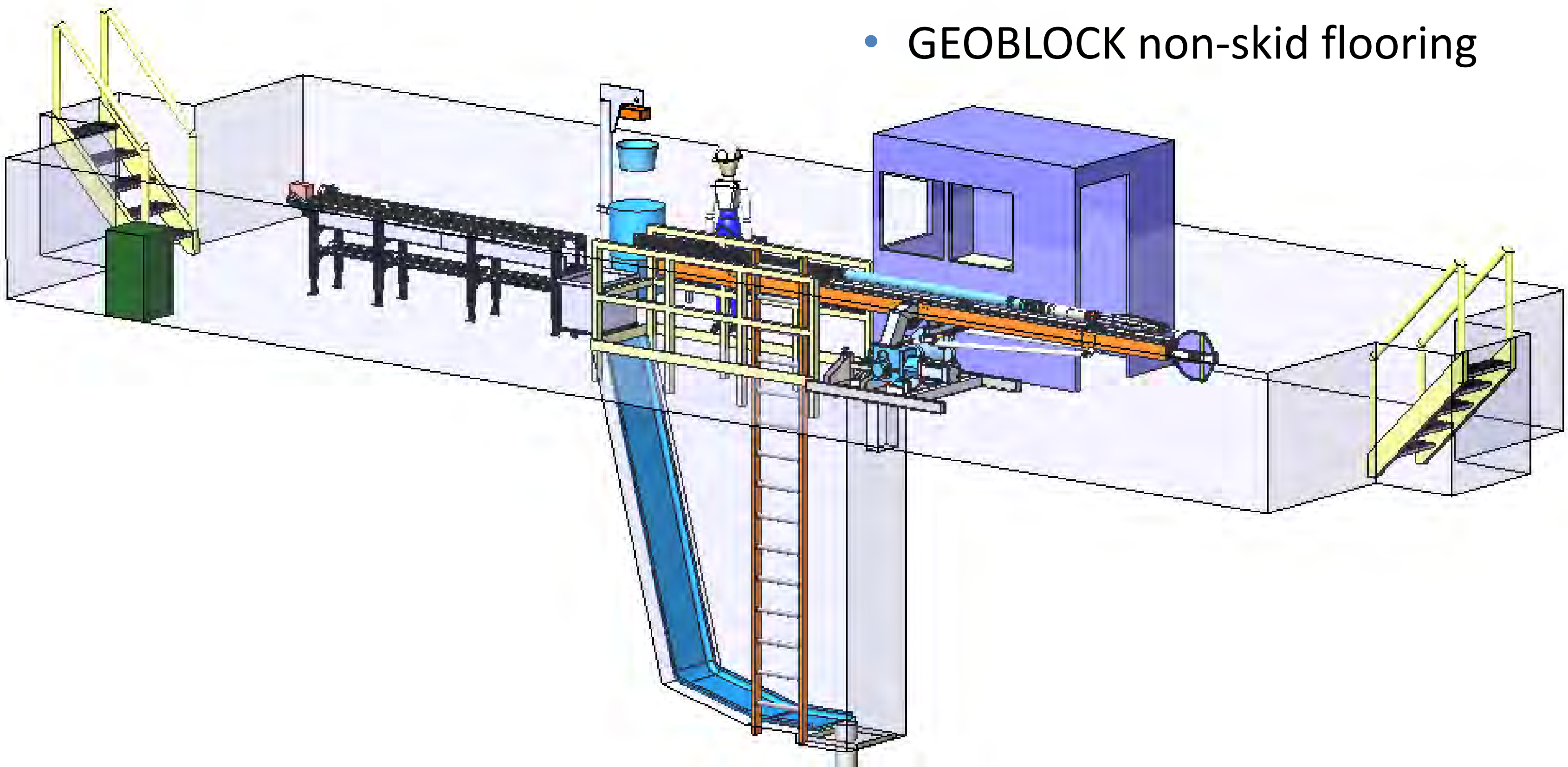
- Two single part fluids are being considered
  - Isopar K
  - Estisol 140
- Will need 132 drums for a 1,500m deep hole
  - Assumptions:
    - Fluid level maintained at 75m
    - 30% loss rate
    - 200l per drum

Safety

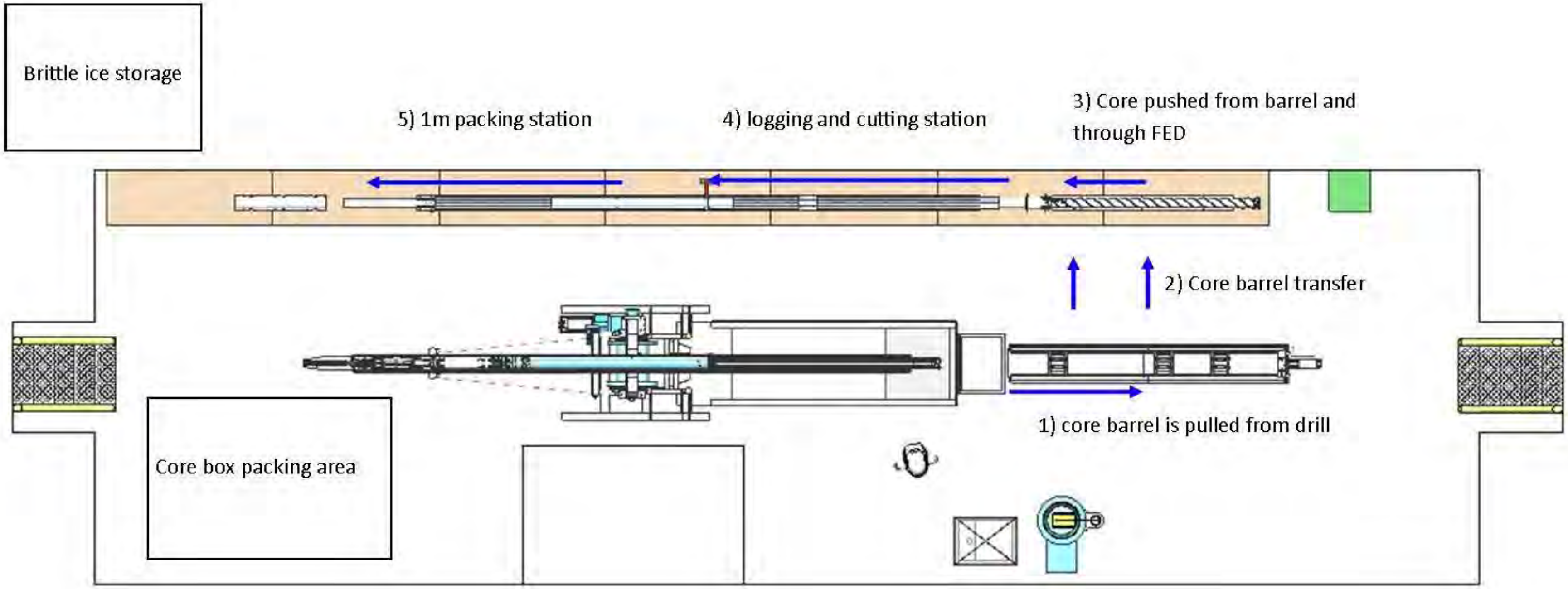
- FMEA - completed
- PPE
  - ECW gear for working with drilling fluid
  - Harnesses and fall protection
  - Eye protection
  - Clip-on air monitor for slot entry
  - Hard hats
- Safety Plan including confined space procedure
- Pre-season training
- Centrifuge control remotely mounted
- E-stop system

Safety

- Non-skid stairs at building entries
- Ladder for slot entry
- Slot hand rails with toe kick
- Fuel bladder material for fluid containment in slot
- Metal drip pan at casing
- Centrifuge pan hoist
- GEOBLOCK non-skid flooring



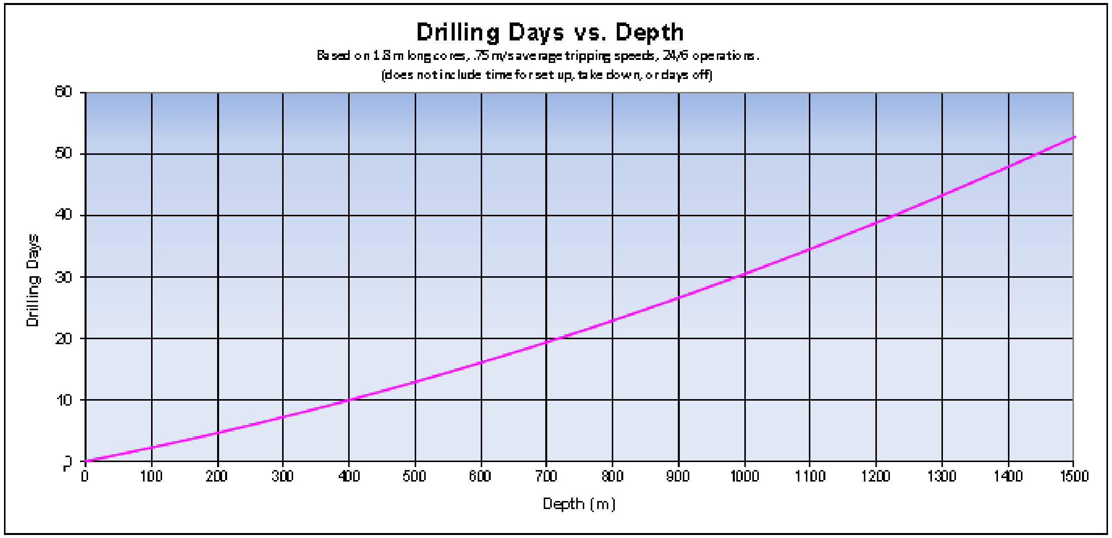
Core Processing Flow



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