FORO DRILL SYSTEM

Preliminary Engineering Design Review

The Foro Drill is IDDO's newest shallow coring drill system

Foro is a Latin word meaning "to make a hole, pierce, or to bore"

The Foro Drill has been designed to replace our aging 4-Inch drill systems, which ICDS/IDDO inherited from PICO

Engineering Requirements

1.0 PURPOSE

1.1 This document outlines the engineering requirements for the cable winch system(s) to be used with the 98mm drill.

2.0 SCOPE

2.1 This document applies only to the 98mm Drill Winch functionality.

3.0 REFERENCES

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 **PM** – IDDO Project Manager

4.4 **QA** – SSEC 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**

6.1.2 Winch drum shall be capable of holding 400m of 5.7mm diameter wireline cable.

6.1.3 Operate at temperatures down to -40°C.

6.1.4 The winch system shall be compatible with Isopar K and Estisol 140 drilling fluids.

6.1.5 System should be designed to withstand a 6,000 N core break.

6.1.6 Winch should have a minimum rated lifting capacity of 148 kg (325 lbs.)

6.1.6.1 Sonde weight allowance - 91 kg (200 lbs.)

6.1.6.2 Cable weight allowance - 57 kg (125 lbs.)

6.1.7 The design should be made to minimize weight.

6.1.8 Design the winch system to be operated by 1 person.

6.2 **Sled Base**

6.2.1 Base assembly shall have skies or skid base with curled tips on both ends.

6.2.2 Skies shall have a ¼" thick UHMW glide surface.

6.2.3 Winch and tower assembly shall attach to sled base.

6.2.4 Ski ground pressure should not exceed 3 psi for transport.

6.2.5 Both ends of base shall have anchor points for attaching a rope and/or ridged hitch for towing behind a snow machine.

6.3 **Winch Drum**

6.3.1 Aluminum construction.

6.3.2 Lebus-grooved core.

6.3.3 The Wireline Slip ring should be built internal to the drum.

6.3.4 **Line Speed**

6.3.4.1 System shall be capable of smooth, controlled line speeds down to 1.0 mm per second.

6.3.4.2 System shall be capable of spooling cable at an average line speed of ≥ 0.75 meters per second.

6.4 **Tower**

6.4.1 Sufficient height to separate the core barrel from the drill in the vertical position.

6.4.2 Easily assembled in the field with minimum tools required.

6.4.3 Able to be disassembled into sections for easy transport.

6.5 **Crown sheave**

6.5.1 Shall be instrumented to read cable payout.

6.5.2 Shall be instrumented to read cable load.

6.5.3 Should incorporate means to prevent the cable from being able to jump off the sheave.

6.6 **Transportation**

Twin Otter or similar-sized aircraft or Bell 212 helicopters are commonly used to reach remote sites. The winch system should be designed for transport by either of these types of aircraft.

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

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

6.6.3 All sub-components shall require no more than 2 people to move.

6.7 **Power System**

6.7.1 The system shall be designed to be powered by a 5 kW or smaller portable gasoline generator.

6.8 **Safety**

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, safety of personnel during field projects is paramount. 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

Engineering Requirements (cont.)

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.

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

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

6.8.3 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.

6.8.4 Minimize environmental impact of the drilling operations.

6.8.5 Provide identification and protection from dangerous voltages.

6.8.6 Provide safety interlocks (Lock-Outs) to prevent the inadvertent operation of the equipment that would endanger personnel.

6.8.7 Provide emergency stop and emergency power-off systems to respectively halt motion of 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. (The winch must engage the brake and hold its last position in case of a loss of power.)

6.9 **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.

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

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

6.10 **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.

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

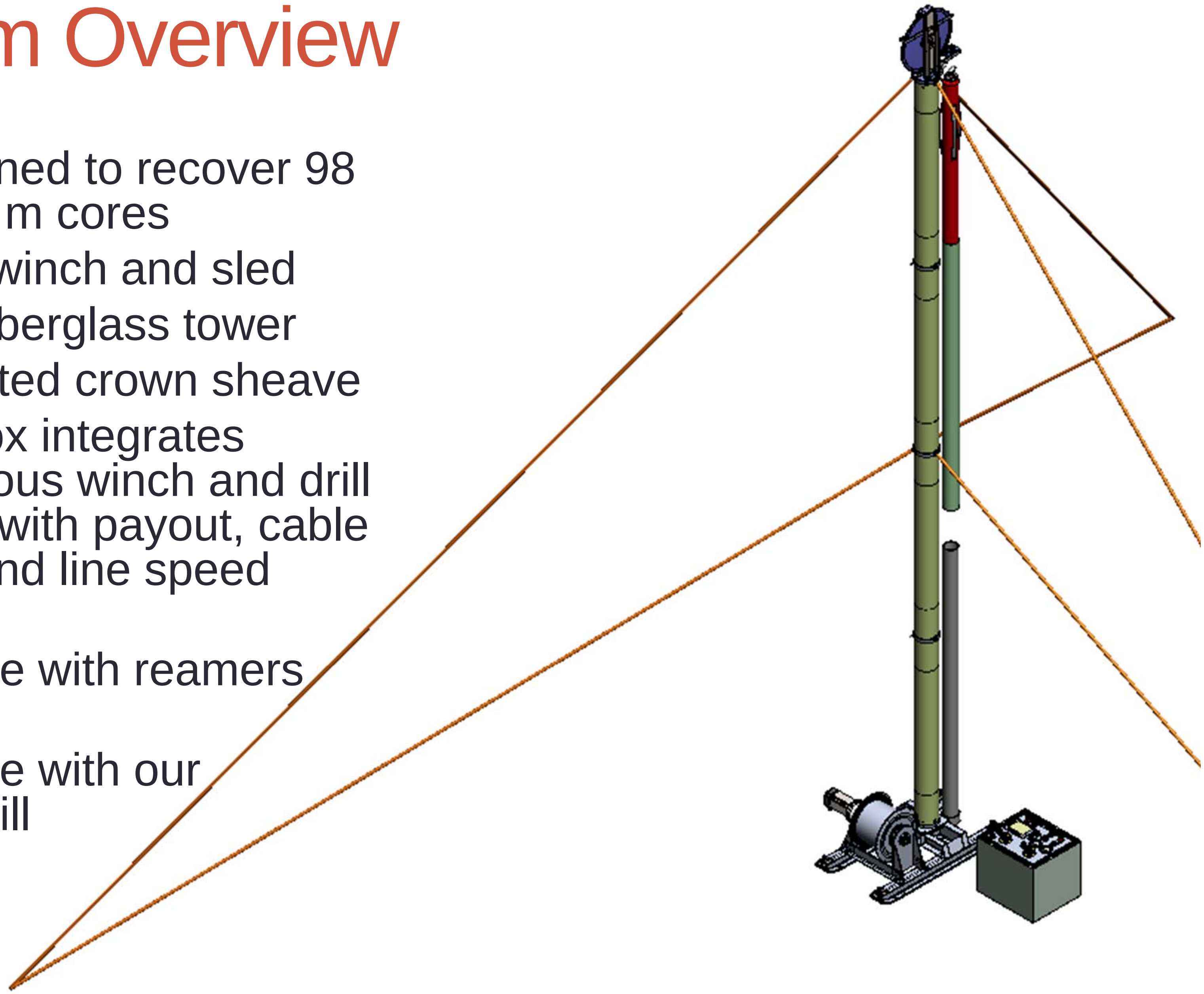
6.10.2 Reduce the time needed to drill and recover cores to a minimum and maximize safety.

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

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

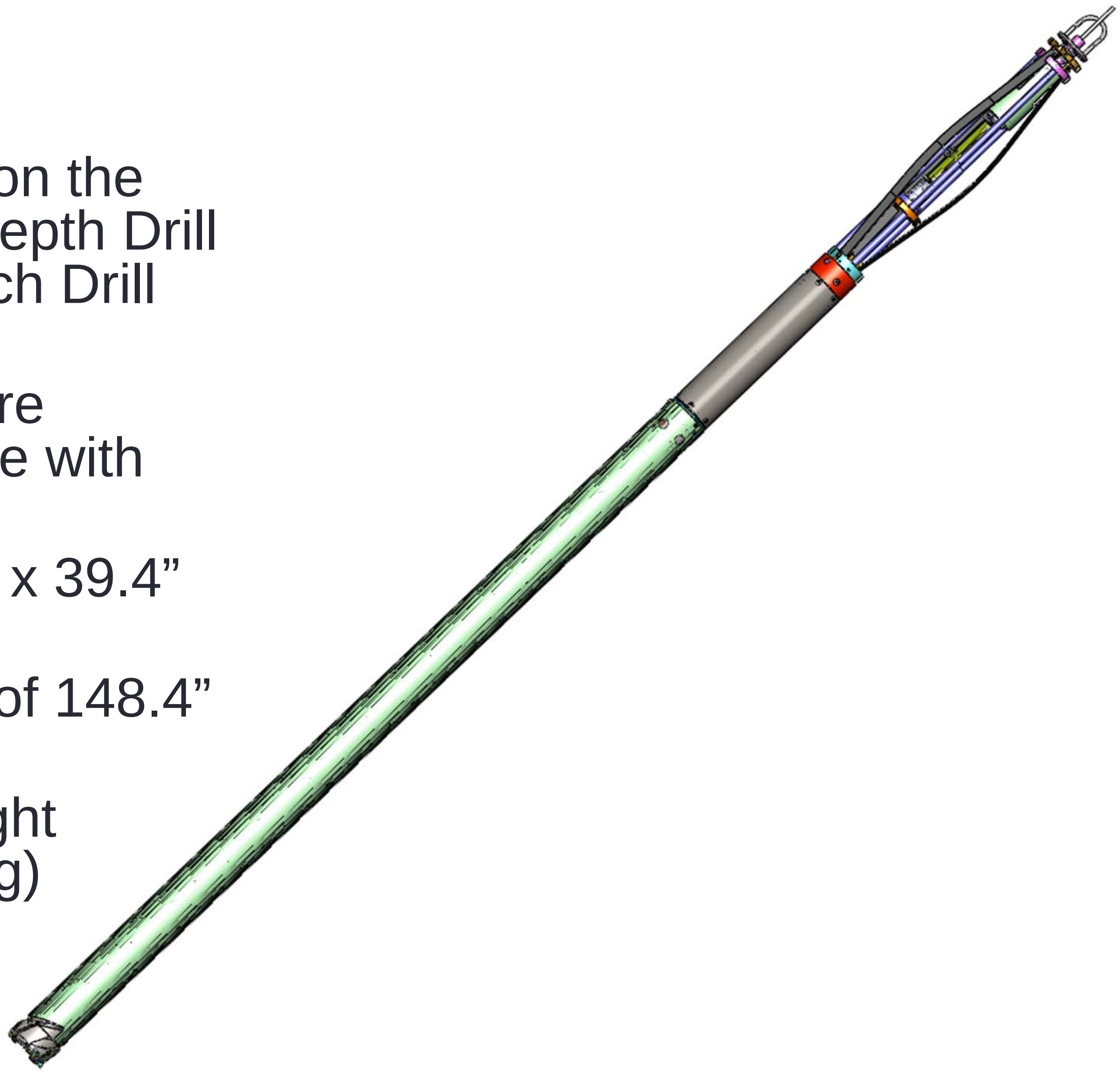
System Overview

- Drill designed to recover 98 mm Ø x 1 m cores
- Compact winch and sled
- Modular fiberglass tower
- Instrumented crown sheave
- Control box integrates simultaneous winch and drill operation with payout, cable load, and line speed feedback
- Compatible with reamers up to 12”
- Compatible with our thermal drill



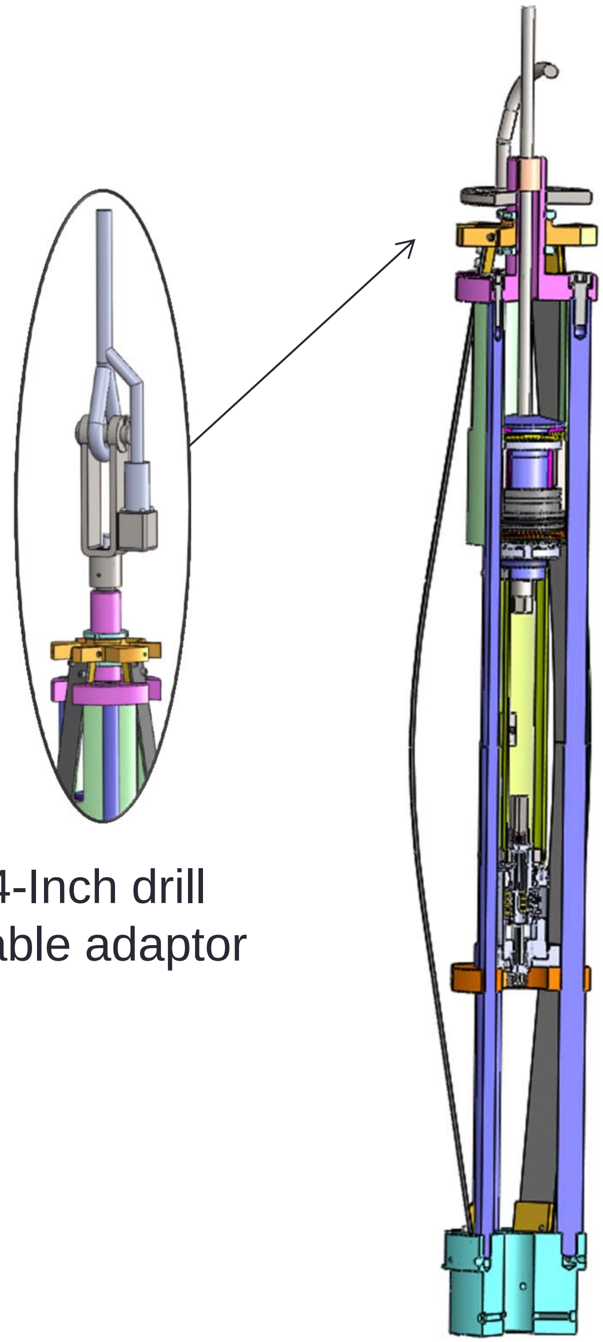
Sonde

- Design based on the Intermediate Depth Drill (IDD) and 4-Inch Drill designs
- Components are interchangeable with the IDD sonde
- 3.9” (98mm) Ø x 39.4” (1m) core
- Overall length of 148.4” (3.8m)
- Estimated weight is 141lbs. (64kg)



Anti-Torque

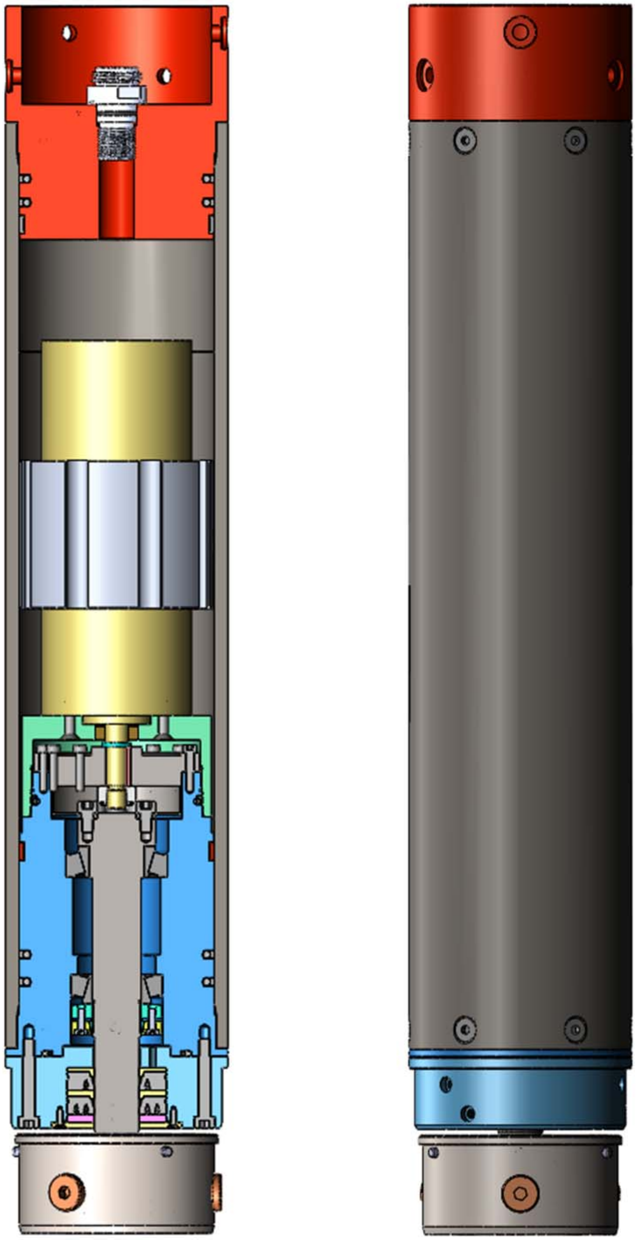
- Design is identical to the IDD Drill
- Incorporates the updated cable bearing assembly
  - Tapered roller bearings replaced with a needle and thrust bearing package
  - Teflon seals
- Fully terminated cable can be easily disconnected
- Integrated Anti-Torque slip sensor
- Sealed 4-channel slip ring
- Adaptor has been designed so the Foro Drill sonde can be used with the existing 4-Inch Drill System equipment



4-Inch drill cable adaptor

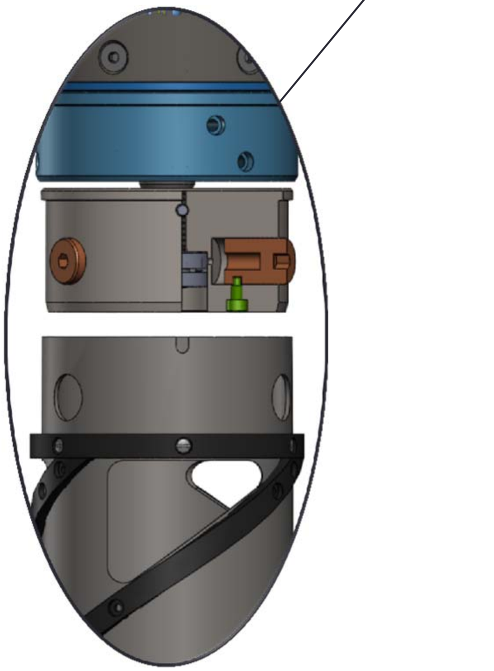
Motor Section

- Shorter version of the IDD motor section
  - Shortened by 6.9” (175 mm)
  - No internal motor power supply (MPS)
- Permanent magnet brushed DC motor
  - 500 W (0.68 hp)
  - 220 V
  - 5400 rpm
- 80:1 harmonic drive speed reducer
- ~63 rpm cutter speed
- Minimum pressure rating of 4,000 psi



Core Barrel

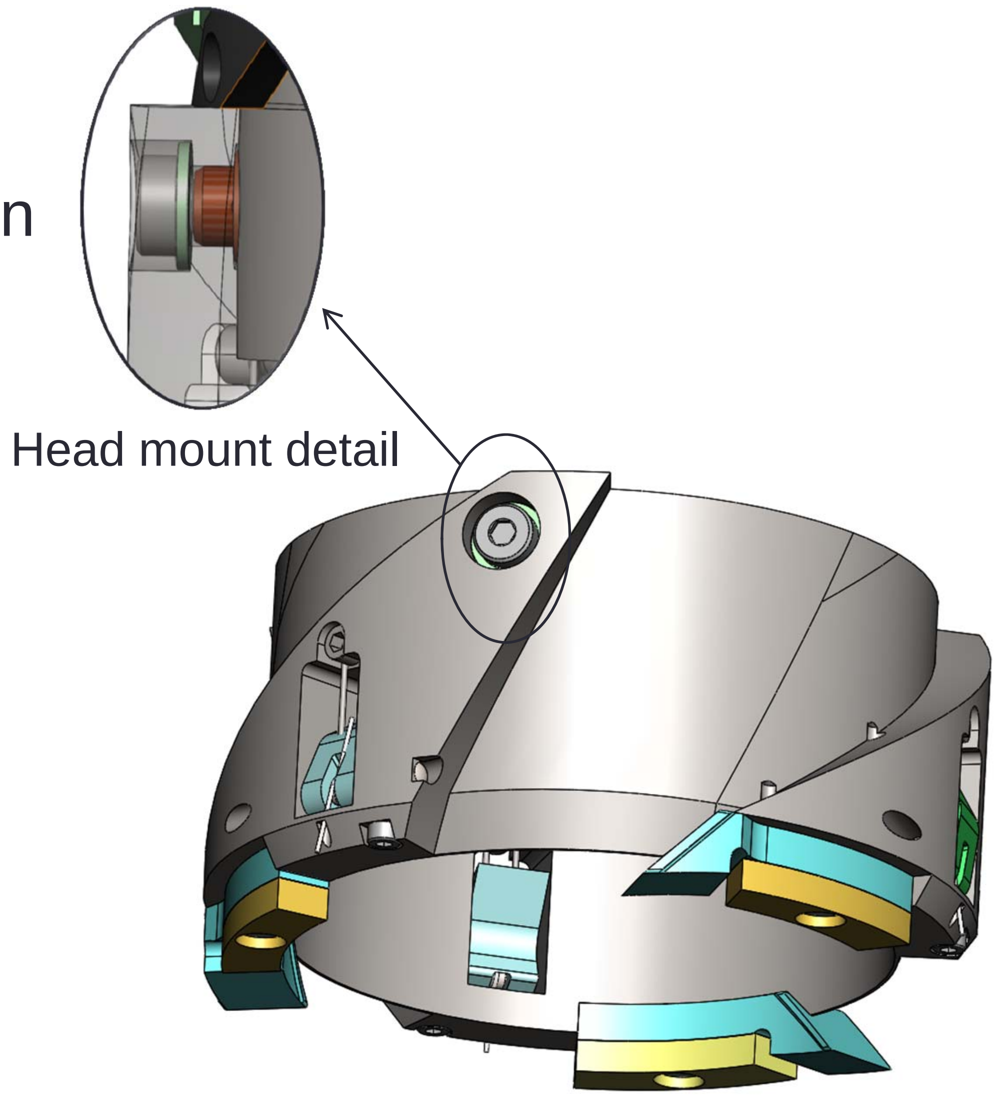
- 90” (2.30 m) long barrel
- 304 Stainless Steel tube
  - 4.09” (104 mm) OD, 3.94” (100 mm) ID
- Polyethylene flights
  - 200 mm pitch
- Chips collect in barrel above the core
- 1.13 m long core length with 1.5:1 chip expansion ratio



Core barrel drive and window

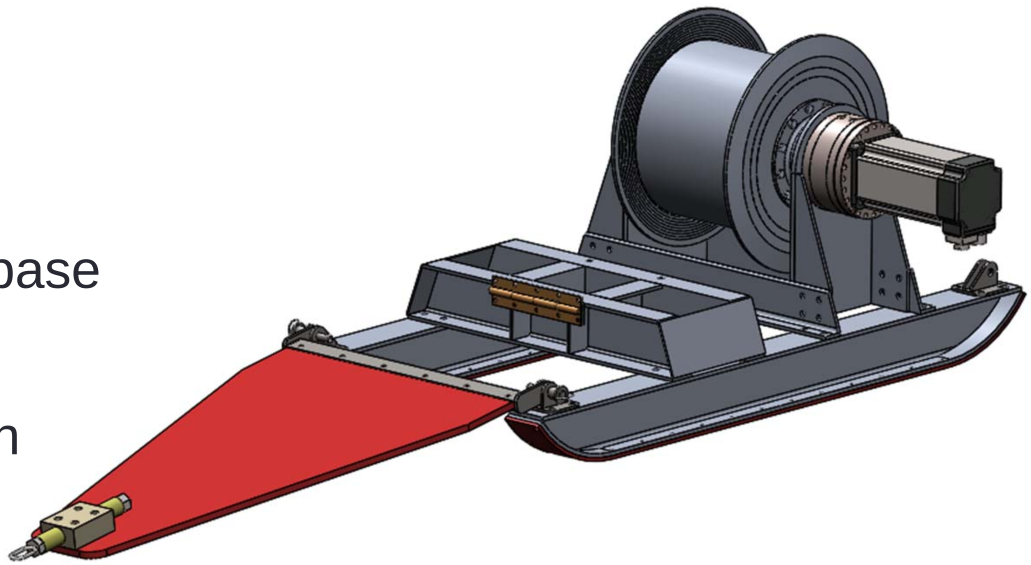
Cutter Head

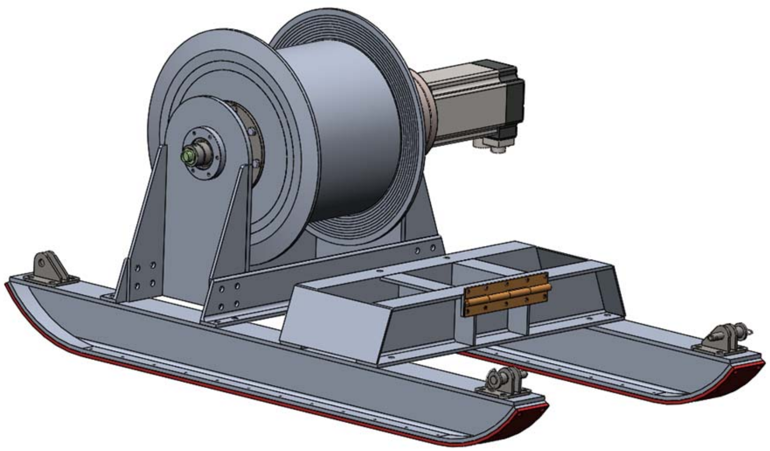
- Identical to the IDD design
- Three cutters and three core dogs
- 98 mm Ø core
- 126 mm Ø borehole
- Cutters
  - Updated IDD design
    - 7.5° relief angle
    - 45.0° rake angle
- Shoes for 1 mm to 5 mm penetration rates
- Head is "pinned" to core barrel



Sled

- 24” wide by 48” long
- Two aluminum skies with UHMW plastic lining
- One-piece aluminum tower base weldment with hinged tower mount
- Integrated tow points on both ends
- HDPE tongue with shock absorbing hitch
- Weight of sled with winch (no cable) is 168 lbs. (76 kg)
  - Sled alone weighs 53 lbs. (24 kg)
- 1.4 psi snow load with 400 m cable
- 17.0 psi max snow loading at core break
  - Dunnage may need to be placed under the skies to spread the load

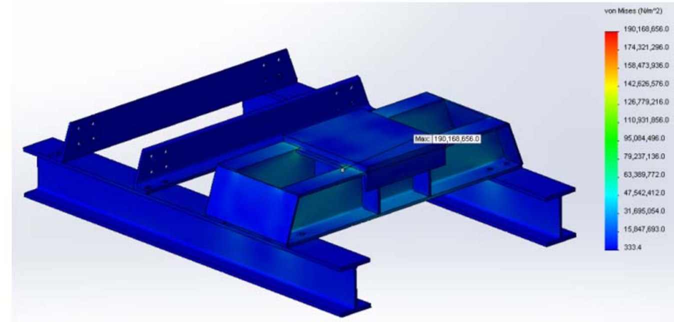


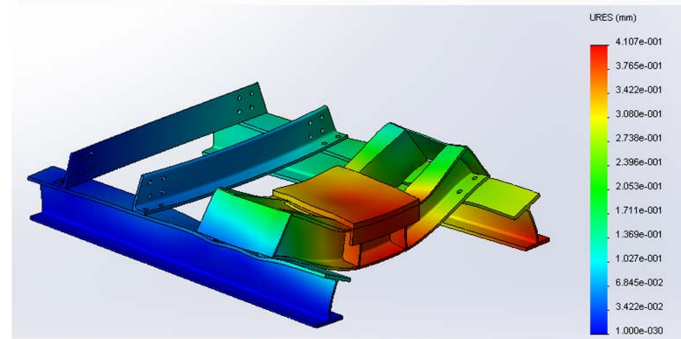


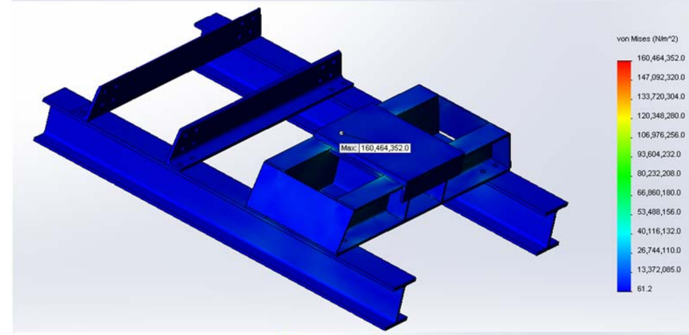
Sled (cont.)

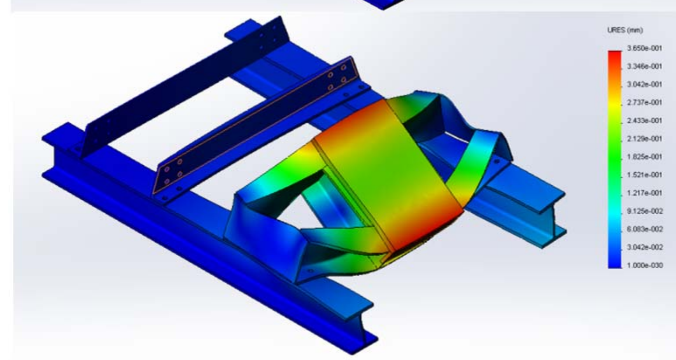
Analysis of vertical and torsional loading of the tower base weldment

- 2.9 safety factor with 5,094 lbs. (22.6 kN) vertical load
  - 4,496 lbs. (20.0 kN) core break load
  - 598 lbs. (2.7 kN) guy rope load
- 3.7 safety factor under torsional loading
  - Maximum moment that can be applied to the tower before the sled will begin to tip is 624 lb·ft (846 N·m)
  - This is worst case loading before guy ropes are installed on tower
- Weldment will need to be solution heat treated and artificially aged after welding



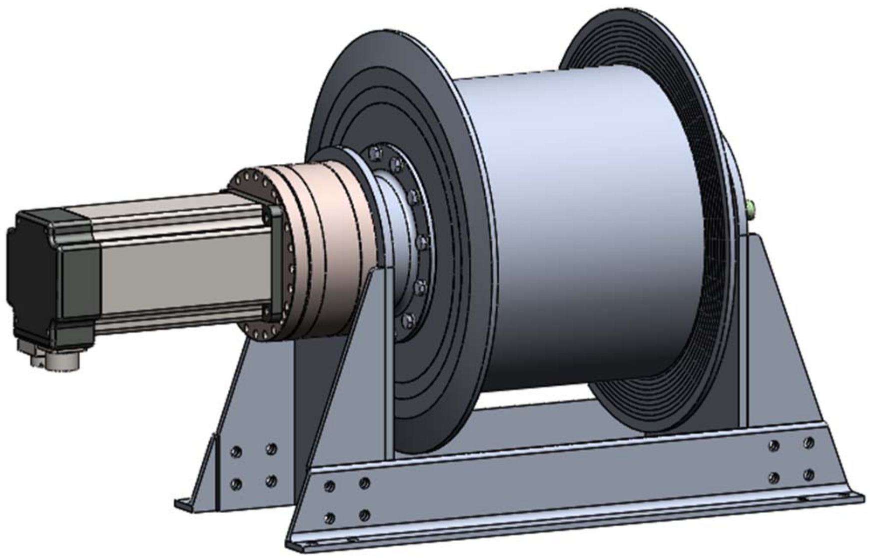


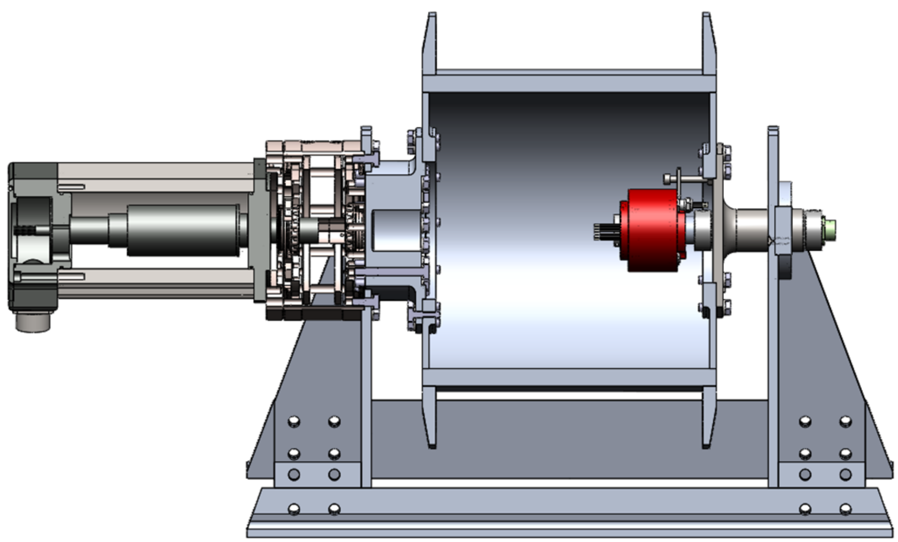




Winch

- One piece aluminum drum
  - 400 m cable capacity
  - 4-channel Internal slip ring
  - Lebus grooved core
  - 12.0” Ø core x 9.9” wide drum
  - 16.25” diameter flanges
- Compact 83:1 ratio cycloidal type gearbox
  - Internal bearings support one end of winch drum
- Aluminum frame assembly
- 0.9 to 1.1 m/s max tripping speed
- Winch motor is removable without loss of gearbox lubricant
- No Level Wind
  - 1.1° max fleet angle
- Weight of winch assembly is 115 lbs.
  - 200 m of cable adds 58 lbs.

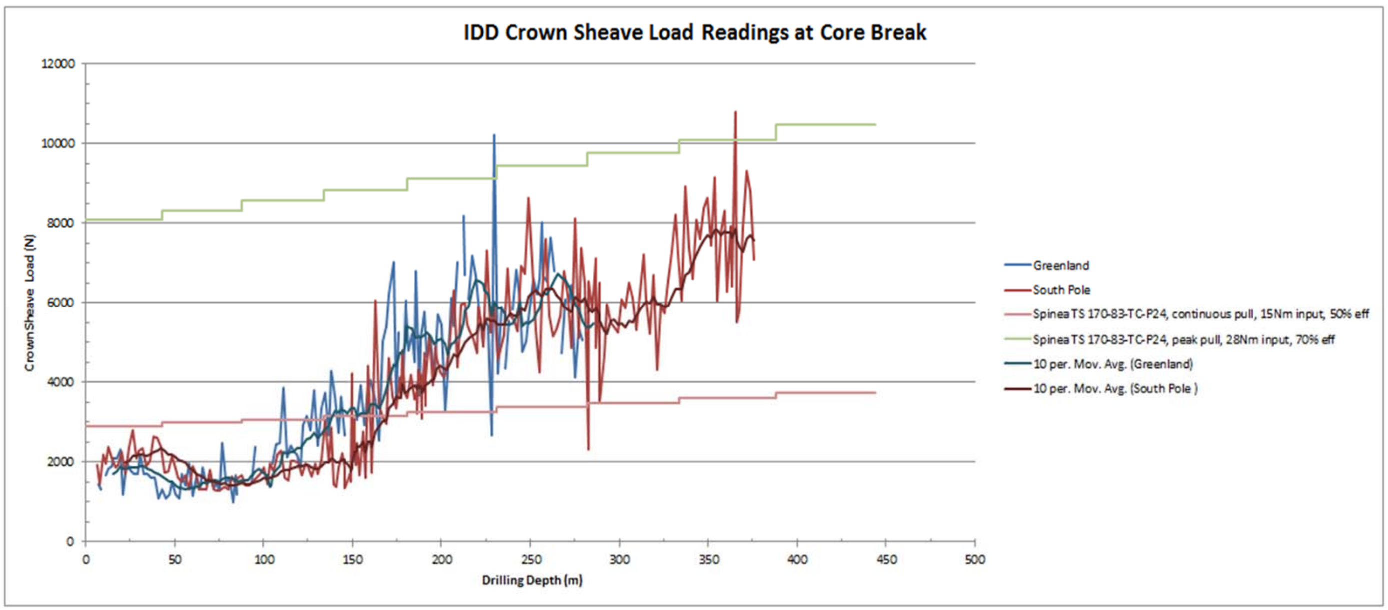




Winch (cont.)

- Drive is capable of short duration line pull of 8.0 kN to 10.5 kN for breaking core
- Exlar SLM 115 servo motor
  - Smaller version of IDD winch motor
  - Internal resolver and fail safe brake
  - Optional extended rear shaft for manual driving

Stator	SLM115 238-45	
Continuous Motor Torque	122.1	lbf-in
Peak Motor Torque	244.2	lbf-in
Torque Constant (Kt)	6.8	lbf-in/A
Continuous Current Rating	20.09	A
Peak Current Rating	40.18	A
Voltage Constant (Ke)	46.4	Vrms/Krpm
Resistance	0.212	Ohms
Inductance	3.87	mH
Bus Voltage	230	V
Speed @ Bus Voltage	4500	RPM
Thermal Time Constant	1934.6	s
Number of Poles	8	#

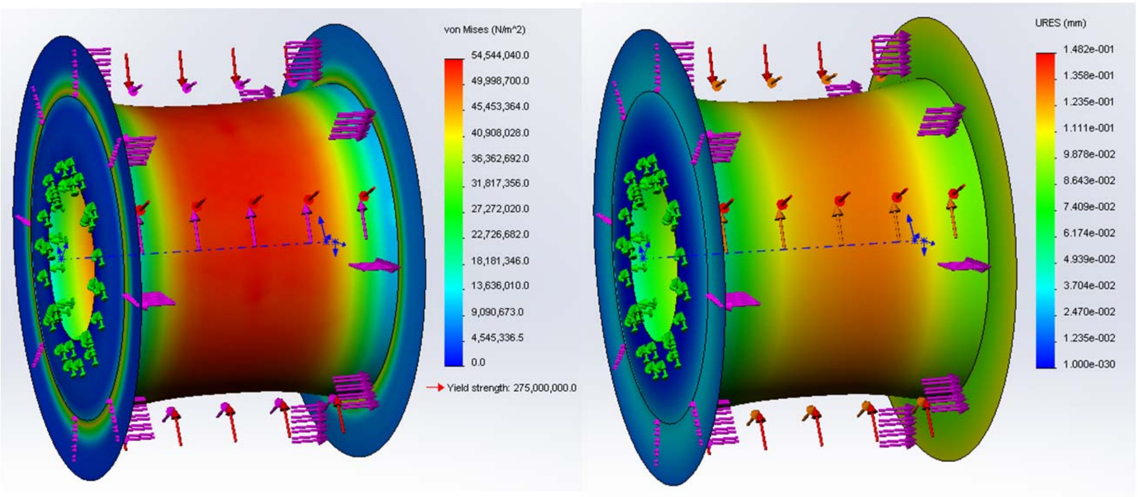


Winch (cont.)

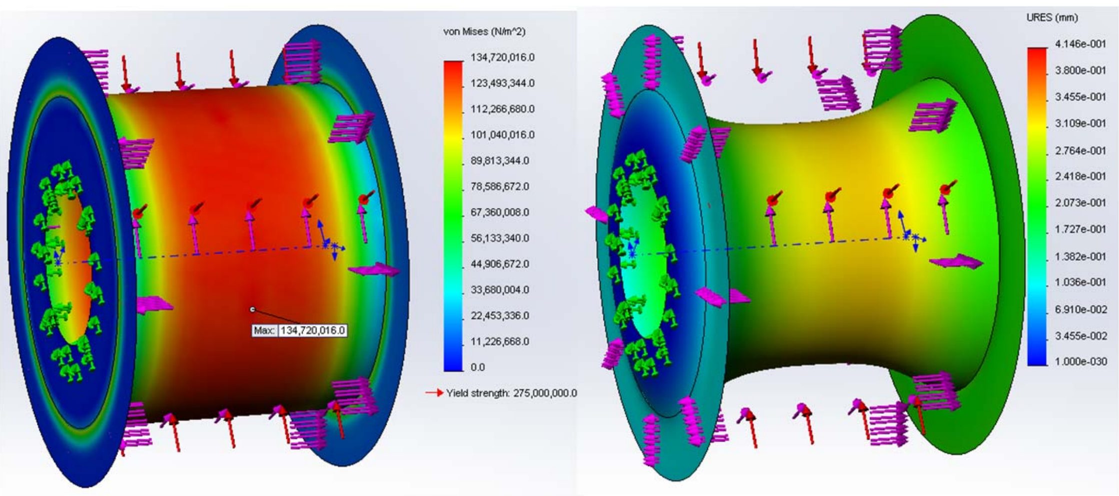
Load analysis of winch drum

- Nominal spooling tension assumes loads only due to cable and sonde weight and friction of the drill in the borehole
- Max spooling tension assigns each cable layer with the max force the drive can deliver for that layer
- Drum will be solution heat treated and artificially aged after welding

Component	Material	Yield strength	Torque applied	force applied	Highest Stress	Saftety factor
Units		N/m^2	N/m	N	N/m^2	
Gearbox output flange	Al6060-T6	2.75E+08	1603	10000	3.46E+07	7.9
Stub shaft	304SS	2.07E+08		10000	1.45E+08	1.4
Stub shaft	304SS	2.07E+08		5000	7.27E+07	2.8
Stub shaft	304SS	2.07E+08		2500	3.64E+07	5.7



Stress and displacement at **nominal** spooling tension



Stress and displacement at **max** spooling tension

Winch Cable

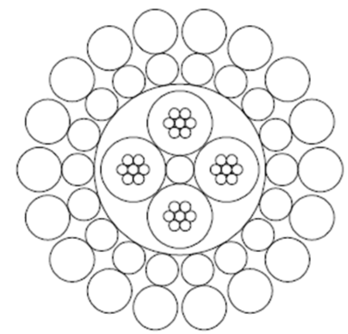
- Manufactured by Rochester Wire & Cable
- FEP (Teflon) wire insulation
- Four internal conductors
    - Two conductors for the drill motor
    - Two conductors for the Anti-Torque slip sensor

751 Old Brandy Road
Culpeper, Virginia 22701

Tele: 540 825-2111
Fax: 540 825-2238

DATALINE®

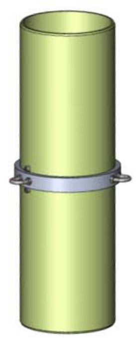
Description	mm	Inch
CONDUCTORS (4) #24 AWG, 7/0.008" (0.20mm) BC	0.61	0.024
INSULATION 0.012" (0.32mm) Wall PFA	1.22	0.048
CORE 4 insulated cdrs twisted with fillers as necessary. Protective bedding over core.	2.97	0.117
ARMOR: Spec GIPS Wire		
Inner: 18/0.022" (0.56mm)	4.09	0.161
Outer: 18/0.031" (0.79mm)	5.66	0.223



CABLE CHARACTERISTICS (Nominal Values @ 20°C)	Metric	English
PHYSICAL		
Overall Dimensions	5.66 mm	0.223 in
Wt. in Air	131 kg/km	88 lb/kft
Wt. in Fresh Water	109 kg/km	73 lb/kft
Temperature Rating, normal	246 °C	475 °F
intermittent	260 °C	500 °F
MECHANICAL		
Breaking Strength (Minimum)	20.5 kN	4,600 lbf
Bend Diameter	30 cm	12 in
Elongation (approx)	0.81 m/km/kN	3.6 ft/kft/klbf
ELECTRICAL		
Voltage Rating	600 Vdc	600 Vdc
Insulation Resistance	15,000 MΩ•km	50,000 MΩ•kft
dc Resistance		
cdr	85.3 Ω/km	26.0 Ω/kft
armor	16.4 Ω/km	5.0 Ω/kft
Capacitance (cdr-armor)	148 pF/m	42 pF/ft
Velocity of Propagation @ 1 MHZ	69%	69%

Tower

- Four tubular fiberglass tower sections
  - 6.83” ID x 6.5” OD x 61” long
- Fiberglass couplers
  - Aluminum center rings with integral guy rope connection points
  - Locating pins to align tower sections and crown sheave
- Buckling capacity is equivalent to the existing 4-Inch Drill tower
- Tower is guyed with six ropes - three at the mid point and three at the top
  - 30° rope angle used for load calculations

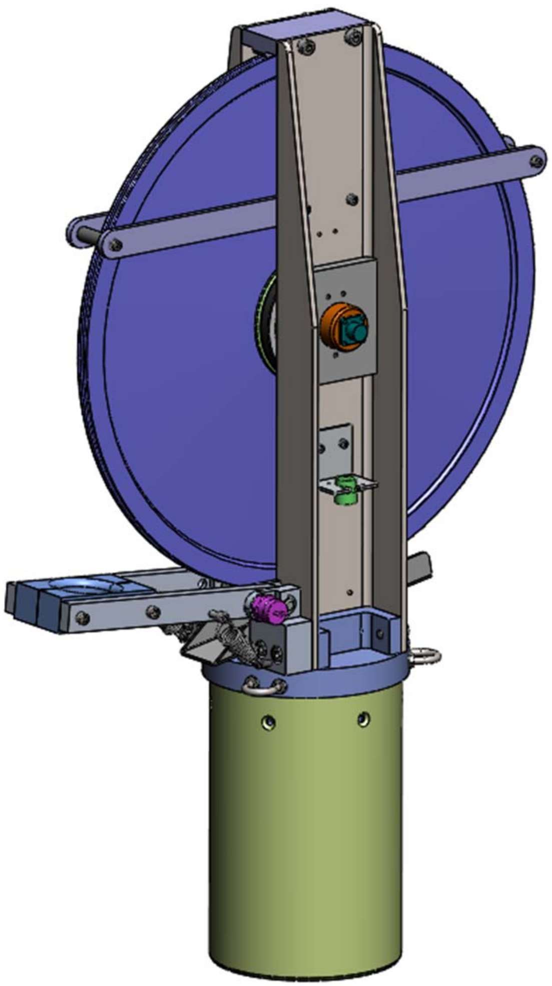


Tower Buckling Calculation

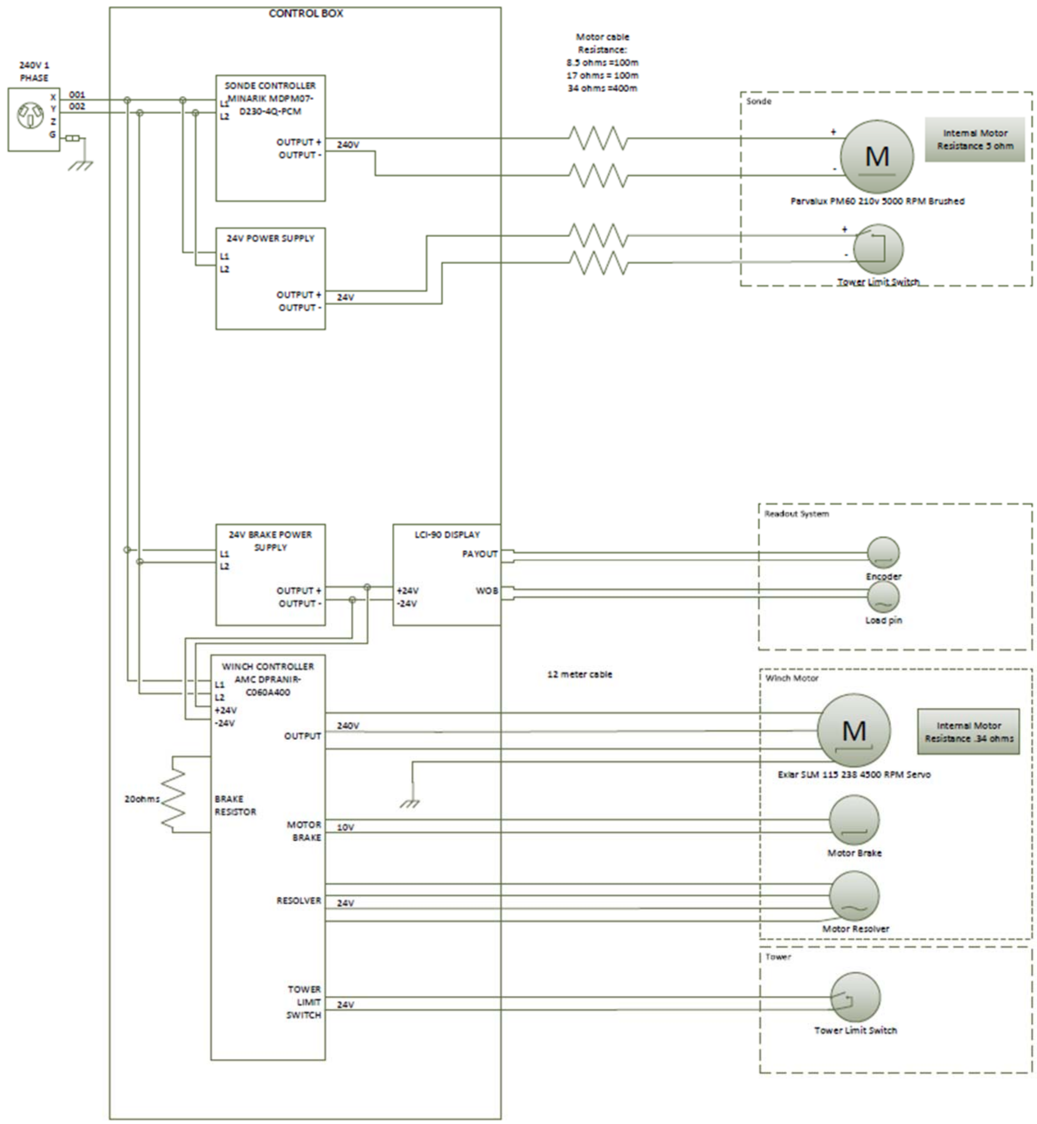
	Matl	OD	ID	I	E	K	L	Actual Load	Load Limit	Density	Weight	SF	
	--	in	in	in4	psi	--	in	lbs	lbs	lb/in3	lb	--	
Amalga E-glass tubing, Foro Drill tower	Fiberglass	6.75	6.5	14.27	1300000	1	124	4496	11897	0.072	23	2.6	3.15m = 124"
Amalga E-glass tubing, Foro Drill, tower coupler	Fiberglass	6	5.75	9.95	1300000	1	21	4496	289290	0.072	3	64.3	3.30m = 248"
Ciba tubing, 4" Drill tower	Fiberglass	6.73	6.4	18.34	1300000	1	124	5094	15285	0.072	30	3.0	
Amalga E-glass tubing, Foro Drill tower, thick wall	Fiberglass	6.83	6.5	19.19	1300000	1	124	5094	15994	0.072	31	3.1	22660N = 5094lbs
													20000N= 4496lbs

Tower (cont.)

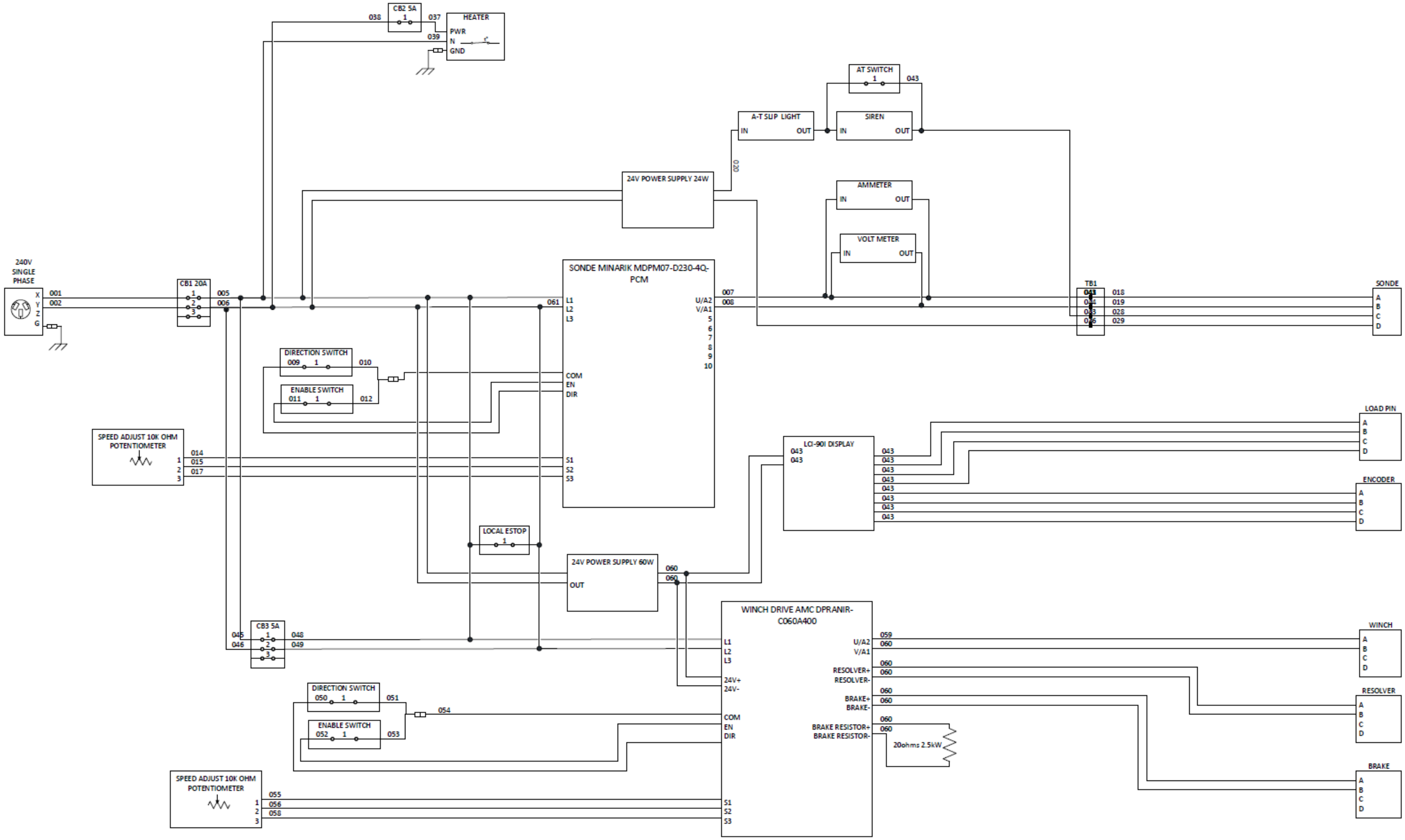
- Crown sheave is identical to the IDD design
  - Ring Encoder
  - Load Pin
  - Cable guide with integral winch cut-out switch
- Tower assembly weighs 123.0 lbs. (55.8 kg)
- Crown sheave assembly alone weighs 33.6 lbs. (15.2 kg)



Drill Control System

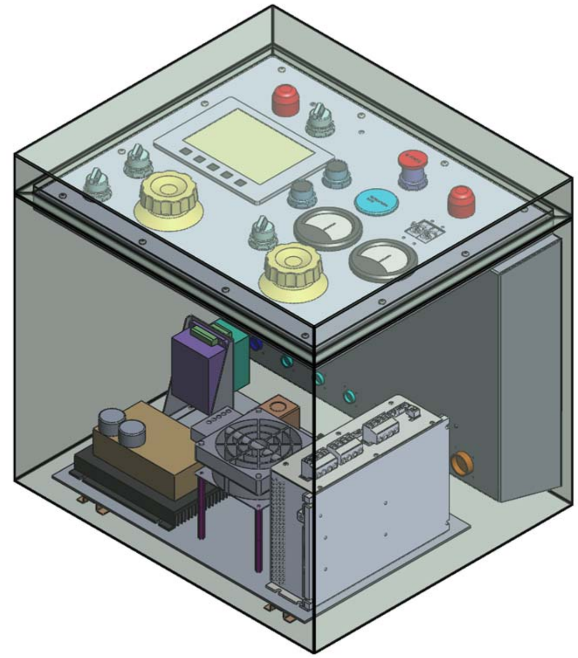


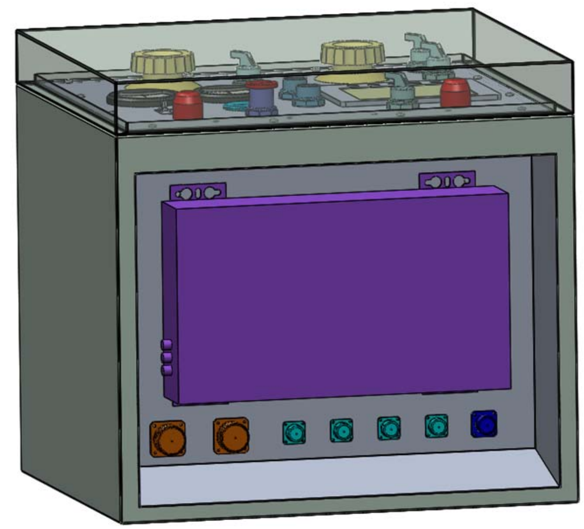
Control Box Schematic



Control Box

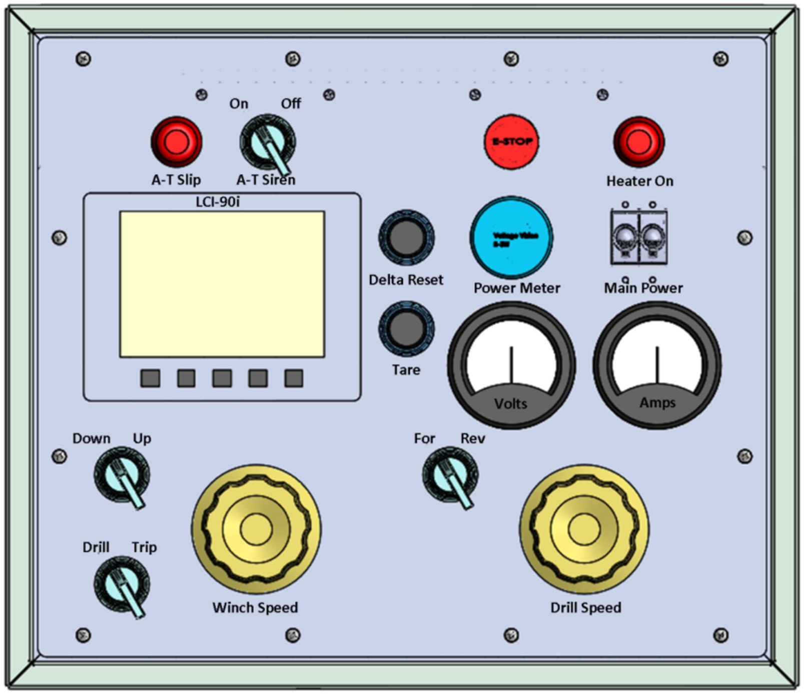
- Aluminum case with removable lid
  - Weather tight with lid open or closed
- Removal back panel for access to cable connections and to provide cooling for the winch motor brake resistor
- Case as shown is 21.75” L x 18.75” D x 20.50” H
  - Case design is being finalized so dimensions may change
- Estimated weight is 80 lbs.
  - Combined weight of 4-Inch Drill control and readout boxes are 115 lbs.

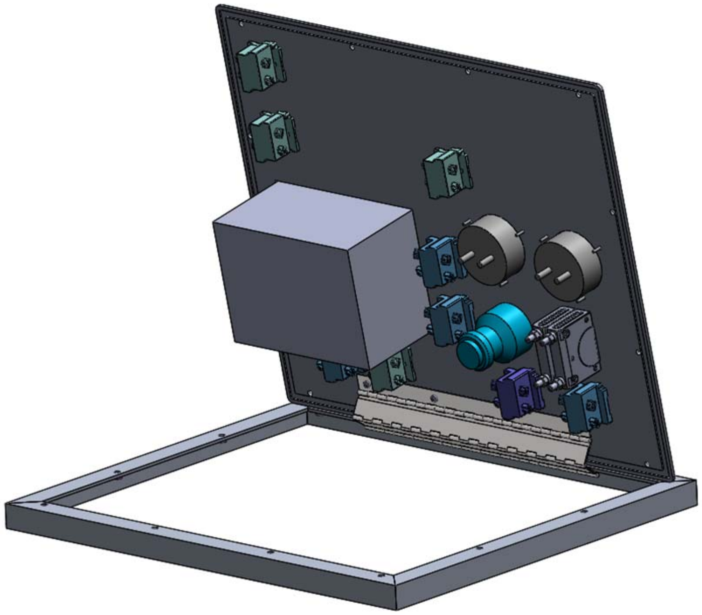




Control Box (cont.)

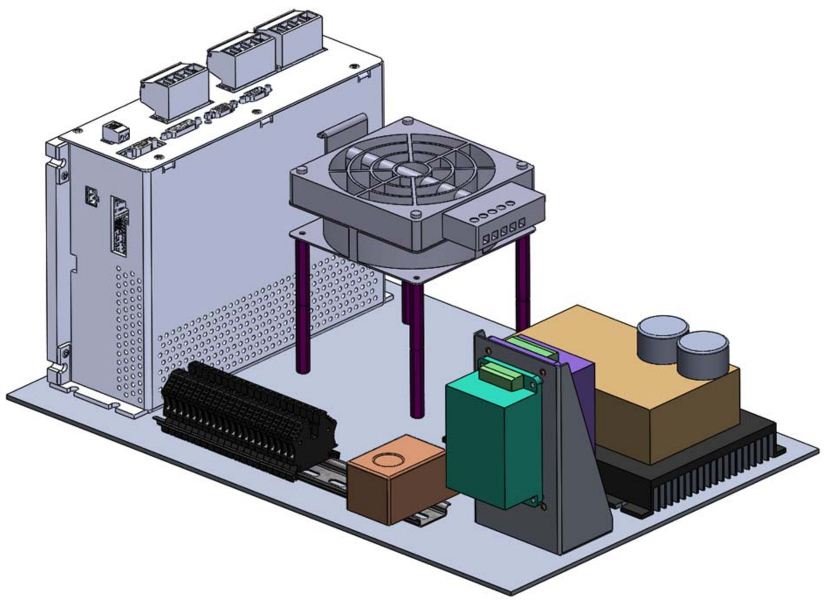
- Winch and drill can be operated at the same time
- Winch controller provides full speed control down to 1 mm/s
  - Fail-safe break sets, when motor is stopped
- Variable drill speed control
- Large knobs for easy operation with gloves
- LCI-90i Line Control Meter
  - Payout, delta depth, load, and speed data acquisition
  - -40° C operation
- Hinged face plate with a gasket seal





Control Box (cont.)

- All internal components are mounted on a removable sub plate
- Fan heater will keep the inside of the box above freezing during operation
  - Rated for -40° C operation
- Drill motor controller has been tested to operate at -40° C
- Winch controller is rated for 0° C operation and -40° C storage
  - Will likely operate at lower temperatures; however it has not been tested yet
- Both power supplies are rated for -40° C operation
- DIN rail mounted terminal blocks and circuit protection fuses



Power Consumption (full load rating)

Component	Watts
Sonde Drive	350
Winch Drive	3,000
AT Power Supply	24
Feedback Power Supply	60
Enclosure Heater	150
Total:	**3,584**

Both Honda EB5000 and EB6500 are capable of providing up to 7,000 W for up to 10 sec.

Logistics

- Drill System can be deployed on one Twin Otter or Bell 212 helicopter flight
- 200 m system can be broken down, so individual pieces weigh less than 100 lbs. and are under 6 ft^3

Item	Weight (lbs)*	Cubes (ft^3)*
Anti-Torque	39	0.88
Motor Section	60	0.29
Core Barrel	35	1.07
Sled with winch**	226	16.33
Tower	89	6.67
Crown Sheave	34	2.96
Control Box	80	5.24
Totals	563	33.45

* Crates not included

** includes 200 m cable

DISCUSSION