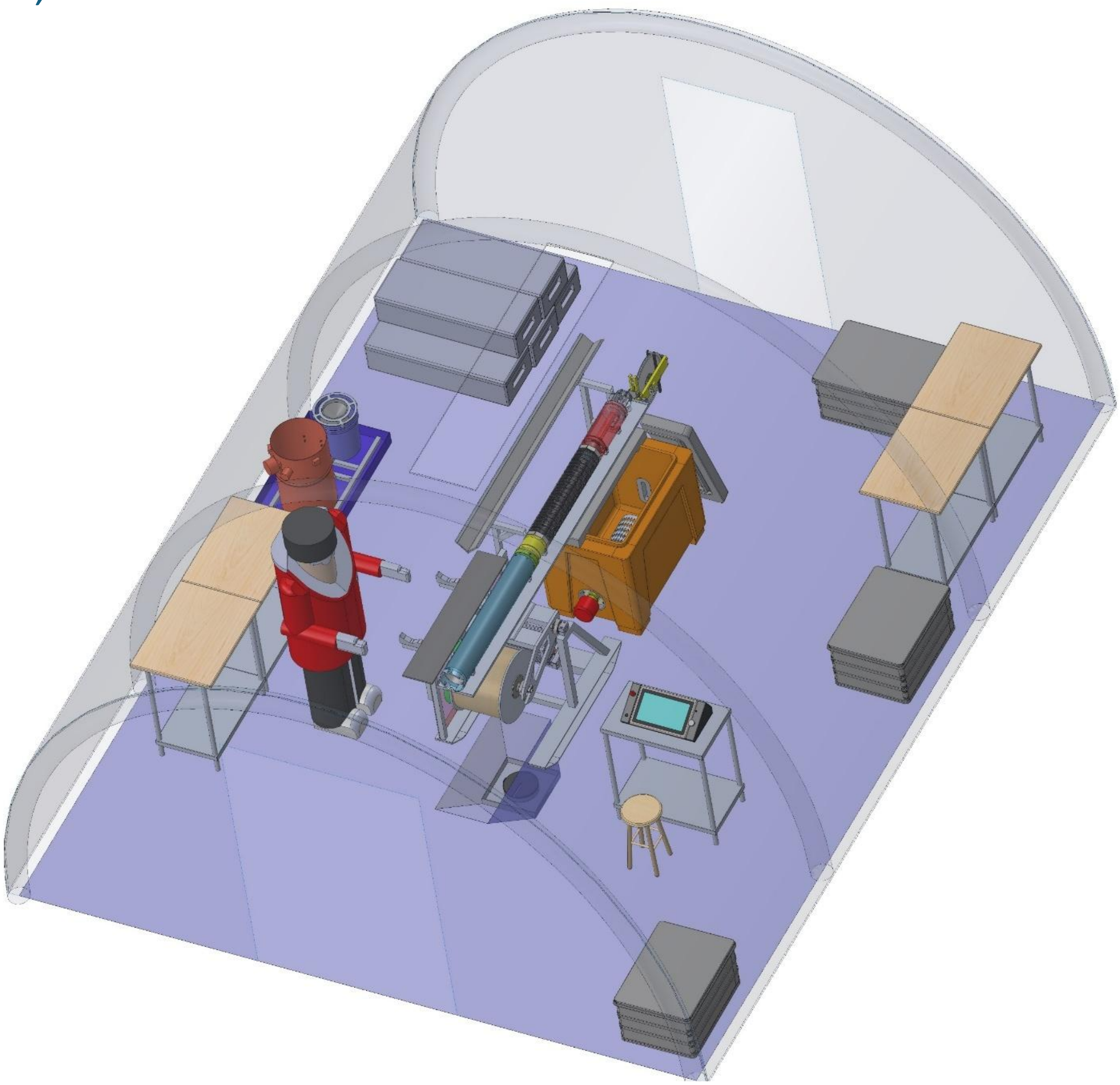
BOLD Drill

Conceptual Design

July 30, 2026



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Background

Over the past decade, IDP has used existing drills in the IDP inventory to drill ice cores in support of COLDEX and other science projects in blue ice at Allan Hills. The age of this ice both increases its scientific value as well as how difficult it is to drill, with cores from this area having quality problems ranging from moderate to severe. To determine what could be done to remedy these issues, IDP was tasked in program year 2024 with conducting the Blue Ice Core Quality Feasibility Study. Following the results of this study, the 2025 Long Range Science Plan called for the conceptual design of a next generation Blue Ice Drill (BID), with the Science Requirements finalized in January 2026. At the same time, IDP combined components of several existing drill systems to deploy a Shallow Wet Drill (SWD) for proof-of-concept testing at Allan Hills to determine if drill fluid would improve core quality. The addition of fluid starting at 115 m depth immediately brought core quality from rubble to excellent, and an understanding of fluid column requirements to maintain quality was developed throughout the season. With the assistance of the scientific community and international experts, IDP has created the conceptual design for this drill, known as the Borehole of Large Diameter (BOLD) Drill.

Scientific Requirements

1. The target ice core diameter should be nominally 162 mm (6 ⅜ inch).
2. The target ice core length is 100 cm.
3. The target depth for the drill is 250 m for dry drilling, or 400 m for wet drilling.
4. The design process should compare the associated drill complexity and logistical burden between dry drilling to 250 m depth and wet drilling to 400 m depths.
5. The newly developed drill would be available for use in the 2027-28 field season, pending NSF approval for design and funding for construction of the drill.
6. The drill should be rated for storage down to -40 degrees C, and operational at ambient surface temperatures down to -30 degrees C.
7. Drill liquid and chip management equipment should be customized for agile use at shallow coring sites where the only shelters would be tents.
8. Set up and drilling of a 250-meter core should be possible in 21 or fewer single-shift operational days.
9. The complete drill system (not including generators) and tent packed for shipping should have a target weight of 6,000 lbs. or less, and individual components need to be moveable without using heavy equipment.
10. A fluid bailer is required to bail the hole.
11. The drill tent should be able to be set up in winds up to 18 knots. Appropriate space for core processing and packing the 162 mm core needs to be accommodated in the drill tent.
12. The ability to drill a second core without relocating the tent is strongly desired, but the design should balance this priority with overall setup efficiency and transportability.

Safety

Safety of personnel using this drill 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 care. Even small mishaps may have severe consequences in this environment. In addition to the safety of 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 result in the loss of an entire drilling season. The following are safety requirements for the drill system.

1. Create a safety plan that defines how key issues for the project will be identified, managed, assessed and addressed during the system development.
2. Conduct a Failure Modes and Effects Analysis (FMEA) to identify and manage mechanical/physical/chemical and personnel hazards for the system.
3. Provide operational and safety trainings, as identified by the FMEA, to address safety hazards.
4. Provide operational and safety trainings, as identified by the FMEA, to address quality issues.
5. Provide hardware and/or software protection devices to prevent damage to the equipment due to overloads in the system, such as torque limiters, over-current protection, and limit switches.
6. Provide appropriate Personal Protective Equipment (PPE) for operating the drill system and handling drilling fluids, as identified in the FMEA.
7. Minimize environmental impact of drilling operations through mitigations identified in the FMEA.
8. Provide identification of and protection from dangerous voltages.
9. Provide safety interlocks (Lock-Outs) to prevent inadvertent operation of the equipment that would endanger personnel.
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. (Examples include the winch or tower mechanisms, which must engage the brakes and hold their last position in case of a loss of power.)
11. Create an operations plan and procedures for normal drilling and system surface operations.
12. Create safety and maintenance check lists that will be completed at defined intervals to verify safety equipment is in place and the drill system is in proper working order.

System Description

Tent

An overarching plan that drives many downstream decisions is the use of an inflatable tent. Several of IDP’s drills use a tower to both hang the sonde and support the tent, but this requires much of the drill system to be assembled before tent erection can begin. This requires a full day of good weather, a rare occurrence at Allan Hills, and causes delays and shortened drilling seasons. In the 2024-25 season, the start of drilling was delayed by 15 days (a quarter of the field season) due to wind, highlighting the importance of solving this problem. By separating tent setup from drill setup, a weather window of only a couple hours is necessary to erect the tent. At that point, all drill equipment can be brought inside the tent, and the remainder of setup can occur within the shelter.

Figure 1 NIXUS Tent Used by the Danish Program - G. Boeckmann, University of Copenhagen

The Danish drilling program used a NIXUS inflatable tent at the Muller Ice Cap in Canada in 2025. The tent was composed of two sections totaling 6.1 m wide x 7.5 m long x 3.3-4.5 m high and its structure was provided by 110 mm diameter pneumatic tubes inflated to 6-8 bar, with aluminum purlin braces between the tubes. This was a great success, with a windstorm providing wind gusts up to 40 kts with no loss of pressure or problematic deflection of the tent. Grant Boeckmann (Niels Bohr Institute - University of Copenhagen) noted that setting up both sections took five hours total but believes it could be brought down to 2.5 hours with practice.

IDP engineers worked with NIXUS to design a 5.1 m wide x 6.1 m long x 2.8 m high tent, with a slot in the roof to allow the tower to tilt. 155 mm diameter pneumatic tubes are specified for additional strength given Allan Hills' wind, and NIXUS noted that 18 kt winds during setup should not be problematic. A double-wide door at one end eases cargo and core box movement, while a single door at the other end can help vent the tent. The tent's total weight and cost is expected to be similar to the MAST tents currently in use by IDP, though it should reduce shipping volume by approximately 10 cubes. It also provides 50% more standing room, with adequate space for personal bags and a break area. The added space also allows the drill system to be rotated 180° within the tent, allowing a secondary borehole to be drilled within the tent after 1 day of rearrangement.

An Eskimo 850XDP tent (5 m long x 2.4 m wide x 2 m high) is also specified after proving crucial for keeping equipment out of the elements and drying clothes during the 2025-26 Allan Hills season. The two operating generators and a fuel drum will be placed in the downwind end of the tent, while the remainder of the space will include a drill suit rack and boot storage.

Winch Assembly

Once the tent is erected, the drill components can be brought inside for assembly. Most IDP wet drills use a tilting tower to transition the sonde between vertical (for tripping and drilling) and horizontal (for core removal and drill maintenance). These drills require a deep slot to be cut in the firn/ice so that the tower can tilt the drill to the horizontal position. The BOLD Drill uses a tilting tower, but with a very shallow slot (0.6 m deep x 0.4 m wide x 1 m long) to minimize both the tent dimensions as well as the setup needed before drilling.

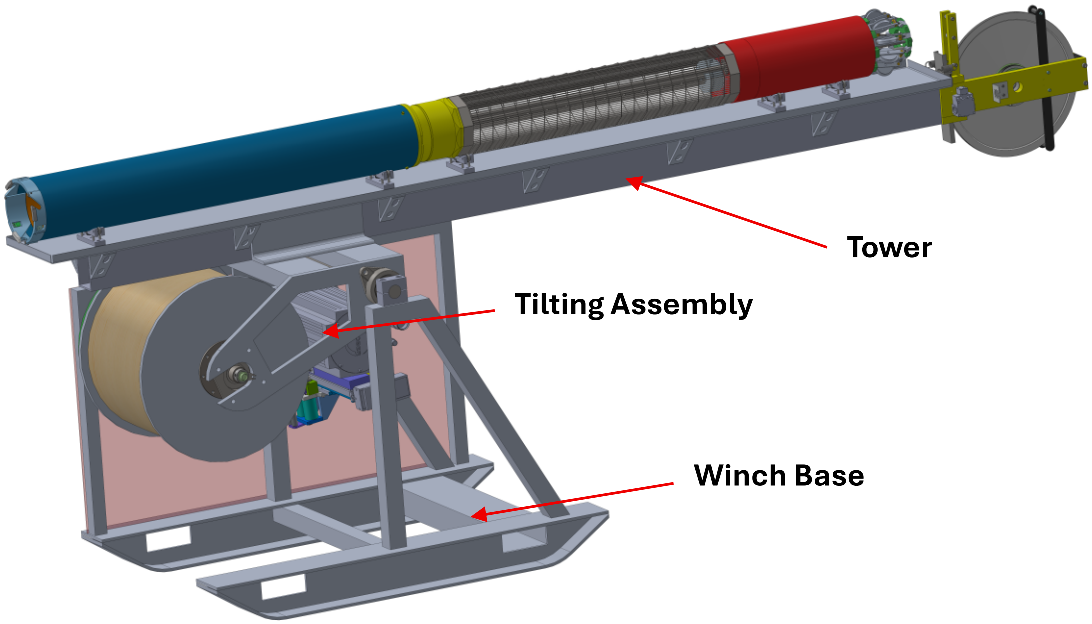

Figure 2 Winch assembly

The winch assembly is composed of three main portions: the base, the tilting assembly, and the tower. The base is a welded aluminum assembly consisting of two skis and a frame which supports the tilting assembly. This allows the base (and, once assembled, winch assembly) to be moved by hand or snow machine in the field. Mounting points for a tow bar are present, and sprung skegs will be attached to the base to ensure good tracking when being towed on uneven terrain, as tested with the BID. The tilting assembly consists of a welded aluminum frame which holds the winch, winch motor, drivetrain, and level wind. The winch will hold enough cable to safely reach 400 m depth. The base and tilting assembly ship assembled together to simplify field setup, and are expected to weigh 700 lbs.

The tower is a bolted aluminum assembly consisting of an extruded rectangular tube to which the crown sheave, main drip pan, and drill support stands are bolted. A load pin in the crown sheave measures cable tension at the surface, and an encoder measures cable payout. A pair of switches are held next to the cable by an arm below the crown sheave; one switch triggers when the sonde is at its home position and the other is an emergency stop to prevent the winch from pulling the sonde into the sheave.

The tilting assembly, tower, and sonde tilt as one, so no slack is created in the cable when the drill is tilted between positions. Assembly requires bolting the tower to the tilting assembly and then attaching the crown sheave to the tower. Signal and power cables are then run to the electronic components.

Sonde

The sonde design deviates significantly from IDP's other deep electromechanical drills, which are based on the Danish Hans Tausen design. The main guiding principles in the development of the sonde concept were to shorten the drill to minimize the sizes of the tower and slot. Additional updates aim to improve chip transport and collection while barrel and anti-torque changes should improve core quality.

Unlike IDP's existing drills, the BOLD Drill uses a rotating outer barrel and static core barrel. Rotating core barrels often create chip rings that bridge between the barrel and (non-rotating) core, increasing cutter torque and occasionally twisting the core apart in the barrel. The static barrel will slide over the core without inducing this chip ring creation. IDP is not familiar with an ice coring drill that has used this configuration for dry drilling. To minimize this risk, IDP built a test fixture and tested eight cutter head variations attached to a rotating outer barrel, refining the design until it functioned equivalently to an existing IDP Foro drill.

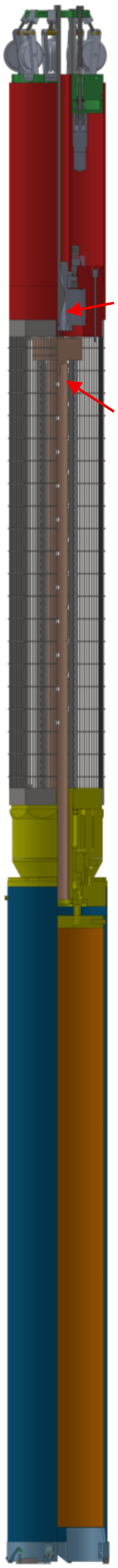

Figure 3 Sonde cutaway

As firn is less robust and more likely pack around the drill during cutting, different width cutters are used to create different borehole diameters for firn (⌀188 mm) and ice (⌀185 mm) with both sets cutting a ⌀162 mm core. While dry drilling, an outer barrel with a larger diameter is used, increasing the chip transport space between the inner and outer barrels. For wet drilling, the outer barrel is reduced in diameter, as this increases the annular space between the outer barrel and borehole to reduce fluid drag.

Chip transport and storage for dry drilling will be similar to the BID, utilizing a 2 m long core barrel divided into two regions by a chip separator plug from above. The 1 m long core is drilled and stored in the lower 1.1 m of the core barrel. The chips are transported upwards between the inner and outer barrel via helical flights, falling into the inner barrel at the top and forming a pile on the chip separator.

Problems with wet chip transport in IDP's existing drills can only be resolved by trial-and-error changes made on the surface, moving and adding boosters and changing valving to modify the flow. The BOLD Drill utilizes a positive-displacement pump with a controllable motor so that fluid flow can be adjusted in real time. The pump selected is a progressing cavity type, which was used successfully in the PICO 5.2" drill (Wumkes, 1994). The chip chamber for wet drilling is a wedge wire screen, providing high filtration surface area and easy cleaning. The design of this arrangement was heavily influenced by Dr. Pavel Talalay's research on the KEMS drills (Talalay, 2006). The use of a pump also opens the possibility to develop a stinger for sampling subglacial bedrock, as pumped flow is necessary for clearing rock chips.

The cutter motor section is mounted below the wedge wire screen, maximizing the screen's volume and filtration area as no mechanical motion needs to be transmitted around or through the screen. The pump pulls fluid from the barrels through the center of the motor section. Motors and gearboxes have been found that fit the expected power and packaging requirements for both the pump and cutter motor.

The upper canister of the sonde contains the electronics section. The electronics section is pressure-sealed, utilizing O-rings for static seals and pressure-sealed feedthroughs where power and signal wires enter. The electronics will closely follow the Foro sonde's proven design, though the board layout will be adapted to the space available. A notable update is the inclusion of a load cell in the sonde's slip ring assembly. This will allow accurate measurement of tripping and core break forces, providing maximum tripping down speed in fluid without creating slack in the cable.

The anti-torque (AT) mechanism is attached to the top of the sonde. Akin to chip transport, any AT problems currently require trial and error at the surface to resolve. The BOLD Drill uses a DC motor to adjust the AT mechanism, allowing downhole changes to minimize wasted time. The motor axially moves a plate which is connected to 9 anti-torquing elements, setting the total force applied to the borehole wall. Each element is independently sprung to account for borehole variations. In ice, these elements will be sharpened discs, as used successfully for DISC Drill replicate coring (Chris J Gibson, 2014) as shown in Figure 4. These roller discs minimize stick-slip, which is often a problem when drilling with fine cutting pitches. In soft firn, the discs can be replaced with blades to minimize damage to the borehole wall. During tripping, the blades can be retracted to reduce wear on the edges and minimize the likelihood of wall blowout.

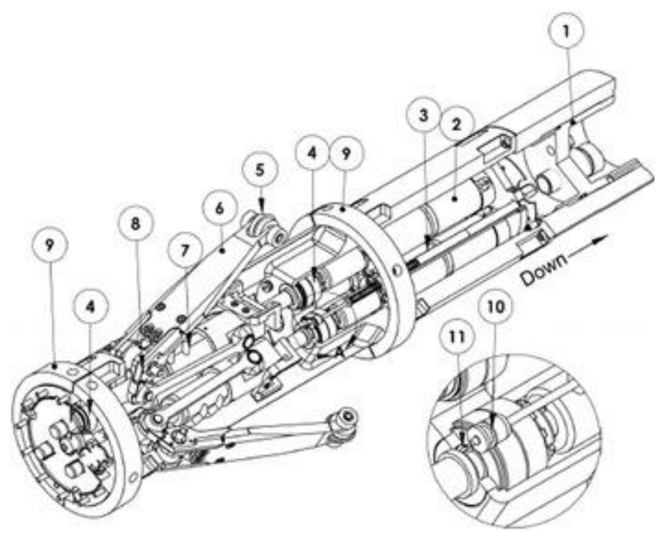

Figure 4 DISC Drill Anti-Torque Section

Control System and Sonde Electronics

The control system will be similar to that used with the 700 Drill, incorporating the upgrades determined after two seasons of use. A control box houses the winch power supply, central controller, and associated electrical equipment. The central controller is an IDP-designed board that establishes and uses control logic to manage communications between the control console, sensors, power supplies, winch, and sonde. It also manages power load shedding during tripping operations.

The drill is operated through a separate control console housing a touchscreen, control knobs, and switches. The touchscreen displays drill metrics and can graph (among other variables) weight on bit, cutter motor current, and sonde rotational heading. Errors and exceptions to the control logic can be reviewed and updated through this screen. Control takes place through both the touchscreen and physical devices. If desired, a keyboard can be connected to the console to simplify numerical input.

The sonde has its own IDP-designed circuit board which steps the 600V provided by the sonde power supply down to the various voltages needed for the control circuit, cutter motor, pump motor, and AT motor. Borehole pressure and temperature are measured, as are the temperatures of some sonde components. A navigation module provides sonde rotational position (useful for detecting anti-torque spin) and inclination.

Surface Operations

A borehole cover assembly is placed at the bottom of the slot, consisting of a small drip pan, hinged borehole cover, and sensor indicating whether the borehole is open or closed. It is kept closed except for when the sonde enters and exits the borehole, preventing items from accidentally falling downhole.

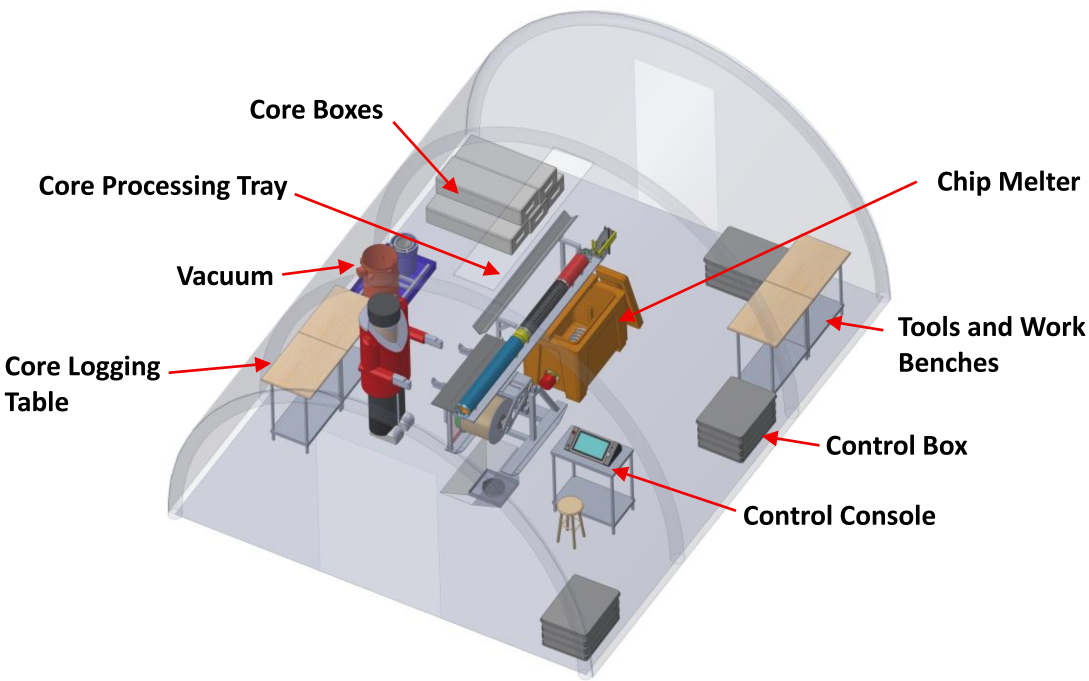

Figure 5 Drill site layout

Once the sonde returns to its home position on the tower, the tower is tilted horizontal, putting the sonde at a good working height. The outer barrel is disconnected from the motor section using a hex key to depress three quarter-turn pins. The outer barrel is then slightly slid away from the motor section, exposing one more pin that connects the core barrel to the motor section. Once that pin is depressed, the barrels are free and can be rolled onto the table directly next to the tower and placed in the barrel rests. The core can then be pushed out into the core tray and the barrels cleaned. When dry drilling, the chips would be removed at this point by pulling out the chip separator. They can be kept as core box fill or deposited outside. During wet drilling, the chip slurry is contained in the wedge wire filter. The filter hinges open and allows the slurry to fall into the drip tray underneath the drill. Any fluid remaining in the barrels is released when the barrels are separated, falling likewise into the drip tray underneath the drill.

The core processing tray will be fiberglass to minimize heat conduction to the core, and the length allows two cores to be placed end-to-end for marking alignment. An additional pair of tables allows for further core analysis. A half dozen core boxes can easily be kept inside, and core box packing can occur within the tent.

Fluid Handling

The components of the fluid handling system are nearly identical to the 700 Drill. The main upgrade is the placement of the chip melter directly underneath the main drip tray, allowing chip slurry to be drained directly to the melter. This reduces hauling and dumping 5-gallon buckets of slurry, easing physical strain on the drillers. The melter is an insulated HDPE tote with an electric heating element at the bottom. A window on the side allows assessment of water and drill fluid levels, while valves at different heights allow selective draining of either. A vacuum can be used by both drillers and core processing personnel for fluid removal, with the vacuum mounted on a tilting base to allow easy dumping into buckets. While tripping up, a cable cleaner is wrapped around the cable, allowing the vacuum to remove the excess fluid.

A Lutz pump is used to transfer drilling fluid from drums into the hole, with collapsible fire hose used where necessary to ensure the fluid enters below the firn-ice transition. Fluid bailing will be done similar to the 700 Drill, using a check valve at the bottom of a long length of tube. For chip bailing, we expect to be able to use the drill, as it pumps fluid through the wedge wire filter.

Prime Power

IDP has encountered issues with shipping generators. To reduce shipping weight and remove these complications, the BOLD Drill would utilize 120V single-phase generators from the logistics provider. Since one 5 kW or 6.5 kW generator is too small to adequately power the system, the BOLD Drill is designed to simultaneously draw power from multiple generators. As a point of comparison, the 700 Drill, which has roughly the same power requirements as the BOLD Drill, ships with two IDP-supplied 12 kW generators totaling 1,200 lbs. and 62 cubes, with one generator used for operations and one serving as a spare. For the BOLD Drill, this weight and volume does not need to be shipped from Wisconsin to the drill site, freeing valuable space on planes and ships. The logistics provider would only need to transport their generators the final leg to the field site. Likewise, if multiple generators fail, the logistics supplier will likely have more of the same model available as well as spare parts to implement field repairs.

Maintenance Equipment

Adequate spare parts would be included with the drill system for anticipated damaged or lost components, including at least two copies of all downhole parts. A complete set of common tools, plus any specialized tools needed for this particular drill system, would be included for maintenance and repairs. No stationary power tools are planned, although a quality set of battery-powered hand tools (e.g. drill, angle grinder) would be provided.

Operations

Operation of the BOLD Drill is expected to be accomplished by a team consisting of two IDP operators and one core handler provided by the science project per shift. A single shift is anticipated for most projects, although project duration could be reduced by running multiple shifts with additional crew members. Up to five people may be needed to accomplish drill system assembly and disassembly, with the additional people drawn from the camp support or science project members. No heavy equipment is needed for system set-up. The drill is designed to be stored down to -40° C and operated at -30° C.

Only simple camp infrastructure is required, with adequate cooking/eating space, and would be supplied by the logistics provider. A camp manager or experienced lead scientist is needed to handle logistics and camp support duties. Cooking responsibilities can be shared by the project team members or provided by a dedicated cook/camp support person. Individual mountain tents are anticipated for sleeping.

Assuming 10-hour shifts, a 400 m hole is expected to take 25 days to drill with five additional days needed for setup and takedown. Rest and weather days can extend this timeline.

Transport Logistics

The BOLD Drill can be shipped as either a dry or wet drill. In blue ice areas it is expected that acceptable core quality can be maintained to 100 m depth without the use of drill fluid. The depth at which drill fluid becomes necessary varies by site, and any scientist proposing a project should consult with IDP's engineers to determine whether dry or wet drilling is most appropriate.

Drill	Weight* lbs	Cube*	Core Area cm^2	Cores per Box
BID	5100	291	457	1
BOLD Dry	4838	332	206	2
SWD	6727	403	75	6
BOLD Wet	5798	432	206	2

*Table 1 Drill Comparison, * includes generators*

All components of the BOLD Drill are designed to fit in a Twin Otter airplane. Estimated system weights and cubes are outlined in Table 2. Figure 6 shows the number of Twin Otter flights needed to bring cargo one direction, assuming an allowable cargo load (ACL) of 2,200 lbs and 384 cubes, which is average for the 150 mile flight from McMurdo to Allan Hills. The heaviest component is the winch sled at 700 lbs, which is significantly less than the BID sled and comparable to the 700 Drill's generators and winch.

Components	Weight (lbs)	Cubes
Winch and Tilting Assembly	700	47
Mast	220	14
Main and Generator Tents	573	43
Sondes (qty 2)	780	22
Electronics	530	37
Tools	375	24
Fluid Handling	565	69
Core Processing	645	74
Generators (qty 3)	960	78
Spares	450	24
Total	**5798**	**432**

Table 2 Drill System Weight and Cubes

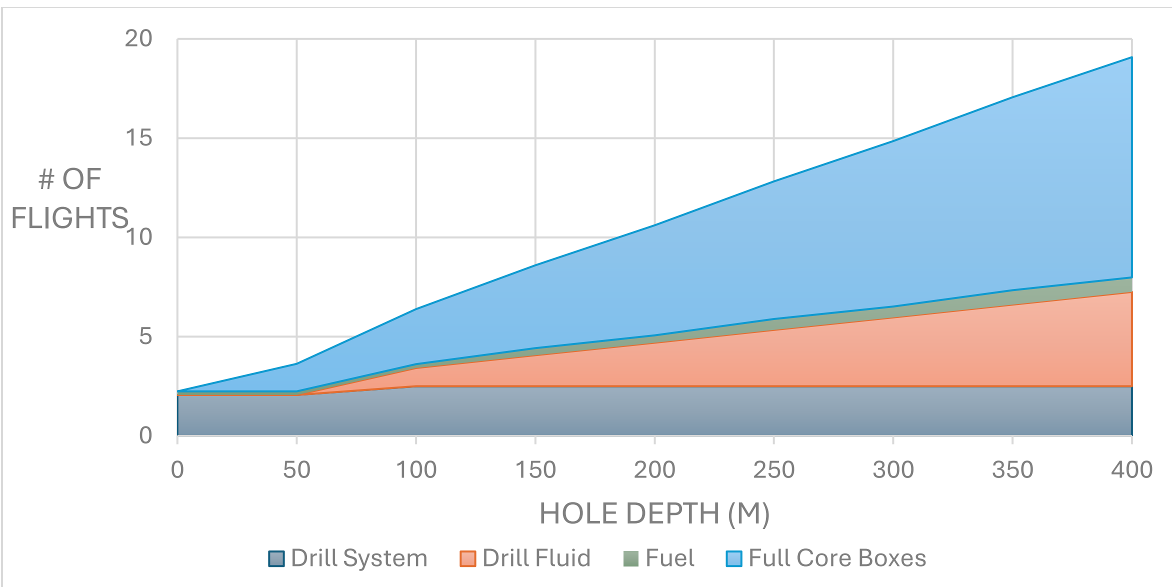

Figure 6 Twin Otter Flights for System Transport

Schedule and Cost

Pending NSF approval, IDP engineering and personnel availability, and no other competing development projects, estimated duration for the development of the BOLD Drill is eighteen months. This includes completing the detailed design, fabricating components, system assembly, functionality testing, and packaging the system for shipping.

The cost for completion of the development of this system as of July 2026 is estimated to be $612,000 to $734,000. Delaying fabrication is estimated to increase total costs by 3% per year. This estimate includes materials and equipment costs, associated indirect costs, and an allowance for unforeseen factors common to new system designs. IDP labor, contractor services, and associated indirect costs are not included, as they are covered by the IDP Continuing Grant from the NSF. A list of the high-level equipment costs is presented in Table 3.

Subassembly	**Cost**
Sondes (Main + Spare)	$178,000
Winch Sled	$79,000
Tower	$23,000
Chip Handling	$8,000
Fluid Handling	$18,000
Core Processing	$11,000
Control Box	$23,000
Console	$7,000
Power Distribution	$9,000
Tools	$25,000
Tents	$26,000
Drill Site	$7,000
Spares	$37,000
Shipping Cases	$20,000
Pre-deployment Test	$8,000
UW Indirect Costs	$133,000

Table 3 Estimated System Cost

Conclusion

The design of the proposed BOLD Drill was guided by and meets all science requirements, with special attention paid to reducing drill fluid quantity and shipping weight/volume. Compared to the existing BID, this drill would bring new capabilities to the field that will improve IDP's ability to meet science goals, simplify setup, and reduce downtime due to downhole problems. It will also provide quality of life improvements for the team, reducing physical strain and providing a better workspace. It is recommended that, if approved by the NSF, the development of the BOLD Drill be executed based on this Conceptual Design.

References

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