Ice Drilling Program

Dartmouth _ University of Wisconsin-Madison _ UNH

DOCUMENT IDENTIFICATION		
Title:	**SCIENCE REQUIREMENTS: CLEAN DEEP HOT WATER ACCESS DRILL**	
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DOCUMENT APPROVAL	
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REVISION HISTORY (maintain last 3 versions)			
REV	DESCRIPTION	DATE	APPROVAL
1.0	Initial Science Requirements	*April* 2026	Venturelli, Vick-Majors, Fudge, Talghader, Mikucki

Science Requirements: Clean Deep Hot Water Access Drill

Background:
Rapid changes in speed of fast-flowing tide-water glaciers, outlet glaciers and ice streams observed over the past decade create urgency to understand their dynamics. Properties of the ice-bed interface exert strong control on the flow of glaciers and ice sheets. Modular hot water access drills that are mobile and capable of drilling to the bed of glaciers and ice sheets in much less than one season and for drilling multiple holes per season are needed for measurements of temperature, heat flux, pressure, and microbiology sampling. The drill design should be similar to the deep clean hot water drill developed by the British Antarctic Society (BAS). The scientific requirements for a U.S. deep hot water clean access drill are:

Scientific Requirements

1. Produce access holes through ice to depths of up to 3,000 m.

2. The drill should be modular, with built-in redundancy, so that a drill appropriate for approximately 1,500 m would have additional components to reach depths up to 3,000 m.

3. For biologically clean applications, the drill should be consistent with the SCAR Code of Conduct for the Exploration and Research of Subglacial Aquatic Environments (SAE) and should have attributes consistent with the NRC 2007 Report. That would mean that the drill needs:

    a. Mechanisms to reduce the number of microbial cells in or on the volume of any instrument or material to less than the number present in the basal ice being passed through.

    b. Mechanisms to limit the introduction of chemical contaminants (e.g. toxic or biodegradable) to limit environmental impact.

4. Diameter of holes needed will vary, with most likely in the 10-30 cm diameter range.

5. The borehole diameter should be predictable over its depth, likely requiring the use of an instrumented drill head.

6. The design should include the ability to drill a 30 cm diameter, 3000 m deep hole and keep it open with occasional reaming for 24 hours after initial drilling.

7. The drill should be operable at 2,000 m altitude in borehole and/or ambient temperatures down to -30°C. The drill should survive winter storage at temperatures of -55°C.

8. The drill should be mobile on site, in order to drill multiple holes within 500 m of emplacement, possibly moved around by PistenBully or Arctic trucks.

9. Setup time for the drill (including making the seed water and the below surface cavity before creating the main hole) on site under good weather conditions should be within 10 days for a prescribed drill crew size.

10. Drilling depth and the rate of drilling progress should be actively available and recorded.

11. Capability for periodic imaging of borehole geometry (i.e. borehole camera).

12. All components of the drill should be able to be transported by ground traverse, with some key components able to be transported by helicopter sling load on occasion if needed.

13. The drill should have stand-alone capability for operation at small field camps at remote sites (sites that do not have significant infrastructure/logistics nearby).

14. Some drill equipment should be housed in dedicated tents to enable continuous drilling operations in poor weather conditions.

15. Minimal dedicated staff should be required for drilling operations in the field and determined on a case-by-case basis for the site. Other field camp staff in support of drilling operations and drill tent setup should be provided separately.

Additional Information

1. Comments from Terry Benson, Director of the University of Wisconsin Physical Sciences Lab (PSL) and IceCube Engineer/Project Manager:

   Requirement 2 on modular design: As with SCHWD (and the BEAMISH drill upgrade), it likely cannot be a linear scaling of equipment (i.e. just add more of the same pumps, heaters, and hose). Beyond a certain set of requirements (depth and time), the hose diameter needs to increase and parts of the architecture need to change.

   Requirement 5 on borehole diameter: Diameter vs. depth can be modeled, even in real time, but cannot be guaranteed. In hot water drilling, the water/ice boundary is constantly changing at all locations, so it's not possible to deliver a hole of uniform and constant diameter for any length of time. We can predict the diameter, and drill so that we think we know what that diameter is at a specific snapshot in time, but then it immediately changes after that, and it's only a model. Any upset conditions that veer off a perfect drill plan, like stopping for a minute to fix something, will change the hole profile. This is a far different scenario from mechanical methods that guarantee a known diameter for long periods of time. But including a version of the requirement drives a need for an instrumented drill head, which I think is a good thing.

   Requirement 6 on keeping the borehole open for 24 hours: Keeping the borehole open will probably require multiple drill/ream passes before the hole is useable for the size drill being envisioned.

   Requirement 12 on transport: We obviously would not want to commit to everything being transportable by helicopter. But if a major subsystem component broke down, like a pump or heater, making those things helicopter-ready would be good and reduce the logistical burden of on-site spares.

   Requirement 15 on staffing**:** Given all the other requirements, I would avoid committing to specific staffing numbers in these requirements.

2. Survey of existing hot water drills

Quick Reference Sheet – Existing Hot Water Drills

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- This list has been put together to aid in discussions about the capabilities of a future hot water drill.
- This list is not a complete inventory of all hot water drills, just those deemed relevant to the discussions.
- This list is for reference use only and should not be used for field season planning.
- Information has been compiled from various presentations, publications, websites, and personal communications. Errors may be present.

System	Owner / Custodian	Max Depth	Clean	Requires Traverse	Comment
Small Hot Water Drills	IDP	60m	No	No	
Arctic Hot Water Drill Scalable 200-800m	BAS	800m	No	No	
Mid-Scale Hot Water Drill	IDP	900m	No	No	IDP took custody from University of WY (Neil Humphrey)/University of MT (Joel Harper) in 2025.
Ice Shelf Hot Water Drill Scalable 500-1000m	BAS	1000m	No	No	
Ice Shelf Hot Water Drill Scalable 500-1000m	NZ	1000m	No	No	Copy of BAS drill with PLC/SCADA upgrades.
Ice Shelf Hot Water Drill Scalable 500-1500m	KOPRI	1500m	No	No	Built by BAS for KOPRI.
WISSARD Clean Hot Water Drill	UNL	1000m	Yes	Yes	Would require funding, staffing, and refurbishment for use.
BEAMISH Hot Water Drill	BAS	2300m	No	Yes	Hose reel requires a traverse, everything else can transit via Twin Otter.
CASCA Clean Hot Water Drill	KOPRI	2300m	Yes	Yes	Developed in collaboration with BAS. First use planned in 2028/29.
Enhanced Hot Water Drill (EHWD)	ICECUBE	2650m	No	Yes	System has never left South Pole, likely impractical to traverse any significant distance in current state.
Sub-glacial Lake CECs Clean Hot Water Drill	BAS	2700m	Yes	Yes	Add-on equipment to BEAMISH for depth and cleanliness. 80% completed before loss of funding.
Sub-glacial Lake Ellsworth Clean Drill (SLE)	BAS	3300m	Yes	Yes	No longer exists.
Deep RAD – Sub-glacial Lake Qilin	PRC	3600m	Yes	Yes	First use planned in 2026.

3. Publications relevant to clean access:

Doran, P.T. and Vincent, W.F., 2011. Environmental protection and stewardship of subglacial aquatic environments. *Antarctic subglacial aquatic environments*, *192*, pp.149-157.

Makinson, K., Pearce, D., Hodgson, D.A., Bentley, M.J., Smith, A.M., Tranter, M., Rose, M., Ross, N., Mowlem, M., Parnell, J. and Siegert, M.J., 2016. Clean subglacial access: prospects for future deep hot-water drilling. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *374*(2059), p.20140304.

Makinson, K., Anker, P.G., Garcés, J., Goodger, D.J., Polfrey, S., Rix, J., Silva, A., Smith, A.M., Uribe, J.A. and Zamora, R., 2021. Development of a clean hot water drill to access Subglacial Lake CECs, West Antarctica. *Annals of Glaciology*, *62*(85-86), pp.250-262.

Michaud AB, Vick-Majors TJ, Achberger AM, et al. Environmentally clean access to Antarctic subglacial aquatic environments. *Antarctic Science*. 2020;32(5):329-340. doi:10.1017/S0954102020000231

National Research Council. 2007. *Exploration of Antarctic Subglacial Aquatic Environments: Environmental and Scientific Stewardship*. Washington, DC: The National Academies Press. https://doi.org/10.17226/11886.

Priscu JC, Achberger AM, Cahoon JE, et al. A microbiologically clean strategy for access to the Whillans Ice Stream subglacial environment. *Antarctic Science*. 2013;25(5):637-647. doi:10.1017/S0954102013000035

Rack, F.R., 2016. Enabling clean access into Subglacial Lake Whillans: development and use of the WISSARD hot water drill system. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *374*(2059), p.20140305.

Siegert, M.J. and Kennicutt, M.C., 2018. Governance of the exploration of subglacial Antarctica. *Frontiers in Environmental Science*, *6*, p.103.