# Ice Drilling Program

*Dartmouth – University of Wisconsin - University of New Hampshire*

| DOCUMENT IDENTIFICATION | |
|---|---|
| Title: | **SCIENCE REQUIREMENTS: Replicate Coring for the Foro 3000 Drill** |
| Date: July 30, 2021 | Revision: Final |

| DOCUMENT APPROVAL | |
|---|---|
| Science Community Representatives: | Eric Steig, Sarah Shackleton, Robert Hawley |
| IDP: | Mary Albert |

| REVISION HISTORY (maintain last 3 versions) | | | |
|---|---|---|---|
| REV | DESCRIPTION | DATE | APPROVAL |
| | Final | 7-30-2021 | Steig, Shackleton, Hawley, Albert |
| | | | |
| | | | |

# Science Requirements: Replicate Coring Capability for the Foro 3000 Drill

*Background:*
The Foro 3000 drill is the deep ice coring drill that will be used for ice coring at Hercules Dome, Antarctica. The IDP Science Advisory Board has identified development of replicate coring capability for the Foro 3000 drill as a high priority in the IDP Long Range Science Plan 2020-2030; the first step in the process is the establishment of the IDP Science Requirements for Replicate Coring. When the Foro 3000 drill development was under consideration, a comparison of DISC versus Foro 3000 capability and logistics (Johnson and Kippenhan, 2017) indicated that a passive design for replicate coring would be advisable. A preliminary analysis (Zeug, 2017) found that a reliable approach using a whipstock in the parent borehole is feasible for retrieving replicate cores at specified depths from the parent borehole. There may be other approaches as well, but they must also fit within the overall goal of avoiding the electronic and mechanical complexity that would accompany a steerable drilling system, which is a more costly endeavor than is feasible now. From discussions organized by IDP with iterative discussions between representatives of the ice core science and borehole logging science communities and IDP staff, the following are the science requirements for Replicate Coring Capability for the Foro 3000 drill:

## Scientific Requirements

1. **Target depths: specific depths for replicate coring below 100 m in the main borehole will be identified as early as possible but at least six months before replicate coring begins.**
2. **Ice core diameter: the same as the main core, 98 mm +/- 3mm**
3. **Minimum core length: a minimum core length of 1 m is required, although 2 m would be desirable if possible.**
4. **Possibility of collecting multiple replicate cores from the same depth interval: wouldn't need to be the exact same (e.g. one could start several meters up from another, but both would include bottom 150m of ice)**
5. **Should be able to get close to the bed (or near the bottom depth of the parent borehole)**
6. **Ice pieces should fit together snugly without gaps once full diameter deviation is achieved.**
7. **Core should be collected with an angle of deviation of less than 20° from vertical; 10° or less is desirable.**
8. **Depth/angle tracking to be able to compare to parent borehole depth is desirable.**
9. **The drilling fluid should be the same as used in the parent borehole.**
10. **The parent borehole must remain open after replicate coring is completed.**
11. **If a whipstock is used, it should be removable or drillable in order to minimize damage to the parent borehole to the extent possible.**
12. **The equipment should be operable in the same temperature ranges as the Foro 3000 drill.**
13. **The replicate coring technology should be well documented, so that it could be used, repaired and upgraded by a drilling engineer who was not the developer.**
14. **Because this is not a steerable drilling system, it is not a requirement to drill on the uphill side of the parent borehole.**

Discussion

The following comments were from previous drafts of the requirements.

*From Sarah Shackleton:* Comments/suggestions attached. Also - during the second day of the Herc Dome meeting several early career scientists (including myself) who work with proxies that require larger sample sizes emphasized the utility of a replicate core for the deepest section of Herc Dome.

*From Eric Steig*: I agree with Sarah's edits. A key point is that for Hercules Dome, the most important place for replicate ice will be the Eemian -- which will be in the lower 100-200 m. This implies that would potentially drill multiple cores from roughly the same starting point. For example, if we knew the Eemian were at 50 - 60 m above the bed, we could drill three cores to bedrock: the main core, a replicate that starts at 80 m above, another at 70 m above. If all three went to bedrock (or near) then it wouldn't matter, for borehole logging tools, which one was the "main" hole.

*From Bob Hawley*: My greatest concern of course is if we have replicate holes that the logging tools will default into, which don't reach the bed. That said, I think that 1) the logistical issues alone make it most sensible to use the passive whipstock, and 2) I don't see an easy/affordable way to get a passive whipstock to favor the uphill side of the borehole.
As Eric points out, if the replicate holes all go to the bed, it probably doesn't matter which hole the logging tools use, though it could be problematic if the tool ended up in different replicates on different descents. But I view this as relatively unlikely.
One thing NSF could consider is the idea of a logging sonde that could be 'steered' into the uphill side so as to remain in the main hole if that was needed (like if replicate coring didn't reach the bed or if there was some problem in a replicate hole)- I could imagine an articulated wand out in front of a downward-looking camera, that an operator could use to direct the instrument into whichever hole is desired. Creating this technology would be almost certainly far less expensive than the steerable drill concept, or the increased logistical burden of the DISC drill.

*IDP response on 6/11/21:* Even if a passive whipstock approach is used, we anticipate we'll be able to remove it to keep the parent borehole open. We would seek to adapt existing orientation software in the drill to try and set a whipstock so that it encourages drilling of a replicate hole on the uphill side. An oriented, removable whipstock should be possible, but will require significant development and testing. With that said, if there are multiple replicate holes near a given depth (e.g. bottom 50-60 m), then we'll likely need to drill one replicate hole and another 180° from it to prevent intersection of the holes. It is theoretically possible that we could then 'plug' the downhill replicate hole for future logging of the parent borehole. Or, it sounds like there might be options with the logging operations if that downhill replicate hole 1) went to the bed, 2) if the logging tool would find/select that replicate hole each time for repeatability of logging measurements or 3) if a logging sonde could be 'steered' to follow the parent hole. IDP has also briefly considered 'passive deviation' by purposely drilling an inclined parent hole and then drilling a replicate hole via gravity without a whipstock. This becomes more challenging, however, if multiple deviations are required, as a risk of borehole intersection would exist.