RAPID ACCESS
ICE DRILL

RAID
Rapid Access Ice Drill

Field and Logistical Plan
McMurdo Area Antarctic Field Trial
2016-17 Antarctic Field Season

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1. INTRODUCTION

1.1 Background

We are designing, fabricating, and testing a new rapid access ice drill (RAID) for use on the ice sheets of Antarctica. Our goal is to rapidly drill to deep ice (drilling penetration up to 3300 m depth), followed by coring of ice, ice-sheet bed interface, and bedrock substrate below. This novel drilling technology will provide an entirely new way to obtain *in situ* measurements and samples of ice, glacial bed, and rock for interdisciplinary studies in geology, glaciology, paleoclimate, microbiology, and astrophysics. The RAID drilling platform will give the scientific community access to a rich record of geologic and climatic change on a variety of timescales, from the billion-year rock record to thousand- year ice and climate histories.

Phase 1 of RAID development resulted in completion of a comprehensive design for an integrated drilling system, with buildable engineering diagrams, testing and deployment plans, and a detailed budget and construction schedule. Phase 2 of the project entails construction, assembly and testing of the RAID drilling platform, through to staging in Antarctic for future scientific operation on the East Antarctic ice sheet. In anticipation of readiness for commissioning once fabrication, integration, bench tests and field tests are complete in the 3rd quarter of 2015, this document outlines our plan to conduct a field trial with the RAID system in Antarctica during the 2016-17 summer field season in order to validate its operational readiness for science drilling.

In early 2015, we completed a system-level field test of the RAID drilling system in Utah (North American Test), which demonstrated the ability of RAID to drill through ice and take core with its principal components consisting of the drilling rig, fluid recirculation system, and bottom-hole assembly. We successfully established that all components of the RAID system will function as designed, and nearly all of the goals defined in the North American Test Plan were achieved. By demonstrating the capability of the drilling rig and fluid recirculation system to drill ice and take core in cold-weather, high-altitude field conditions, the North American Test was an unqualified success and completes a major milestone. In addition to the field tests completed in Utah, we have also completed a comprehensive set of bench tests and computational fluid dynamics modeling studies that validate key components of the RAID system and the drilling process. We are therefore confident that RAID will perform as expected in Antarctica. Based on the success of our bench tests, modeling studies, and field test in North America, the next logical step is to conduct a full-scale set of field trial in deep ice of Antarctica.

1.2 Goals and Rationale

Shop and field tests to date have validated all components of the RAID drilling system, with the exception of:

- Firn auger
- Borehole packer

- Airlift system for pressure regulation

These components have not yet been tested because we require thick firn and deep ice to do so. The first two of these components will be independently tested during the 2015-16 field season at McMurdo Station in coordination with engineers from the IDDO; we will test a 7" auger system to cut and evacuate firn, and we will test the packer in homogeneous, non-porous ice to verify its ability to seal against borehole walls and maintain overpressure. The airlift equipment was installed and used to evacuate drilling fluid during the North American Test, but due to a lack of time and the shallow depth of the test hole, we were unable to validate the ability of the airlift system to regulate down-hole pressure. In short, the combination of completed and soon-to-be-completed shop, North American, and McMurdo tests will demonstrate both the effectiveness of all individual components and, although limited in depth of penetration, the successful integration of the principal drilling and fluid recirculation systems.

Having tested what we can in North America, we now need to conduct a field trial in thick firn and ice in order to validate our operational plan, evaluate full integration of the drilling system in a deep-ice setting, and learn from drilling operations in order to fully prepare for science drilling as an autonomous, traverse-capable system. NSF considered and ruled out the possibility of a Greenland deployment of RAID due to cost and schedule constraints, so Antarctica is the only place to effectively integrate the entire drilling system and evaluate the capability of those components designed for operation in thick firn and ice.

In order to prove out the operational capacity of the RAID system, the goals for our proposed field trial include traversing over snow, site set-up, augering of firn and installation of casing, drilling through thick ice, retrieving ice and rock cores, rigging down, stabilizing the borehole, and redeploying to a base station. These goals and associated evaluation criteria are outlined in detail in sections 4-6 below.

The Antarctic field trial will be conducted in the McMurdo Station operational area in order to take advantage of the established USAP transport and logistics system, thereby reducing risk, cost, and footprint in Antarctica. This approach represents the most logical, logistically light, and cost-effective way to evaluate the full operational capability of the RAID system.

1.3 Summary of Field Trial Operations

The Antarctic Field Trial (AFT) outlined here is planned for the 2016-17 austral summer field season and will make use of existing USAP logistics in the area near McMurdo Station. This trial will commence in late 2016 after the RAID equipment is moved from winter storage in McMurdo to the nearby ice shelf, where it will be loaded onto ski platforms. After a short traverse of no more than 3 days, the RAID system will be set up for drilling at a site near Minna Bluff (see below on Site Selection, section 2). We expect to be on site no more than 4 weeks, and then the equipment will be winterized on snow berms at Williams Field in anticipation of traversing to South Pole the following season. The RAID field trial will be conducted autonomously from McMurdo and other Antarctic services in order to provide a realistic exercise of future science operations, but the close proximity to McMurdo will provide a backup of mechanical, field, and medical services if needed.

In addition to the 5 RAID drilling modules shown in Figure 1, deployment of RAID for a field trial near McMurdo will require the following:

- heavy tractors for traversing
- berthing/dining/comms module
- fuel (in bladders)
- approximately 7,580 liters ESTISOL 140 drilling fluid in IBCs
- CAT 297 multi-track vehicle with blade and forks

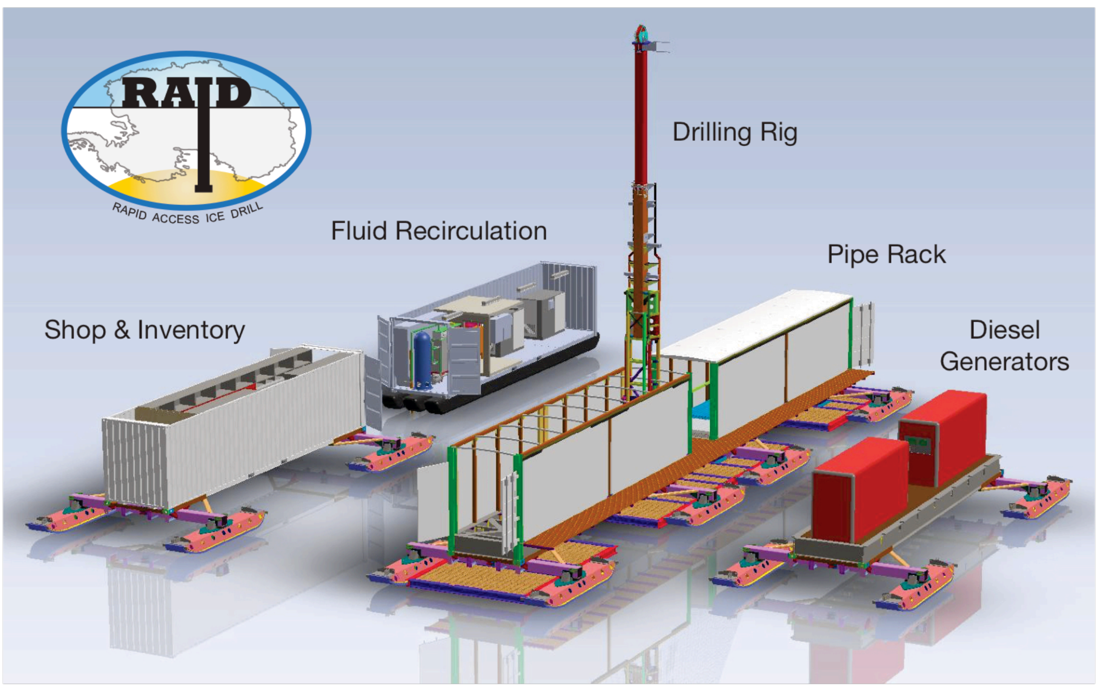

Figure 1. Schematic diagram showing general layout of the RAID drilling system as deployed in the field in Antarctica.

2. SITE SELECTION

The primary criteria for selecting a site to conduct a field trial of RAID are simple — thick, grounded ice. Ideally, a suitable location should be accessible for multi-module deployment, within relatively short traverse range, and be fairly flat with no steep slopes.

Potential sites for a field trial of RAID on thick ice sheets were considered in North America, Greenland and Antarctica. North American sites (mainly Alaska) do not have sufficiently thick ice and are logistically difficult to reach. Sites in Greenland (e.g., NEEM) have thick ice and have established field programs, but they require autonomous support for RAID deployment, would result in significant long-term delay in RAID science deployment because of out-of-phase ship and aircraft schedules, and would require separate funding. The McMurdo area of Antarctica is the optimal location to conduct deep-ice field trial for RAID because: (1) it is the ultimate continent on which RAID will serve as a science platform; (2) McMurdo is served by annual supply vessel; (3) RAID can be deployed with small marginal cost as part of the annual USAP field program; (4) McMurdo is well served with heavy equipment, vehicle shop, machine shop, medical facilities, etc.; (5) heavy tractors, sleds, fluid bladders, and berthing modules are available; (6) helicopter transport is available, if needed; (7) a pre-season surface and shallow subsurface reconnaissance with ground-penetrating radar can be done to determine site characteristics and crevasse potential; and (8) it is the most easily accessible and service-oriented location from which to stage the RAID field trial.

Within the McMurdo region, we considered the following locations: Castle Rock area; Leverett Glacier; and Minna Bluff. Each area contains grounded ice, but they differ in terms of ice thickness, general accessibility, and distance from McMurdo Station. Advantages and disadvantages of each area are listed in Table 1.

Based on the criteria of ice thickness, accessibility, and distance from McMurdo Station, we believe the ice plateaus on the south side (grid north) of Minna Bluff provide the best location for a full-scale field trial of the RAID drilling system (Fig. 2). At Minna Bluff the ice has a known thickness of ≥600 m, is easily accessible by traversing across the Ross Ice Shelf along the established South Pole traverse (SPoT) route, and rises gently above the ice shelf at two small ice plateaus, all within a point-to-point distance of about 90 km. Depending on route chosen, the traverse distance is <200 km and is expected to take about 3 days transit from McMurdo.

Figure 2 shows the region including McMurdo Station, the Ross Ice Shelf, and Minna Bluff. This area is primarily underlain by rocks of the McMurdo Volcanic Group, chiefly alkaline basalts exemplified by the eruptive units on Ross Island, Mt. Erebus and Mt. Discovery. Minna Bluff is a narrow, 45 km-long ridge extending southeast from Mt. Discovery, a Miocene alkaline stratovolcano. The main rock types are basanite and phonolite containing large (up to 5 cm) kaersutite and feldspar megacrysts, abundant comagmatic inclusions (kaersutite-rich), and rare mantle xenoliths. Since the late Miocene, Minna Bluff has been a terminal pinning point for the Ross Ice Shelf and is a local topographic barrier helping to block the Ross Ice Shelf from flowing into McMurdo Sound. Eruptions of alkaline basalt occurred between about 8-12 Ma, during which time lavas partly interacted with ephemeral glacial ice. Minna Bluff is surrounded by thick, relatively stable ice of the Ross Ice Shelf, which extends to McMurdo Station.

Table 1. Evaluation of Antarctic drill sites.

Site	Advantages	Disadvantages
Castle Rock	• Close proximity to McMurdo • Proximity to McMurdo services (mechanics, shop, medical, etc.)	• Ice thickness not known, but probably thin • Steep slope • Close to recreation areas • High geothermal heat flux (>100 mW/m^2)
Leverett Glacier	• On established SPoT route • Flat area on ice shelf • Room to maneuver	• Far from McMurdo (~1000 km) • Ice thickness ≥700 m at grounding zone
Minna Bluff	• Close to McMurdo (~90 km point-to-point; <200 km, traversing) • Branches from established SPoT route • Ice thickness ≥600 m • Grounded ice validated by IPR • Easy access over snow & by helicopter • Relatively flat • Proximity to McMurdo services (mechanics, shop, medical, etc.)	• High geothermal heat flux (~80 mW/m^2)

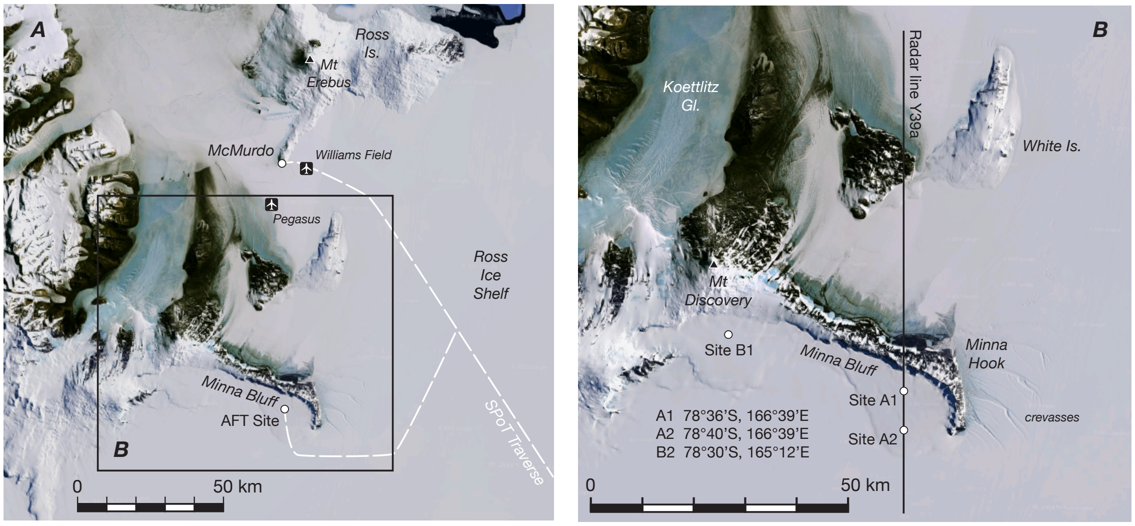

Figure 2. Overview of McMurdo-area field trial location for RAID at Minna Bluff. (A) Satellite view of area near Ross Island, McMurdo Station, and Minna Bluff. South Pole traverse (SPoT) route and proposed route to Antarctic Field Trial (AFT) indicated by dashed white lines. (B) Closeup of Minna Bluff area, showing proposed drilling sites A1, A2, and B1 (in order of priority) on small plateaus of grounded ice. Location of radar profile (Fig. 3) indicated by black line. Geographic locations of target sites indicated.

For the Antarctic Field Trial, we plan to follow the SPoT route from McMurdo onto the Ross Ice Shelf, and then deviate to the south and southwest around sheared ice at the Minna Hook cliffs. Based on proximity, ease of access, and radar structure of ice (see below), our primary drilling targets are as follows (Fig. 2B):

A1: 78°36'S, 166°39'E

A2: 78°40'S, 166°39'E

B2: 78°30'S, 165°12'E

Airborne ice-penetrating radar (IPR) data were recently flown across this area by the University of Texas-Austin to image the edge of the Ross Ice Shelf in the vicinity of Minna Bluff, White Island and Black Island. A representative radargram (Y39a) is shown in Figure 3, which transects the eastern of the two small ice plateaus and the eastern flank of Black Island. On the southern end, this record shows the transition between thick ice overlying water in the Ross Sea and bedrock of Minna Bluff. A grounding line is clearly visible at about -45 km (at the surface break in slope). The very intense, flat reflector at about -400 m depth is the base of floating ice over seawater, and shows strong multiples (reflected radar waves) below. The rougher reflector toward Minna Bluff is the grounded ice interface. Internal reflectors within grounded ice show a continuous record of ice accumulation banked against bedrock. We propose site A1 as our primary target for the drilling trial because it has greatest thickness (≥600 m) and lies farthest from subglacial water of the Ross Sea.

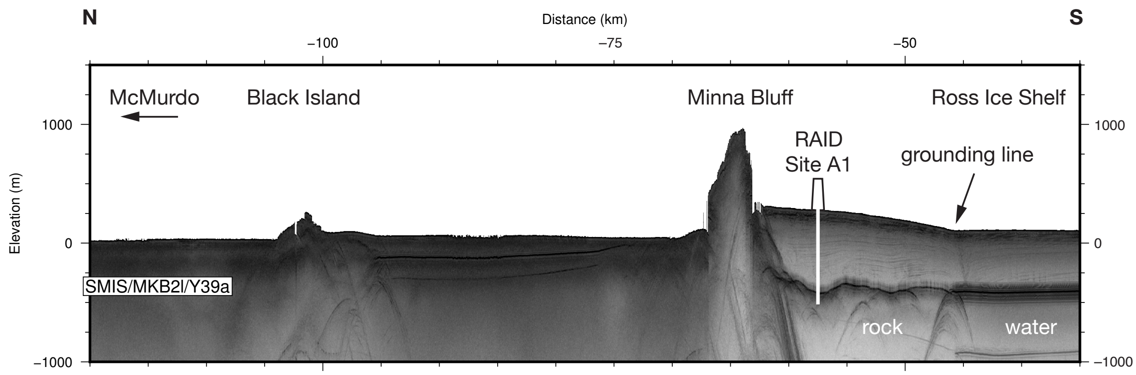

Figure 3. Radargram of line Y39a from north to south across Minna Bluff and the flank of Black Island, showing proposed location of the RAID drilling site A1. Location of radar profile indicated in Fig. 2B. Radar data provided by D. Young (UT Institute of Geophysics).

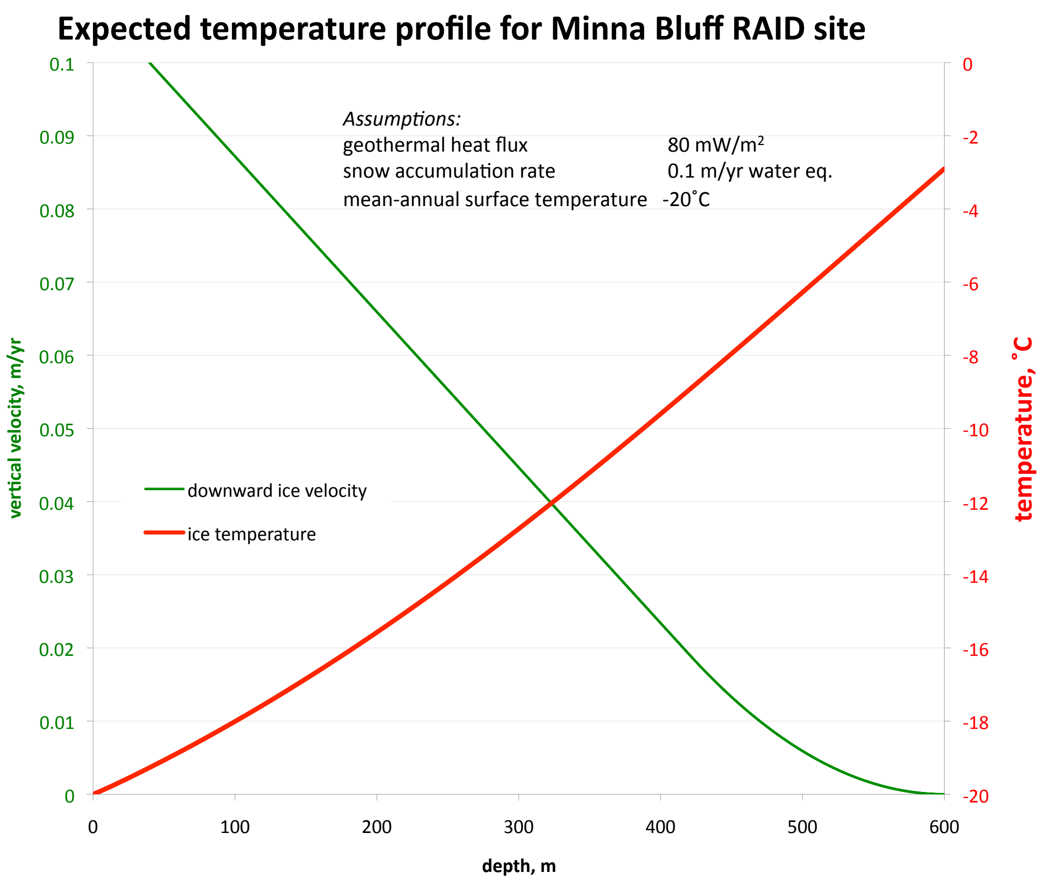

Figure 4. Modeled thermal profile for a 600 m borehole in the area of McMurdo Station and Minna Bluff. Temperatures at base of the ice borehole are expected to be below the pressure-melting point of -0.4 °C given a geothermal heat flux of 80 mW/m^2 and mean annual surface temperature of -20 °C.

Given that the region of Ross Island and Mount Discovery constitutes a young volcanic province, it is worth considering possible effects of high heat flow on ice stability. To address the thermal state of grounded ice in the vicinity of McMurdo, we modeled the thermal profile of 600 m-thick ice using estimated parameters of average annual surface temperature, snow accumulation rates, and geothermal heat flux (Fig. 4). At 600 m depth, grounded ice in this area is expected to have a basal temperature several degrees below 0 °C. These results indicate that drilling in this area is not expected to intersect subglacial hydrology.

3. TRAVERSE RECONNAISSANCE TO MINNA BLUFF (2015-16)

In advance of the actual field trial, ASC shall conduct a reconnaissance mission to the chosen locations shown in Figure 2. Crevasses and other severe surface features are to be completely avoided in search of a safe traverse passage to and from the site's locations from a main approach route. Starting with site A1, the field team will work to confirm that entree is suitable for a heavy traverse to access while towing the drill system containers. Upon selecting the trial site based on a predetermined selection process and communication with the science leads, the traverse team will then prepare a site pad by flagging an approximate 500' x 500' area, conducting a full area ground-penetrating radar assessment, mitigating any surface hazardous features, grade leveling and compaction for future drill system setup. At this point the site will be deemed suitable for safe maneuvering of vehicles, sleds and personnel.

Lastly, by conducting a pre-trial season reconnaissance mission, valuable data and feedback on the traverse logistics and site characteristics will inform the final planning of the Trial season.

The reconnaissance is scheduled to occur towards the end of December 2015 or early January 2016 depending on final input to the Integrated Master Schedule (IMS). The total duration, including equipment and material startup and closeout activities, is for approximately 5 weeks with the actual field duration portion of up to 3 weeks.

Support for the traverse reconnaissance shall include the following key resources and labor:

- Qty. 2: Heavy traverse science tractors (Case Quadtrac with front blade)
- Qty. 1: PistenBully 100 tractor with ground penetrating radar
- Qty. 2: ITASE traverse modules (galley and staff berthing)
- Qty. 1: Fuel bladder + HMW sled + CRREL tool
- Qty. 3: Air Ride Cushion Sleds for other equipment and materials
- Qty. 2: Field generators

- On-Ice dedicated project labor: 1 traverse supervisor/operator; 1 heavy equipment mechanic/operator; 1 mountaineer/GPR technician; 1 operator (PB100)
- Other McM work center labor for setup and take down activities

4. OBJECTIVES OF ANTARCTIC FIELD TRIAL

4.1 Objectives Overview

The primary objective of the Antarctic Field Trial is to probe the RAID system's ability to operate successfully as an integrated whole in a realistic, thick-ice environment. RAID is a complex system whose components have been individually tested, but experience shows that a successful system is much more than the sum of its components. For this reason whole-system testing is crucial. Personnel are also very much a part of this system, and the field trial will involve the same individuals who will ultimately be leading field operations in Phase 3 (if funded).

In addition, for the practical reasons discussed above, the lack of deep ice in North America has precluded a realistic test of the deep-borehole fluid circulation, the airlift process, and other facets of RAID. Although completion of the North American Test required successful integration of key RAID components, the test facility simply cannot reproduce Antarctic deep-ice conditions. Our computational fluid dynamics modeling also indicates no fluid pressure problems, and validates our simpler modeling exercises using the Darcy-Weisbach equation (Figure 5), but given the importance of deep ice drilling to the future success of RAID a real-world field trial is needed.

Also, the speed of penetration and other RAID operational steps must be measured for overall RAID planning purposes and ultimate success in the deep field, and this is only possible in a realistic setting. At the same time, a trial is best done in a low-marginal-cost and low-risk environment, rather than directly on the East Antarctic ice plateau. Taking into consideration all these factors, we have settled upon a field trial near McMurdo at Minna Bluff as the best compromise between realism, cost, and risk.

The Antarctic Field Trial will also present an invaluable opportunity for drillers to learn in the harsh environment of Antarctica. The Minna Bluff site is legendary for its sudden storms ("Herbie Alley"), yet it is relatively close to McMurdo in the event of a true emergency. Safety is the number one priority of RAID operations, and the field trial will provide an excellent chance to flag potential safety concerns and implement mitigation of safety issues. Fire readiness has not been tested in North America, so the Minna Bluff field trial will encompass the first fire drills and fire preparedness training in an environment with realistic temperatures, electric-insulating effects of snow, and hydrocarbon-based fluids.

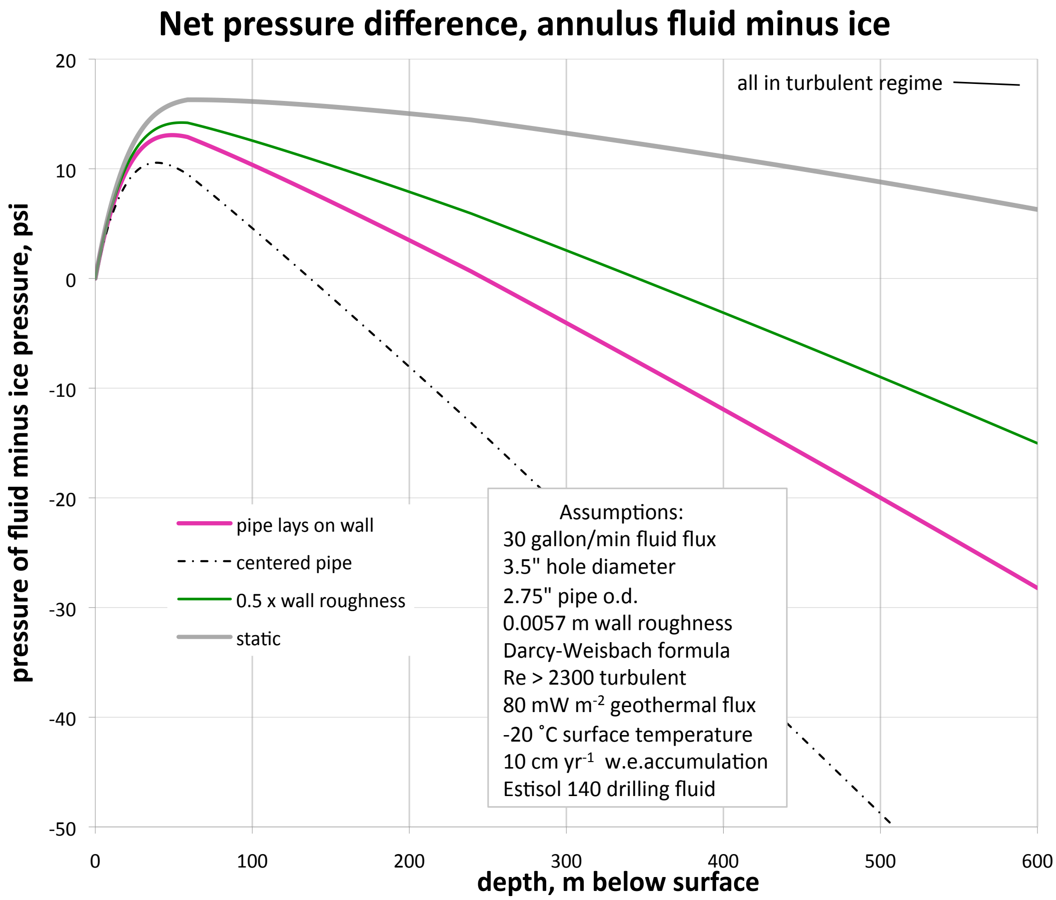

Figure 5. Modeled dynamic fluid pressure losses and ice hydrostatic pressures for a 600 m borehole in the area of Minna Bluff, using the Darcy-Weisbach equation and measured ESTISOL viscosities. Temperatures in borehole are as in Figure 4. The field trial will provide a direct test of this model prediction, from measured borehole fluid pressures in the injection- and return-flow streams.

4.2 Objectives and rationales

The Rapid Access Ice Drill (RAID) concept fundamentally embodies speed, with a design ultimately intended to produce 5 holes to bedrock per season. This translates to a design goal of about 40 hours to drill through 3000 m of ice. Therefore, one important objective of the trial is to measure how fast RAID can penetrate thick ice, including all the pipe handling and fluid recirculation system connections and disconnections. With only 600 m of ice at Minna Bluff, the comparable duration at this speed would be 8 hours. As we do not plan to have multiple shifts for the trial, one 8-hour shift with 3 drillers working full-time seems a logical goal for 600 m of penetration. This goal will also allow the degree of driller fatigue to be assessed (although not, unfortunately, at high altitude). We will therefore consider completion of 600 m of ice drilling in one 8-hour shift as a successful test of RAID ice penetration speed. As the ice thickness is slightly more than 600 m, this will leave a small increment of ice at the bottom of the borehole to be used for further tests of the ice coring and airlift systems, to be completed on subsequent days of the trial.

A multitude of other small tasks must be performed in a nimble fashion if RAID is to ultimately succeed and deliver on its promise of scientific discovery at a high rate. In section 6 below (Evaluation Criteria), we elaborate in detail our "definitions of success" by which the trial can be judged, and many speed-related benchmarks are defined. For example, we define successful augering through the firn as taking less than two hours, and the setting of the casing and packer (which will be lowered in the borehole as a single piece) as taking less than two hours. In this context we note that the feasibility of augering and packer sealing will be tested separately, in the 2015-16 season, prior to the Antarctic field trial (see separate document on auger and packer tests). We presume here that these feasibility tests will have been completed prior to initiation of the activities described in this Antarctic Field Trial document.

Safety is the top priority of RAID operations, and the following list of "Definitions of Success" implicitly includes accident-free completion of the noted task, although it is not stated in each entry. In a similar fashion, all entries implicitly include protection of the Antarctic environment and adherence to the conservation provisions of the Antarctic Treaty as preconditions of success.

5. FIELD TRIAL SEQUENCE

The McMurdo-area Field Trial will take place in the following general sequence:

- Launching from McMurdo following traverse preparation
- Traversing to Minna Bluff
- Preparation of drill site (by ASC, including snow leveling and compacting)
- Setting up RAID system (laying out rig mats, positioning system over the mats, lining up containers, hook up all components, assemble the components at the connection of the rig and rod racks, raise tent, etc.)
- Powering up and making all utility connections
- Rigging up
- Auger the firn
- Install casing, packer, and wellhead, then pressure up the hole.
- Ice drilling at full speed including airlift
- Ice coring
- Borehole video inspection
- Rock coring
- Pull drill string out
- Borehole optical logging (if funded; proposal pending)

- Rigging down
- Stabilize borehole
- Traverse to next hole (3 total) in order to a sustainable rhythm
- Redeployment to McMurdo

The AFT will assume that fit-up of the ski assemblies for the drill and rod racks has already been done in Salt Lake City, and that the auger and packer operations have already been tested the previous season in coordination with IDDO.

6. EVALUATION CRITERIA

6.1 Definitions of Success

A successful Antarctic field trial will:

1. Traverse safely to the drilling site with sleds and containers.
2. Prepare the drilling site with snow blades in <1 hr. Allow for re-sinter.
3. Demonstrate ability to set up rig on a sub-horizontal surface (<3˚ slope).
4. Position all equipment in order to make electrical and hose connections without preventing snow maintenance in the operation area.
5. Connect glycol waste heat transfer loops without spills or leaks.
6. Connect electrical cables and all structures with electrical grounding.
7. Transfer ESTISOL drilling fluid from bladders to Fluid Recirculation System (FRS) without spills or leaks.
8. Erect tent on rig in <1 hr.
9. Start diesel generators and use soft-start system for electric drill motor in order to manage current in-rush. Verify that no circuit breakers trip during motor start.
10. Verify ability of the power container to manage temperature and exhaust without penetration by blowing snow.
11. Auger through firn in <2 hr.
12. Set casing and packer in <2 hr.
13. Verify function of the rod rack to deliver auger flights, casing, and drill pipe.

14. Achieve seal of inflated packer on borehole wall sufficient to maintain 150 psig of borehole overpressure.

15. Drill through 600 m of ice in one 8-hr shift (test of overall system speed).

16. Verify operation of the RAID system with a 3-man crew.

17. Verify ability of FRS to manage ice-chip handling at fluid circulation rates of 20 gpm.

18. Recover one ice core (>50 cm length) from near-basal ice using the wireline coring system.

19. Deploy airlift system during final ice drilling to the bed.

20. Demonstrate successful borehole pressure management with airlift system (flow rate of 30 gallons per minute with no more than 30 psig of surface injection overpressure*).

21. Verify that no borehole closure occurs due to borehole fluid underpressure.

22. Create borehole wall smooth and clean enough for optical logging purposes.

23. Deploy video camera to bottom of borehole for visual inspection. Verify that no "balloon" areas exist in soft, warm ice due to borehole overpressure.

24. Penetrate any subglacial material (not necessarily with core recovery).

25. Recover two rock cores of standard length (5 foot barrel) using the wireline coring system.

26. [If pending proposal funded] Optically log borehole to verify that rock flour on borehole wall does not interfere. Temperature, pressure, inclination also logged.

27. Leave borehole stabilized (with appropriate fluid level for long-term pressure compensation), capped, and ready for future logging.

28. Rig down and redeploy safely to a fixed base.

*Rationale: overpressure in the borehole should not exceed 150 psig during any RAID operations, to avoid risk of hydrofracture. With designed borehole depths and temperatures, fluid pressure viscous losses will be ~5x greater than in the 600 m Minna Bluff borehole. The airlift system must therefore reduce borehole bottom pressure sufficiently to maintain 30 gpm flow with no more than 150/5 = 30 psig overpressure at the surface injection point.

7. FIELD TRIAL OPERATIONS AND LOGISTICS (2016-17)

7.1 Support requirements

ASC project management shall provide necessary project planning to include logistics and operations support in McMurdo Station and the Minna Bluff site for a full RAID drill system trial period. A minimalist approach to support and equipment is being developed and scheduled for the trial season; therefore a basic, field tent to support up to 12 persons shall be erected at the trial site to supplement limited support facilities. Once established, access to the trial site can be conducted via helicopter for personnel movements and resupply. USAP equipment and infrastructure support shall consist of existing inventory items where possible and shall not be fully representative of anticipated traverse infrastructure required to support RAID during any proposed out-year activities.

<u>Tentative 2016-17 Austral summer schedule</u>

October

- Staff arrive McM
- Tractor pre-traverse in McM's vehicle maintenance facility (VMF)
- De-winterize and stage DOSECC modules to Scott Base transition

November

- Assemble or de-winterize ISO2 sleds, ARCS
- Mount DOSECC containers to sleds, pre-traverse DOSECC containers
- De-winterize and stage traverse modules, fuel tanks/bladders, tool shed, generators
- Stage RacTent and camp materials

December

- Final preparations (i.e. radios, food, fuel)
- Helicopter final reconnaissance of route and site
- Traverse depart McM for Minna Bluff
- Setup drill operations, setup RacTent, drillers and science team arrive Minna Bluff
- Begin trial operations

January

- Continue trial operations
- Complete trial operations, winterize DOSECC modules, prepare and stage for return McM, drillers and science team depart Minna Bluff
- Traverse to McM
- Build winter berms near Pegasus Road, winterize DOSECC module and traverse equipment

- End of season reporting and staff departs

Estimated total duration: ~ 12 weeks (includes 4 weeks trial operations)

Major resource requirements

- Qty. 2: Case Quadtrac
- Qty. 1: CAT MT865 w/crane
- Qty. 1: PB100 + 2 GPR units (reproof route)
- ~10 hours helicopter support for reconnaissance / passenger / resupply
- Qty. 2: ITASE modules (galley and staff berthing)
- ITASE generators and H1 on ARCS deck – same as current WISSARD setup
- 8 sect. RacTent + camp galley / dining setup
- Qty.1: IMCS 4 channel system
- Qty. 2: Traverse fuel bladders + HMW sled + CRREL tool

- On-Ice dedicated project labor: 1 traverse supervisor/operator; 1 heavy equipment mechanic/operator; 1 mountaineer/GPR technician; 1 operator (PB100); project coordinator
- Other McM work center labor for setup and take down activities

7.2 Environmental Health and Safety Plans

ASC trial season planning shall include an environmental assessment of the drilling activities proposed at Minna Bluffs. A Record of Environmental Review (ROER) shall be prepared by the project team and ASC's environmental engineering department.

In addition, ASC develops standard field camp and traverse operations risk and safety assessments, planning documents, and direct staff Personal Protective Equipment (PPE). Prior to the field season, full integration of the ASC documents with DOSECC and grantee risk and safety assessments and planning documents shall be reviewed and finalized.

ASC shall reference and tier from existing programmatic documents including the following:

- Conduct Rock, Soil, Ice, or Sediment **Drilling, Coring, and Select Excavation** Activities to Support USAP Scientific Research, 11/5/2009, (PGAN1001.IEE)
- Construct and Operate New or Modified USAP **Field Camps,** 10/16/2008 (PGAN0901.IEE)
- South Pole Traverse CEE/EIS, 2005