Technological and logistical requirements, challenges and possible solutions for a project to investigate the subglacial environment at the interphase between West-Antarctica and the Antarctic Ocean.

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and many, many other people

This document is still work in progress and is thought as a working document in the process of developing a facility for subglacial research.

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General Introduction

The Earth is a complex dynamic system in which all of its parts are intimately interconnected. Changes in global climate affect the amount of snow deposited on continents. In return, melting mountain glaciers and changes in the flux of ice to the ocean in Antarctica or Greenland directly contribute to changes in sea-level worldwide. While it is well understood that water at the base of glaciers and ice sheets influences their flow behavior - “slippery when wet”, we are still far from understanding and incorporating subglacial processes into ice sheet and global climate models. Such understanding however is necessary to properly assess changes in the Earth’s climate and its socio-economic impact.

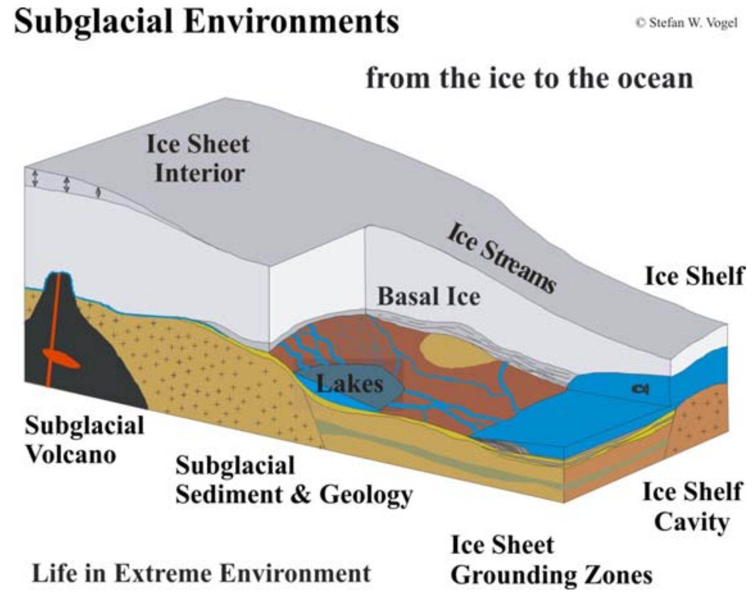


Figure 1: Subglacial Environments
The subglacial environment in Antarctica is as diverse as the surface of any other continent. Influenced by the distribution of basal melting and freezing, a hydrological system with creeks, swamps rivers and lakes exists beneath kilometer thick glacial ice, lubricating the ice sheet base, influencing ice dynamics and providing a habitat for life.

In addition to playing a key role in the dynamics of ice sheets, subglacial environments (Figure 1) are linked to the global environment through the flux of subglacially derived melt water to the ocean and the interaction between the ice and the ocean along the grounding zone at the periphery of the ice sheet. Promoted by the presence of water and fresh glacially-derived sediment, a complex physical and biogeochemical interaction between the ice and its bed mobilizes nutrients (Vogel et al. 2008, in prep). Transported to the ocean with the flux of subglacial water, these nutrients may play a vital role in fertilizing the polar ocean (cf. Raiswell et al. 2006) (Figure 2). In addition, the flux of melt water across the ice sheet’s grounding zone and processes in the sub-ice shelf cavity where the ice sheet deforms and floats over the ocean play an as yet unconstrained role in the formation of Antarctic bottom water (Jenkins and Holland 2002) and its consequent effects on global ocean circulation (Figure 3). A warming Polar Ocean enhances basal melting of ice shelves (Rignot and Jacobs, 2002; Shepherd et al., 2004) with the potential destabilizing effect on the ice shelves to ultimately contribute to ice sheet instability. Lastly, despite the lack of light, subglacial environments provide a habitat for a variety of microbial (Lanoil et al. 2009) and possibly higher order life in one of the most extreme environments on Earth, and act as an analog to extraterrestrial habitats suspected to exist on Mars or beneath the ice surface of Jupiter's moon Europa.

Due to the complexity of the systems, studying subglacial environments requires an integrated system science approach. A proper understanding of biological and bio-geochemical processes also enhances our understanding of physical, hydrological and sedimentological processes through the use of natural biogeochemical tracers and allows the processes to be quantified. Furthermore, parameterization of physical properties allows quantification of the contribution that subglacial bio-geochemical processes make to global bio-geochemical cycles (e.g. Carbon, Nitrogen, Iron …). Applying this knowledge, one can also determine changes in this environment from the geological record and assess their impact on the global environment over glacial/ interglacial timescales (Helling et al. submitted, Vogel et al. in prep).

Direct access to the subglacial bed is either accomplished by slow (year to multi year) conventional ice coring operation or by fast access drilling, which provides access with or with only limited recovery of ice. Conventional ice coring operation however requires large logistical efforts for deployment and operation. Therefore hot water based fast access drilling currently provides the only economical and rapid access to the subglacial environment.

Koci and Gow (1999) proposed the use of a coiled tubing drill (CTD) system for rapid access to the englacial and subglacial environment. The first FASTDRILL workshop in 2002 discussed this technology extensively and confirmed the suitability but also pointed out the technological challenges of adapting a CTD system for ice sheet related fast access drilling. While CTDrilling in it self remains still too challenging, individual components like thermoplastic composite tubing or injector systems are by now off the shelf commodities and could substitute for components of HWDsystems.

While the use of coiled drilling systems for subglacial investigations had been proposed, large uncertainties remain about the suitability of such systems for drilling operations in Antarctica. However since the usage of this technology for Antarctic science was proposed, large advances had been made in the coiled tubing industry and individual components of this technology are now more readily available. While the feasibility of a complete CTD system needs still to be studied in detail, individual components like injector systems and tubing are not only available but also are superior to individual components of conventional hot water drilling systems.

Two of the deficiencies of current hot water drill systems are low strength and limited life expectancy of high pressure hot water hoses and the design of capstan drives, which limits the maximum supportable load on the drill hose.

Smart Fast Access Drill System

General Expectations

During a single field season the traversable fast-access drill system should be capable of providing access to the subglacial environment trough 1000 to 2000 m thick glacial ice at several field sites, which are tens to hundreds of kilometers apart. Access to the subglacial environment will be provided through three different type of borehole, which mainly differ in overall diameter. These are pilot holes, slim holes and large diameter extended science boreholes.

Pilot holes are 2 to 4 inches in diameter and are drilled in a single run. These holes provide access for slim instrumentation like a piston corer or a simple water sampler.

Slim holes are similar to boreholes drilled during the Caltech expeditions and have a diameter of 4 to 10 inches. These holes are in general used for i) sensor deployment and ii) sample recovery, providing access for instruments with a diameter of ~ 8 inches.

The *extended science large diameter boreholes* have anticipated diameters of up to 30 inches enabling the deployment of large instrumentation and advanced instrumentation systems like oceanographic mooring system or a sub ice ROV.

Set-up time of the drill system in the field shall be less fast and the system should be operational for drilling within than 24 hours (desirable 12 hours) after arrival at the drill site. The hot water drill system shall have the capability of drilling a 1000 m 8" slim hole in 12 hours and be capable of extending such hole to an extended large diameter science borehole within 48 to 72 hours. Overall the drill systems shall be designed to provide access through intermediate thick ice to a depth of ~2 km.

It is intended that slim holes will be kept open for a duration of 3 to 8 days and extended science boreholes for a duration of 5 to 14 days. Longer periods may be possible dependent on scientific objectives of the investigation. Borehole will be kept open through repeated reaming followed by deployment of science equipment and the acquisition of water and sediment samples, or may be kept open with an inline reaming and back drilling system, allowing the simultaneous operation of advanced instrumentation systems like a sub ice ROV.

Our mandate for environmental stewardship necessitates that permissible access to the sub ice environment is environmental friendly (NRC, 2007). This can be achieved through development of clean access and sampling technologies which reduces the introduction of chemical and biological contaminats into the sub ice environment.

Hot Water Drilling

Hot water drilling uses the heat transport capability of water to melt ice. With the jetting action of high pressure nozzles at the drill head one can drill either a continuous drill hole or core ice (Engelhardt et al. 2000) (see figure 1,2).

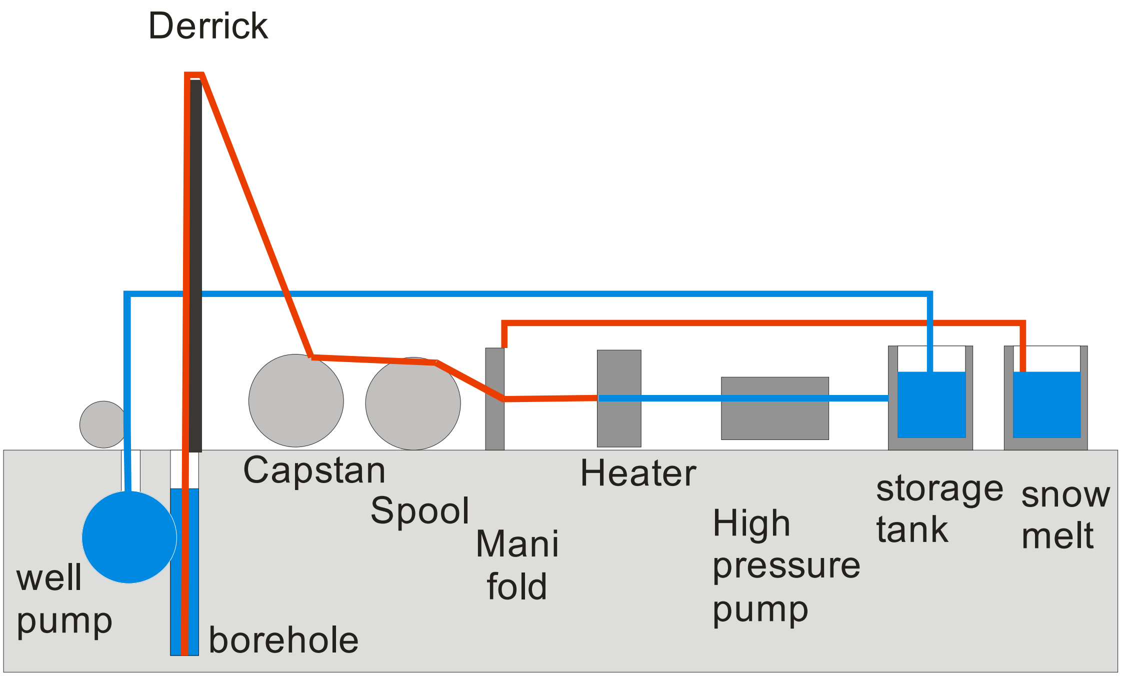


Figure 1 Schematic of a hot water drill system. Snow is collected and melted in a tank (snow melt). The water than is transferred into a storage tank, put under high pressure, heated and distributed to either melt more snow or to be supplied through a high pressure hose to the borehole. The hose is spooled on a winch and a capstan drive controls the speed in which the drill system is lowered or raised in the hole. During drilling water is recirculated from the borehole through an adjacent connected borehole in which a well pump is lowered. Any new system will include a clean access and sampling system, which cleans the drilling water to levels acceptable for connecting with the sub ice environment.

Drill System

Hot water-based drilling is currently the most economic drilling system to provide fast access to the subglacial environment through 500 m to 2000 m thick ice. Hot water drilling has been widely used to gain access to subglacial and englacial environments across the world (Gillet, 1975; Iken and others, 1989; Iken and others, 1976; Napoleoni and Clarke, 1978, Engelhardt et al 1990, Kamb 2000). While predominantly successful these operation also have shown the limitations of the currently used hot water drilling technology.

Hot Water Hose Deficiencies

Hot water hose

One of the main deficiency of current hot water equipment is the *rapidly deterioration* of commonly used high pressure hot water hoses, due to insufficient vapor impermeability at high pressure and high temperatures. This requires the exchange of hoses usually after one to two field seasons. While costly this may be done with the commonly used hoses, costing \$50 to \$70 per meter length. This however is not economically feasible with more sophisticated custom made high strength hoses as required for, for example, the operation of a hydro mechanical rock drill to recover bed rock samples from the subglacial bed or the operation of a sub ice ROV (SIR). The estimated cost for such customized hoses or tubing in the required length of 1500 m are in the order of $200,000 to $500,000, where as the replacement costs for a three quarter inch Synflex hose are in the order of $80,000 to $100,000.

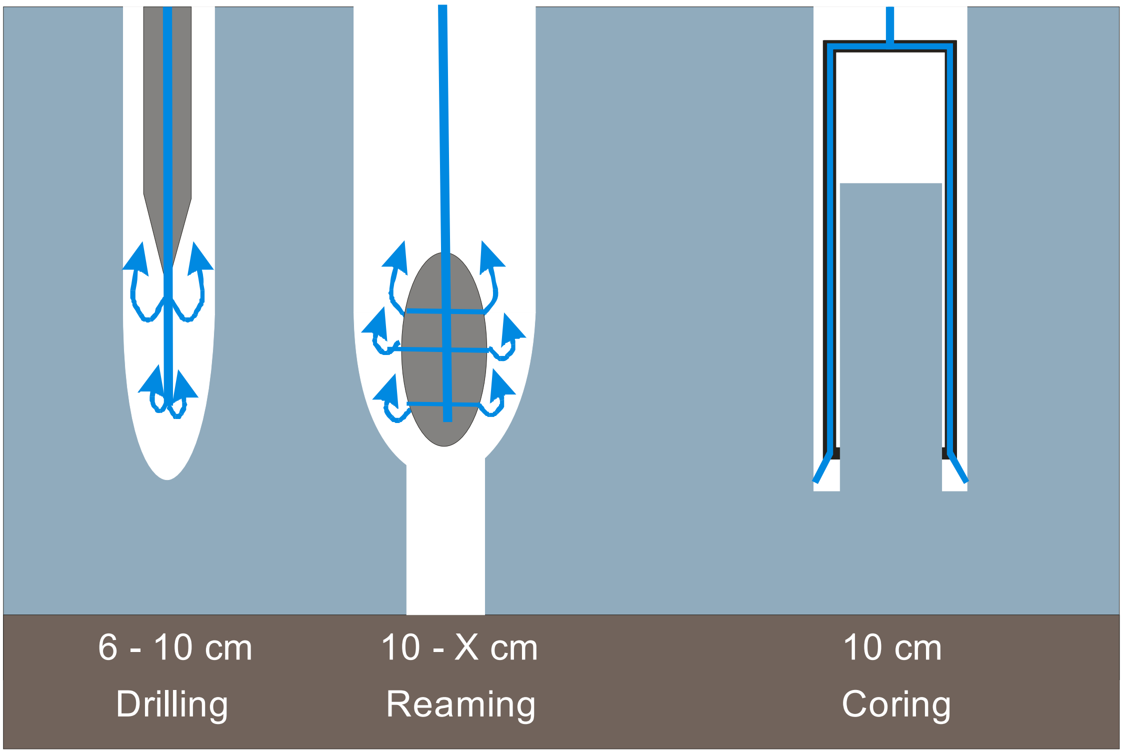


Figure 2 Schematic of hot water drilling (left), reaming (center) and hot water based ice coring (right) using the jetting action and heat of hot water to melt a ice borehole or core ice.

Another weakness is that high pressure hot water hoses are commonly not produced in sufficient continuous length for intermediate (1000m to 2000m) depth drilling, thus requiring coupling of several hoses. While *coupling* of hoses may be necessary due to logistical constraints, like the transport in small airplanes, coupling of hoses is undesirable. As experienced ourselves during the operation of the Caltech drill system in 2000 and as seen in the BAS drilling operation at Rutford ice stream (Smith 2006), couplings are always a potential point for failure, potentially determining the success or failure of a project.

Capstan Drive

The capstan drive allows the controlled deployment and recovery of the drill system down hole. While capstan drive systems are relatively simple to design and easy to set-up, capstan drives reach their limitation if the pulling load increases to a certain threshold. The downfall of the capstan drives is that using capstan drives the hose is pulled out of the borehole while running over a reel under full load. The tensile strength of hoses is usually measured on a straight hose. The tensile strength lessens however if the hose is running over a reel. Repeated unwinding and upwinding of the hose under load damages the hose internal structure, leading to early fatigue and replacement of the hose if not failure of the hose under load. The minimum bend radius of a hose is dependent on the load and design of the hose. So far most hot water drill systems are running under low tensile loading. However future applications like the deployment of a sub ice ROV, the deployment of hydro-mechanical drilling equipment like a rock corer, or the simple enlargement of a hot water drill systems as seen in the Enhanced Hot Water Drill, ICECUBE is currently using at South Pole Station, requires higher tensile loading and pushing generally used capstan drive systems to their limit.

Other Expectations

In addition to these current weaknesses, other future fast drilling operation will face additional technological challenges due to the increasing interdisciplinarity of future science investigations. So for example large interest exists in the recovery of longer subglacial sediment cores as well as rock coring to investigate subglacial geology. A target of particular interest in this regard are subglacial volcanoes. There is also interest in the deployment of autonomous and remote operated instrumentation and sensor packages like the NIU- Sub Ice ROV through ice boreholes to explore ice-ocean interaction in the sub ice shelf cavity or to explore subglacial lakes. In this regard sub ice shelf investigation may provide an ample opportunity to test and refine technology suitable for future subglacial lake investigations or for future space missions to investigate icy bodies like Jupiter Moon Europa or the Marsian Ice caps (REF SALE report and others).

Coiled Tubing and Hybrid Drill System

While coiled tubing drilling may provide one solution such systems are currently still too expensive, large and technologically complex to be readily deployed to the Antarctic. However over the past years many advances have been made in coiled tubing drilling and this technology has also become more readily available. Some of the off shelf coiled tubing equipment can in part compensate for the above described deficiency of current hot water drill systems is readily available and can with very little modification be incorporated in the design of our smart soft coiled tubing hot water based fast drill system. In detail we propose the usage of thermoplastic composite tubing as hose replacement and the usage of an injector system to replace the conventionally used capstan drive.

Thermoplastic Composite Tubing

Over the past few years composite coiled tubing has been developed in the oil industry which is much lighter than the conventional metal coiled tubing and which can be produced in length of up to several kilometers. Thermoplastic composite tubing uses a thermoplastic pressure barrier, which promises to have lower vapor permeability and thus will allow higher maximum operation temperature and lifetime of the hose/tube. In addition customization of such tubing allows incorporation of conductor wires and fiberoptics in the design of the composite tubing (see Figure 3), providing electrical power to run sensors or instrumentation and in return enable real time monitoring of drilling progress or life stream data and video transfer from scientific instrumentation packages. Such tubing also provides higher tensile strength needed to suspend heavier rock drilling equipment and to break a rock core after successful penetration of the subglacial bed. Being capable of providing both hydraulic and electrical power allows further the operation of both hydro-mechanical and electric powered rock drilling or other science and sampling equipment, like hydraulic piston corer.

Fiberspar was one of the pioneers in producing thermoplastic composite tubing and has produced the smart pipe used in the Anaconda project. Fiberspar however showed no interest in working with us in developing a smart hose for our purposes and we are currently discussing our needs with Airborne tubulars. Airborne tubulars, is a company in the Netherlands producing thermoplastic tubing and conducting a Research and Development project for developing smart thermoplastic tubing. Airborne tubulars has come up with a two different concept for incorporating electrical conductors and fiber optics into the thermoplastic tubing (see below).

Thermoplastic composite tubing with a desired 1 to 1.5 inch inner diameter is routinely produced by a number of manufacturers with different specs in regard to operation and burst pressure or tensile strength. Temperature rating of the tubing is dependent on the thermoplastic material used. Using different thermoplastic materials the Airborne Tubulars tubing is rated to 200 F using PEX. The PVDF is 250-270 F, PA is around 190 F. The tube would be designed to 2,500 to 3,000 psi at 95ºC (burst pressure of 12,000 psi (828 bar) at room temperature). For comparison the Fiberspar PEX tubing is rated to 180ºF while the rating for HDPE is 140ºF with a maximum operating pressure of 2,500 psi (3,300 psi maximum design pressure and 6,700 psi nominal burst pressure). The minimum operation temperature in this case is -29ºF making such tube suitable for polar environments.

The minimum storage temperature is currently unknown. A minimum bend radius of 22 inches and minimum spooling diameter of 38 inches (Fiberspar, Airborne not yet determined) would allow a spool holding 2000 m of tubing to fit nicely into an ISO standard container for transport. A tensile strength in access of 10,000 lbs should be sufficient for conventional hot water drilling, sediment coring and rock coring operations.

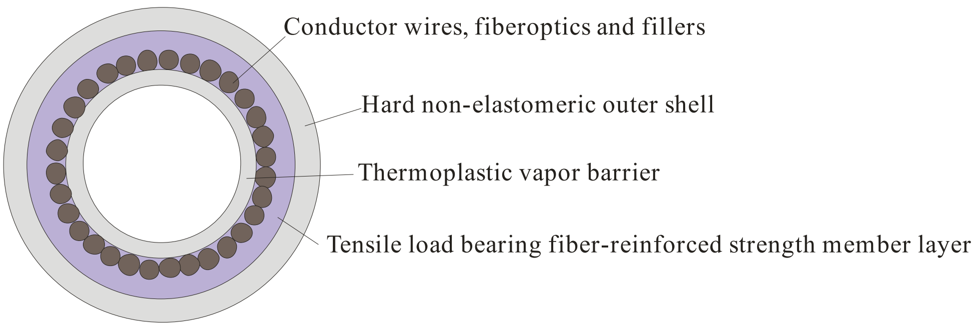


Figure 3 Schematic of Hose Design

Schematic drawing of smart high pressure hot water tubing, showing inner tube a thermoplastic vapor barrier, followed by a layer of fillers, fiberoptic and conductor wires overlain by braided layers of tensile load bearing fibers. The tube is finished with a hard non elastomeric outer shell..

Smart hose

At present it is in possible to produce high strength (10,000+ lbs tensile load) tubing with conductor wires and fiberoptics incorporated into the tube design. Airborne tubulars has come up with a two different concept for incorporating electrical conductors and fiber optics into the thermoplastic tubing (see below). One design is currently a R&D project, which likely will not be available in time for a new fast access drill system. The second is a design borrowed from seismic air gun hoses which boot strap the strength member and wiring on opposite sides of the tube.

Alternatively to producing a higher strength smart hose in one process it is generally possible to bundle off the self tubing with conductor wiring and fiberoptic and a tensile strengthened mantle. Such bundling is routinely done to produce umbilicals used on oil platforms however such bundling would likely result in tube with a larger diameter than smart tubing produced in one process. This is due to additional layering and filling material and such tubing would likely be also heavier. Oyo GeoSpace (see **Appendix 3: ~~Appendix 3: Appendix 3:~~**) who produces the umbilical for the ice borehole ROV had produced in the past air-gun hoses, which combine tubing with umbilical wiring and fiber optics. Anticipated pricing for 1500 m of a higher strength 1” ID smart pipe is in the order of $100,000 to $300,000.

Injector Systems and Linear Motion Drives

As the name says linear motion drives allow pulling or pushing of a wire, tube or rope in a linear motion. This is different to capstan drives which pull the line over a sheave, in this way bending it under tensile load. A specific and commonly used model of a linear motion drive are injector systems Injector systems are specifically designed to pull or inject coiled tubing pipe straight out of or into a borehole, avoiding problems resulting from bending a hoes or tube under tensile load (see capstan drive). Simplified, injector systems are conveyer belts while other linear motion drives use a series of wheels, which grab on the hose and pull or push the tubing out of or into the borehole. This allows for higher tensile loads on the tube as the tube is not bend running over a reel. Further on the tubing is spooled onto the reel under low tension, significantly reducing fatigue problems and contributing to the life expectancy of tubing. Injector systems used in the oil industry are usually highly complicated, which are in general used for more than simple pushing and pulling. Current injector systems have pulling capacities of in cases exceeding 100,000 lbs. The smallest injector system HydraRig currently builds has a 100 HP motor producing a pulling capacity of 35,000 lbs. The system weights 5,400lbs and can move 1” to 2-3/8” tubing at a maximum speed of 115 to 265 feet per minute, dependent on displacement (see **Error! Reference source not found.** for details). In 2006 the HydraRig HR 635 series injector with a simplified control package was in the order of $100,000, a simplified power package would cost in addition $50,000. Pricing for the Sound Ocean linear motion drive ranges XXXX to XXXX.

The development of a injector system specific to the smart hose through ICDS may also be considered if significant cost and fuel saving could be achieved.

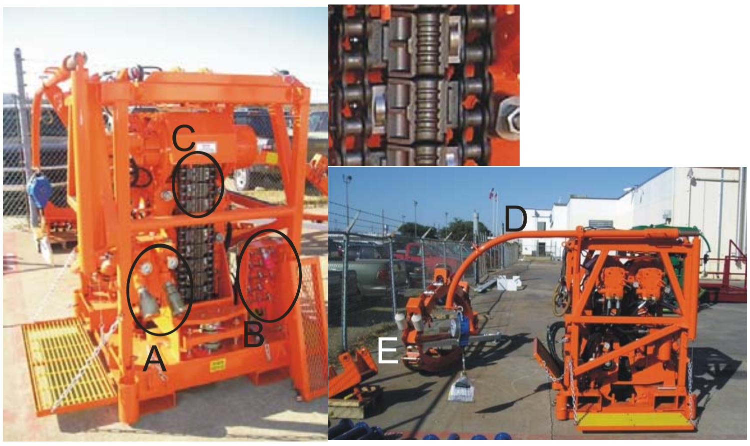


Figure 4 HydraRig Injector System

Side and front view of HydraRig coiled tubing injector system HR635. Individual parts are A) hydraulic power inlet,, B) hydraulic control valves, only 4 of them actually need for a hot water drill system, C) gripper system small insert on top shows gripper system enlarged, D) safety fall arrest installed on top of the injector, E) large radius goose neck feeding the tubing to the reel.

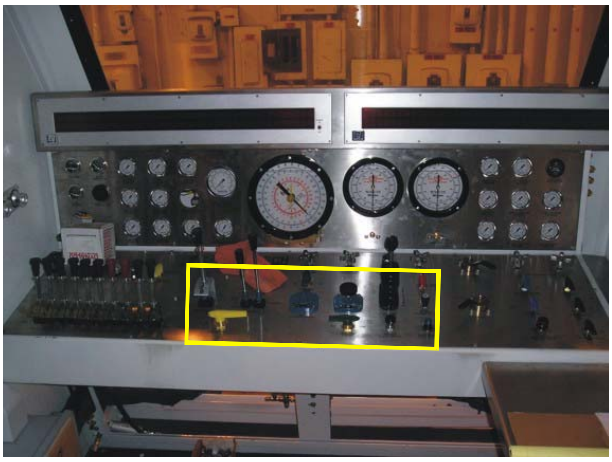


Figure 5 HydraRig Operation Center

Operation center for coiled tubing injector system as used in the oil industry. Yellow square outlines controls needed for injector system (variable speed forward variable speed reverse, pressure control and supplemental hydraulic controls) used in conjunction with the hear proposed SCT-HW drill.

Figure 6 Linear Motion drive used for pulling laying ROV umbilical cables. (Image source http://www.soundocean.com/lctm_4150.htm)

Smart Hot Water based Fast Access Drill System Design

A new fast access drill system will combine advantageous coiled tubing and off shore technology with the proven concept of hot water drilling. The system requires like conventional hot water drill systems a heater and pump unit to produce pressurized hot water. The system needs to be capable of drilling boreholes with diameters of up to 30 inches. The heating system shall be designed to produce a 500m to 1000 m deep slim hole (diameter of 4 to 8 inches) within 12 hours and extend a 500m to 800m deep hole (thickness of ice shelf) by reaming to an extended science borehole (diameter 30 inches) within 36 to 48 hours. This could be accomplished with a 1 to 2 MW heating system. A 1 MW heating system would be able to heat 160 liter of water per minute from a temperature of 0ºC to a temperature of 90ºC. Depending on the heat loss at the surface and in the upper borehole the system would be capable of drilling a slim hole within a few hours and an extended science borehole through the Ross Ice Shelf within about two to three days. During full operation this system would consume ~20 gallons fuel per hour.

Table 1 Drill Time

borehole depth	flow rate	average temp at drill head	time to drill 8" borehole	time to drill 30" borehole
500m	160 l/min	80ºC	2 h	28 h
500m	160 l/min	70ºC	2.5 h	35 h
500m	160 l/min	60ºC	3 h	41 h
800m	160 l/min	80ºC	3 h	43 h
800m	160 l/min	70ºC	4 h	56 h
800m	160 l/min	60ºC	4.5 h	65 h

In the new system the conventional hot water drill hose will be replaced ideally with a higher tensile load strengthened thermoplastic composite tubing, which can serve as umbilical for the operation of the ice-borehole ROV and provides real time drilling information. A linear motion drive will replace the conventionally used capstan drive, allowing greater control on the drilling process, higher pulling forces and avoiding fatigue problem common to capstan drives where the hose/tubing is spooled and pulled over reels under full load.

The availability of electrical, hydro-mechanical and thermal energy at the drill head allows for a variety of attachments being used in conjunction this drill system and extending its versatility enormously. Possible attachments are hot water based and electro mechanical ice corer and electrical or hydro-mechanical rock drilling equipment as well as hydraulic piston coring etc.

Figure 7 Truck Mounted Winch and Injector System

Drill set-up on the sled mounted drilling platform could be similar to this truck mounted winch and injector system. In this configuration the injector, winch system and hydraulic power pack are in line.

Table 2 Drill System Specifications

Drill System	
Flow rate	160 - 240 liter per minute
Drill fluid temperature at surface	90ºC to 95ºC
Heating system with Titanium heat exchanger	
Clean access and sampling system	100 cells per milli-liter
Fuel consumption	80 to 120 liter (20 – 30 gallons) per hour
Drill Hose	
Tube inner diameter	2.5 to 3.75 cm (1 to 1.5 inch)
Maximum operating pressure	2,500 psi
Maximum tensile load	10,000 lbs
Multiple fiberoptics and electrical conductor wires	
Linear Motion Drive	
Line speed by empty drum	30 m (100 ft) per minute

Overview Drill System Components

See Figure 1 for schematic overview of a HWD system.

Individual components are:

i) Water storage including melt tank and borehole recirculation system
ii) Heating and pump system with heat exchanger
iii) Clean access and sampling system (not shown)
iv) Manifold
v) Winch with smart hose and linear motion drive?

vi) Winch with regular hose (spool) and capstan drive ?
vii) Drill and reamers
viii) Well pump system recycling borehole water.

Clean Access and Sampling System

A variety of methods exist which allow cleaning of water and the removal of particulate contaminants. The workshop on Ice Sheet Bed Sampling and Fast Access Drilling (April 30 –May 2, 2008) discussed environmental stewardship and clean access drilling and sampling. Table 3 provides an overview over different cleaning methods and their positive and negatives in regard to utilizing them for a fast access drill system in Antarctica (Source Vogel et al. in prep.).

Table 3 Filtration and Sterilization

	Sterilization	Sand Silt Clay	Microbes	Chemicals	positive	negative
Sterilization						
Heat sterilization	**X**				Part of the drilling process	Chemical Dissolution
UV Radiation	**X**				Relatively inexpensive	
Chemical Method (Ozonation, Chlorination	**X**					Requires removal, Waste
Filtration						
Particle Filters (>1 µm)		**X**			Cost	
Carbon filters (>0.5 µm)		**X**		**X**	Cost	
Micro filtration (>0.05 µm)			**X**			Cost
Reverse Osmosis (>0.0001 µm)	**X**		**X**	**X**		Cost, Logistics

A clean Access and Sampling System for accessing subglacial environments in Antarctica may follow the example of Thorsteinsson et al. (2008) and Doran et al. (2008), using a combination of particle and micro filtration and UV radiation, significantly reducing the viable cell count in the drill water.

Without significant modification a system similar to Thorsteinsson et al. (2008) could be expanded into a two or three stage particle filter system, allowing filtration down to 1 µm, and an expanded UV-radiation system. To remove microbes from the water a microfiltration system (Doran et al. 2008) could be added. Figure 8 shows a schematic of such a system.

In addition to sterilizing and filtering the drilling fluid additional considerations need to be given to disinfecting the drill system prior to use as well as to appropriate testing methods and documenting all aspects of the clean access and sampling system.

Thorsteinsson et al. (2008) noted that results of their test were dependent on the purity of ethanol used to disinfect the system, with 70% ethanol being more efficient. They also noted concerns that drill system components may be attacked by the sterilization fluid. This should be considered during the design process and all components should be checked against their chemical resistance and compatibility for this application. Throughout the development process cleanliness testing of the system needs to be done to ensure that NRC standards are met. In addition, testing methods for microbes adapted to anaerobic and oligotrophic should be included into the testing procedures. The testing should also be done throughout the project in the field and part of documenting the environmental impact a project.

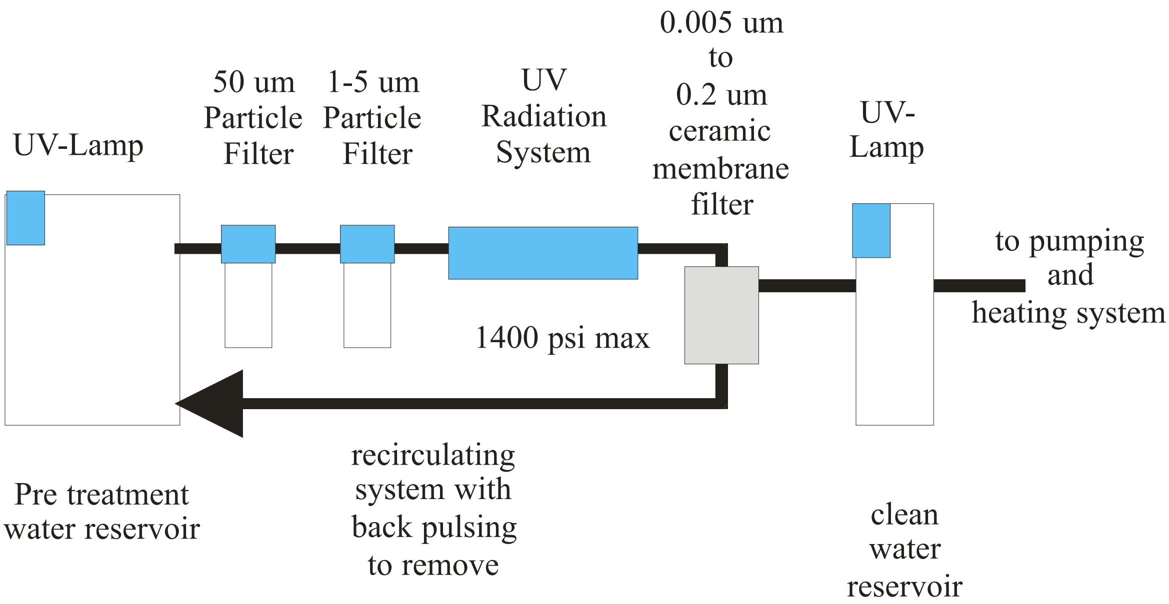


Figure 8 Clean Access and Sampling System

Science Equipment and Integrating Science and Drill Equipment

Science Instrumentation

A number of major sub ice instrumentation developments are underway. This includes a sub-ice ROV, which can be deployed through a relative narrow ice borehole while providing a fully functional heavy duty ROV in the sub ice cavity. The SIR development is supplemented with a variety of other instrumentation for the study of subglacial environments. New customized instrumentation includes: (i) a multi-node englacial (temperature) and subglacial (CTD, Doppler current meter) long-term observatory for measuring turbulent heat flux across the ice-water interface and quantify sub-ice cavity circulation (McLane Ice Tethered Profiler, combined with current sensors); (ii) an active-source sediment coring system to recover 5+ m of undisturbed subglacial till and fluvial sediment as well as marine and lake sediment, and (iii) a Geochemical Instrumentation Package for Sub Ice Environments (GIPSIE) (Vogel et al., 2007, 2008).

Sub-Ice ROV (SIR)

SIR

The SIR a customized "slim-line" design similar to those used for pipeline investigations. The vehicle has a diamtere of ~55 cm (22 inches), has a length of 8.4 m in is rated to 1500 m depth. Power and data are transferred from and to the surface through a neutrally buoyant, strengthened, 3km-long umbilical tether of fiber optic and power cables. Navigation is by Doppler velocity logs (from two Doppler current meters) and a gyro (FOG) compass so the ROV/AUV is used either in automated mode with this AUV technology to do spatial surveys, or is manually driven by a surface operator using real-time video imagery to investigate specific features and operate in enclosing spaces. The vehicle is highly instrumented for obtaining both remotely sensed data as well as collecting and recovering samples. The wide range of sensors and sample collectors provides data for studies in oceanography/limnology, sedimentology/stratigraphy, glaciology, biology/microbiology, geochemistry and geophysics, and includes

SIR-instrumentation

Visual imaging:	1 high-definition camera + HMI lights (broadcast quality images), 3 lower-resolution cameras + 4 quartz lights (piloting, down-hole viewing), digital still camera (high-resolution images)
Vertical scanning sonar	long-range imaging for spatial orientation and navigation
Doppler current meter	determine water current velocities
Multi-beam sonar	image and swath map bottom topography
Sub-Bottom Profiler	profile sub-sea-floor sediment for geological history
CTD	determine salinity, temperature and depth
DO meter	determine dissolved oxygen content in water
Fluorometer	determine organic matter in water
Transmissometer	determine suspended particulate concentrations in water
Laser particle-size analyzer	determine sizes of particles in water
Triple laser-beams	determine size and volume of objects
Thermistor probe	measure in situ temperatures of ice and sediment

Shear vane probe	determine in situ strength of sediment
Manipulator arm	deploy instrumentation packages, collect samples
Ice corer	collect ice samples and glacial debris
Water sampler	determine sea water/freshwater composition, calibrate real-time sensors, sample microbes
Sediment corer	sample sea floor, in-ice and subglacial sediment (stratigraphy, facies, particle size, composition, structure, fabric)

Umbilical

Umbilical Specifications.

Diameter	1.105	Inch
Min bend radius	23	Inch
Weight in air	419.4	Lbs pos per 1000 ft
Weight in freshwater	16.6	Lbs pos per 1000 ft
Weight in saltwater (Sp. Gravity. 1.028)	5.3	Lbs pos per 1000 ft
Break strength	4390	Lbs
Working load	500	Lbs
Volt rating	4500	AC-Volts
Actual	3300	

Sampling Hotel

The sampling hotel is a device with individual trays in which sampling devices and aquired samples or autonomous instrumentation packages can be placed and transferred to and from the surface. The sampling hotel can either be directly attached to the umbilical or integrated with the reaming and back drill system of the smart HWD system. The design of the sampling hotel is modular, to adapt to future scientific objectives. Exact configuration and functionality is currently discussed and will consider the drill design specifications.

Command center

The ROV command center houses the surface electronic and control components of the SIR system as well as the data acquisition system. It provides work space for 6 people. The Pilot and Co-Pilot fly the ROV and oversee the control panel of the ROV, the Navigator is responsible for navigation, while the Chief scientist oversees the science mission makes decision about the targets and directs the Pilot accordingly. The chief scientist is assisted by a co-scientist. Both are responsible for science equipment operation like, sampling arm or sampling devices, as well as overseeing data recording and data back up. One additional seat is available for mission specific tasks. The Command center will have a wired and wireless computer network, connecting the command center to other facilities of the scientific traverse system, with the potential for life stream data and video sharing. A uninterrupted power back system will provide continuous power supply to all critical electronic parts. The use of solar technology for the light system inside of the container and possibly the operation of computers and other electronics is currently investigated. The estimated weight for the ROV command center is 10,000 to 15,000 lbs.

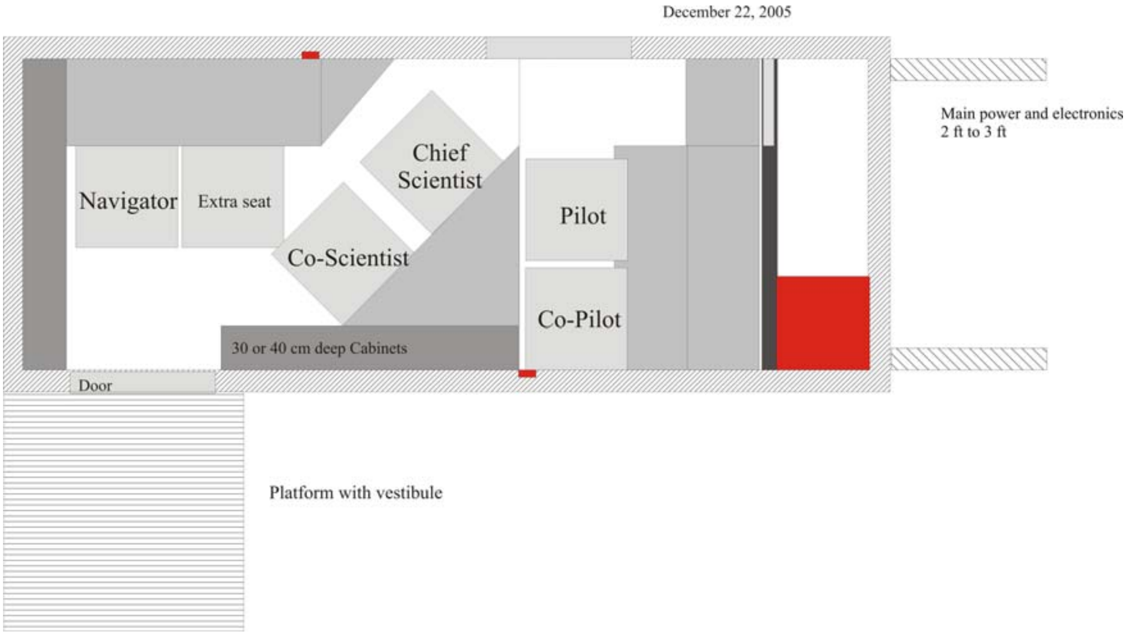


Figure 9 ROV Command Center

SIR Storage and Maintenance Unit (SIR-SMU)

The SIR Storage and Maintenance Unit (SIR-SMU) is the home of the SIR during field operations. It contains a wall mounted storage rack for the 6 SIR frame segments, storage for SIR instrumentation, workbenches and equipment for routine SIR maintenance. The anticipated weight of the SMU is 10,000 to 15,000 lbs and may have space for additional equipment.

SIR Launch and Recovery System (LARS)

The Launch and Recovery System (LARS) for the SIR enables the unfolding of the SIR from its underwater flight mode (box shape open configuration) into the deployment mode (cigar shape closed configuration). For this a crane extending to a height in excess of 10 to 12 meter is needed. The SIR is lowered to water surface on a steel cable which latches onto the umbilical head. The LARS is designed around a standard 20 ft ISO container flat rack. The LARS includes aside from the SIR umbilical winch and steel cable deployment winch a multi-purpose winch system for the deployment of the GIPSIE and slide hammer piston corer. The anticipated weight of the LARS is 30,000 to 40,000 lbs.

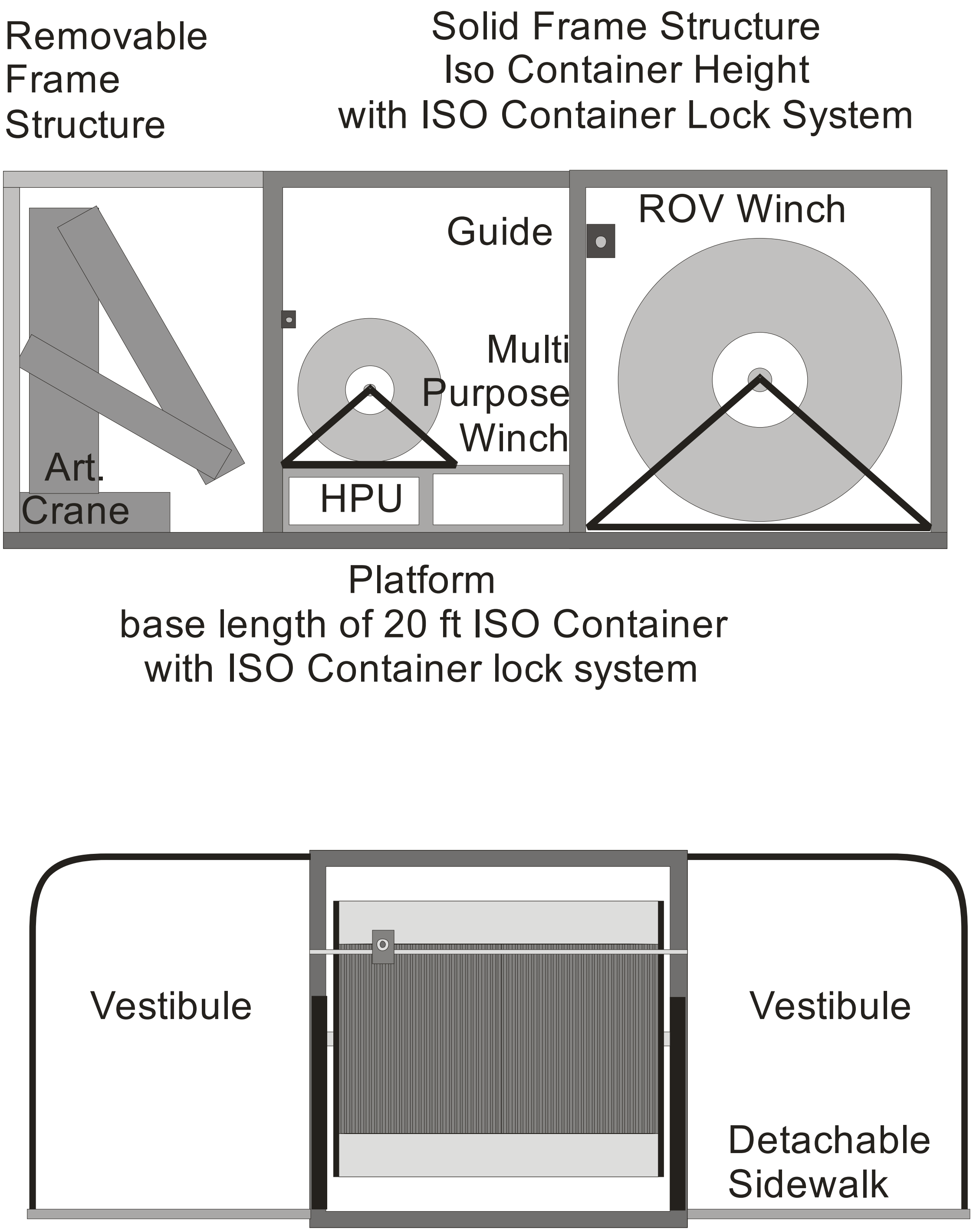


Figure 10 :Sketch of LARSystem with removable side walls and detachable side walks, based on a 20 ft ISO container dimensions.

Geochemical Instrumentation Package for Sub Ice Exploration (GIPSIE)

GIPSIE is a wire line-deployed profiling system and consists of a number of off-the shelf deep-ocean sensors (Table II) among others to measure major nutrients and dissolved gases. GIPSIE will be used to conduct a basic physical and geochemical characterization of the subglacial hydrosphere and profile the upper 50 cm of the subglacial bed. Sensors are off-the-shelf equipment mounted in a borehole deployable frame. Individual components are stringed and arranged to fit through a 15 to 30 cm diameter ice borehole, depending on each unit's limitations. Scientific objectives of each mission will determine whether the individual units will be deployed: (i) individually on a wireline, or (ii) strung-up as sub-ice profiler, or (iii) individual components as an autonomous long-term observatory as part of the SIR deployment. The profiling unit sensors are linked to the surface via a multiplexer for real-time data transfer and topside instrument control. Thus, GIPSIE can be operated in a remotely operated mode or pre-programmed for autonomous profiling. The GIPSIE profiler is lowered by a multi-purpose winch system that can also deploy the sediment coring system and other instrumentation packages.

Contros	CO_2 & CH_4
Seabird 19plus-V2	CTD incl. dis. Oxygen
WET Labs ECO-FLNTU(RT)D,	Chlorophyll & Turbidity
WET Labs C-Star Deep	Transmissometer
Sequoia LIST-DEEP	particle analyzer
Envirotech Nutrient analyzer	NH_4, NO_3, Si, PO_4
Envirotech	automated water sampler
Deep-Sea multi cam 2065	Color camera
Teledyne DVS-6000	Doppler Current Meter
Unisense Porewater profiler	pH, redox,T,H_2,HS,O_2,N_2O

Sampling equipment

Ice Coring:

The ice coring operation will be the responsibility of IDDO. In general three different options for obtaining ice samples are possible, currently available is a 3 inch diameter hot water based ice corer. Different types of electro mechanical ice corer designs are available for adapting to coring in a water filled fast access hole. An electro thermal drill may also be a possibility. Details need still to be discussed with IDDO. With power conductors included in the hose design, a hybrid coring system consistent of an electro mechanical corer for coring and the possibility to deliver hot water in case the electro mechanical corer freezes into the ice could be possible.

Hot water based ice corer:

Caltech had developed a hot water based ice corer, which successfully was able to core glacial and basal ice. Basal ice recovered with this core had small amounts of sediment included. Small modification on the core catcher design may improve the ability for coring ice with small to intermediate sediment content (Vogel accepted , J.Glac).

A downside of a thermal drill whether hot water or a electro thermal drill is the temperature stress the drill exerts on the ice. Also while the corer is capable of coring good ice cores in non sediment laden ice, the quality of the core is compromised in sediment laden ice. The heat used to core also melts the cement, which holds the sediment particles together.

Electro thermal ice corer:

Similar to the hot water ice corer an electro thermal ice corer cores the ice by melting a cylindrical column around the ice core. This is done electrically by heating up coils at the bottom of the corer and not by jetting hot water. While the electro thermal ice corer also exerts thermal stress on the ice core, it has the advantage that it will not create turbulent flow, in this way improving core quality in clean ice. It however has the great disadvantage that sediment particles will accumulate in front of the heat coils significantly limiting the ability to drill through sediment laden ice.

Electro mechanical ice corer:

An electro mechanical ice corer produces an ice core by cut the ice producing large amounts of ice chips, which need to removed from the cutting head. This is our standard rotary ice corer, like the WAIS divide drill or the eclipse drill.

This type of corer provides the best core quality. However this has never been done in a hot water drilled borehole. In a water-filled hole, the danger exists that ice chips freeze together and cementing the corer into the ice. To prevent this one would need to make some modifications to the coring system. Such modifications could be incorporation of heating elements in the cutting shoe or along the side of the drill system. This can either proactively prevent the corer from freezing in or be used to recover the corer in case it gets stuck.

Sediment laden ice has been recovered previously with electro mechanical ice corer. The efficiency of the electro mechanical corer in thick sediment laden ice is however not clear. In general a cutting shoe, which performs well while cutting ice is not well suited for cutting rocks and vice versa. Overall a modified electro mechanical ice corer appears to be the best option to obtain uncompromised sediment laden ice cores. This is a new technical development.

Water samples:

There are many options for water sampling. These include conventional bailers, automated water samplers, pump systems and filter systems which only sample suspended material from the water.

Bailers

The easiest is a bailer like Niskin bottle. This is good option for sampling water from a larger sub ice cavity, if only one sample is needed. A big adavantage is that large quantities can be sampled. If more than one sample is needed this can become a labor and time intensive task as during a single deployment usually only one sample can be obtained at a time. The time needed for a single deployment and recovery amounts to 1 to 2 hours per run. The recovery of multiple samples can take up a good portion of a day.

Automated water samplers

Automated water samplers use a pump or syringe system to store water in a storage container, often a sample bag. A valve system distributes individual samples to the individual storage containers.

NIU has acquired an automated water sampler from Envirotech. http://www.envirotechinstruments.com/aquamonitor.html. This is a syringe type sampler, which stores water in sample bags. A variety of different sample bags are available which allow sterile storage as well as gas sampling.

The sampler will be incorporated into the Geochemical Instrumentation Package for Sub Ice Exploration (GIPSIE), which allows user controlled targeted water sampling based on real time data.

see GIPSIE on S. Vogel's webpage for further details: http://jove.geol.niu.edu/faculty/svogel/Technology/Technology-index.html.

Pumping water directly up to the surface and sampling at the surface:

A submersible pump will be lowered to the bottom of the hole or desired depth and water will be pumped up to the surface and collected in appropriate sampling containers. This is suitable if extra large quantities are needed. It however has to be noted that the pump will have to be a very strong pump as it will have to overcome a head of 70 m to 100 m height, the distance between the ice surface and the water level inside of the ice borehole.

There can also be complication due to frazil ice formation when pumping supercooled water from a depth of 700 m to 1000 m depth to the surface, which can clog up the tubing and damage the pump.

Filtering of water

For science investigation concerned with particulates in the water, particulates may be collected using a filtration system. Here only the filters are collected and suspended particulate is available for analytical work. This allows filtration of large amounts of water without actually collecting the water. Such system could easily be integrated into the GIPSIE. If the pump system is used with a vlave system multiple samples can be collected.

Sediment

A variety of sediment samplers are available. Due to the space constraints only cylindrical corer will be suitable. A coring system is usually designed for recovering a specific type of sediment. The type of sediment can be distinguished by their stiffness. Soft sediment are usually collected using short cores, with corers which do not disturb the much. Corer with deeper penetration encounter usually sediment with increased stiffness and therefore are built stronger. This however usually also increases the disturbance of the sediment collected.

Simple gravity corer:

Simple gravity corers consist of a plastic liner, which gets pushed into soft sediment by the gravitational force of a weight. Water inside of the tube evacuates through a valve at the top of the tube. Such corers usually recover 50 cm to 100 cm of soft sediment. This corer has problems with stiffer and clast rich sediment, which can damage the fragile plastic liner. UCSC has a small lake sediment corere which could be deployed using a wireline rope. Soft sediment can also be collected with the SIR.

Steel barrel piston corer:

This is a corer, similar to the Caltech piston corer. A steel barrel and a cutting shoe made of steel protects the core liner. The Caltech piston corer was able to recover of up to 3 m of sediment. Dependent on the stiffness and the number and size of clasts in the sediment, the Caltech corer recovery ranged from a few tens of centimeters (~50 cm) to 3 m. The design of this system is simple and a new system could be fabricated at relative low cost (estimated $5,000 to $10,000). The Caltech corer is part of the IDDO inventory and could made available after refurbishing the existing parts.

Active coring systems:

There are several different active coring systems which allow penetration of stiffer sediment. Vibro coring systems and slide hammer corers are commonly used systems. NIU is currently developing a slide hammer corer: This corer has an active weight drop system (hammer), which allows active penetration of stiffer sediment. Anticipated corer length if 5 m with potential extension to 10 m if successful. This is a significant technology development, which can further our science significantly extending sedimentological as well as biological and chemical studies beyond the 3 m previously recovered by the Caltech system. The diameter of the corer is not yet defined. A larger diameter (4 to 6 inch) may be advantages. While the core cutter can push smaller pebbles out of the way a larger diameter would allows to swallow medium sized clasts. While pushing away or squeezing in clasts creates disturbance of the corer it will allow penetration beyond that of a smaller corer.

The sediment corer has a double wall barrel, which allows water from the top of the sediment corer to flow within the core barrel wall to the cutting shoe. This modification reduces significantly the amount of suction produced during the recovery of the sediment corer and in this way enables the recovery of long sediment cores (anticipated up to 10m) without heavy duty winch system to overcome the enormous suction during core recovery. In addition the outer shell of the sediment corer can be released and serves as borehole casing. This allows reentry and either the acquisition of a second sediment core or the acquisition of a rock core using a rock drill.

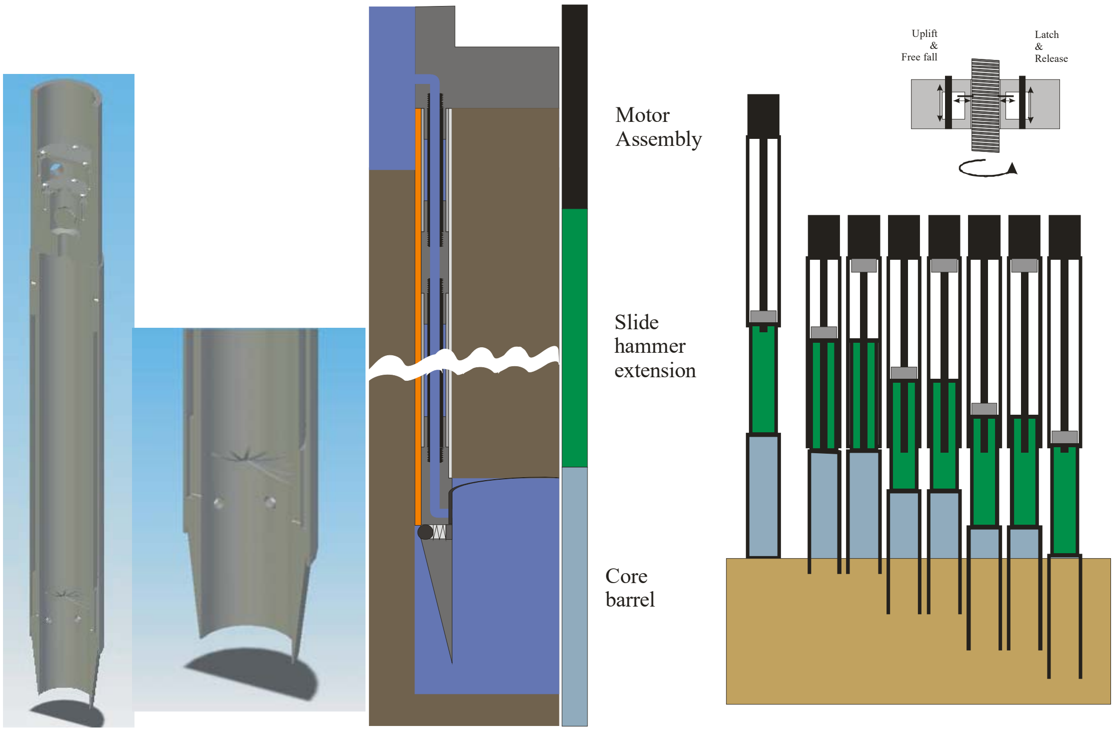


Figure 11: Suction-less Sediment Corer. Left) Solid work model of the core barrel assembly; center) schematic of double walled core barrel allowing fluid migration and optional borehole casing (orange) and complete slide hammer corer with components. Bottom right: Schematic of deployment and sediment penetration, Top right: Schematic of drop weight catch and release mechanism.

Rock Coring

A hydromechanical rock drill is available. This system was purchased by Caltech and transferred with the Caltech HWD to ICDS. One core barrel and the XXXX valve were lost during a test on Kamb Ice Stream during the 2000/01 field season. The system requires maintenance and initial testing. The proposed thermoplastic tube should enable safe deployment and operation of the rock coring system and thus the system should be operational for sampling of basement rocks if such will be encountered at the ice sheet bed. Weight ~ XXXX lbs.

Some General Considerations:

Deployments into the sub ice environment on Whillans Ice Stream do not compare with deploying something into a lake in the Dry Valleys. Any instrument/ sampler is not deployed through a few meters of ice like in the Dry Valley lakes. We deploy this through a narrow borehole to a depth of 700 m to 1000 m. At a speed of 30 m per minute the one way deployment time is ~30 minutes. We can expect that each experiment will take between 2 and 5 hours. I would estimate that at a maximum one can plan 5 to 8 deployments per day. This means that in order to acquire all samples, ice, water and sediment, including repeat coring for the different purposes will take easily 2 to 5 days of borehole work.

Traverse Equipment

Figure 12 Concordia Traverse

Challenger pulling trailer and sledges on Concordia traverse (source: Concordia traverse report REF)

General Traversing Considerations

Continued development of ground traversing capability for the USAP was one of the recommendations of the subcommittee on U.S. Antarctic Program Resupply (Swift, Link et al. 2005). The development of scientific fast access drilling traversing capability for the US program should therefore be inline with the recommendations of the subcommittee on U.S. Antarctic Program Resupply. Following the recommendations of the committee the traverse could provide an opportunity to

- optimize traversing equipment,
- further develop traversing protocols
- increase experience with heavier scientific traversing expeditions and extend the cadre of traversing experienced personnel, and
- explore and establish a safe traversing route to support science activities in West Antarctica

The traverse needs to provide transportation and shelter to scientists and support personnel as well as for their scientific equipment, samples and resupply items like food and fuel. Following the example of many other traversing expeditions the traverse could house much of its equipment in sled mounted 20 ft ISO standard shipping containers. In addition the traverse will need a specialized sleds mounted drill platform, which will host most of the drilling equipment. Other platform sleds are required to transport loose equipment like boxes, skidoos for local transportation and extended camp activities. The traverse also needs to have the capability of lifting and moving heavy drilling and science equipment (forklift, crane) as well as moving snow (snowblade or shuffle to level the drill site and in its melted form as drilling fluid). One or two vehicle mounted cranes would be desirable.

The traverse needs snow mobiles for local transportation around the drill camps for site surveying and supplemental science activities.

Container Units

Following the example of many other traversing expeditions the traverse could house much of its equipment in ISO standard shipping containers. ISO containers are the standard shipping method around the globe and can be handled at almost any locations in the world including Mc Murdo station. ISO containers are rigid enough for ground traversing and provide protection from damage to equipment during shipping as well as environmental protection in the field. ISO containers come in standard length of 20 and 40 ft and have been customized to fit into LC-130 aircrafts. Insulated ISO containers can be used as personnel shelters, providing kitchen and office space, berthing, laboratory and work space or as temperature controlled sample storage. Specialized light weight sleds for the usage with ISO containers were available for the first South Pole traverse (see section on sleds further down). A specific type of ISO container are the MECC containers. These containers are 20 ft ISO standard container with downfoldable side walls. Covered beneath a tent structure in the deployment mode this triples the available workspace. Also Weatherhaven has a interconnector kit which allows two MECC containers to be connected to each other, allowing people to walk between the two structures without having to get outside. A stacking kit also exists which allows two units to be stacked on top of each.

Vehicles

The traverse requires heavy pulling vehicles. In addition scientists will require access to skidoos for local transportation for, for example, route scouting, site survey and supplemental science activities.

Tractors

The Concordia traverse has experimented with a variety of pulling vehicles. They used Kassbohrer Pistenbully PB330s as grooming and pulling vehicle for small loads and Caterpillar Challenger tractors for towing of heavy load (see **Concordia Traverse Report**). A similar configuration could be used as part of the traverse. However this needs to be discussed in detail with NSF-OPP logistics and Raytheon and decisions should be made based on experience made on other traverse like the NSF-OPP resupply traverse to the South Pole, which is currently in its final project year (2005/06 field season), or the German lead Kohnen traverse.

Overall vehicles need to be capable of towing 50,000+ lbs. At least one or two vehicles need to be equipped with a small crane and forklift to lift and move heavy equipment around camp. At least one vehicle must be equipped with a snowblade in order to level the drill site and to prepare the site where the equipment will be winter-over in the field. A loader would be helpful to gather snow, which in its melted form is used as drilling fluid in the drilling operation.

In addition to the heavy pulling vehicles one or two lighter vehicles like the Pistenbully 100 would be useful to carry a crevasse detection radar and/or tow geophysical equipment like a geophone string or ice penetrating radar (GPR) antennas for a continuous seismic and GPR survey along the traverse route.

Overview vehicle needs

- 1 vehicle with forklift
- 2 vehicles with overhead cranes
- 1 vehicle with a front loader
- 1 vehicle with grooming equipment

Redundancy may be desirable.

Sleds

Aside from people there is different equipment and supplies, which need to be transported on the traverse. In detail these are:

- Containerized science and drilling equipment as well as living quarters and office space,
- Individual non containerized science and drilling equipment,
- Specialized sled mounted drilling equipment,
- Fuel.

Much of the equipment will be housed or come be preinstalled in 20 ft ISO standard containers. In addition some of the lose equipment (for examples: crates, boxes or skidoos) will have to be transported on regular transport sleds or has to find a space on the roof of one of the sled mounted transport containers.

Figure 13 Sled Designs

Top left: sled mounted container (source: Herbs welding). Top right: light weight sled design for Concordia traverse (REF). Center left: housing structure mounted on transport sled (source: Herbs welding) center right: Lehman sleds with housing container and fuel container (source Lehman Maschinenbau GmbH). Bottom left: Fuel sleds in Mc Murdo (source: Herbs welding). Bottom right: fuel container on Lehman sled (source Lehman Maschinenbau GmbH).

There are two general sled systems designed for the use with ISO standard containers. The first system is a regular transport sled with a platform onto which containers or other equipment can be secured. In the case of the second system two pairs of skis lock into the lock system at the front and back of ISO standard containers (Figure 13 top left). While the first system is more versatile, can carry a variety of equipment it is also heavier. The second system is only suitable for the equipment for which the sled was specifically designed, in this case ISO standard container. ISO standard containers in general should be able to support its own weight and the weight of its content and likely also has enough rigidity for traversing across rough terrain in Antarctica. Such sled system was use for example in the French Concordia traverse (Figure 13 top right, REF report) and is used by NSF to move containers in Mc Murdo (Figure 13 top left).

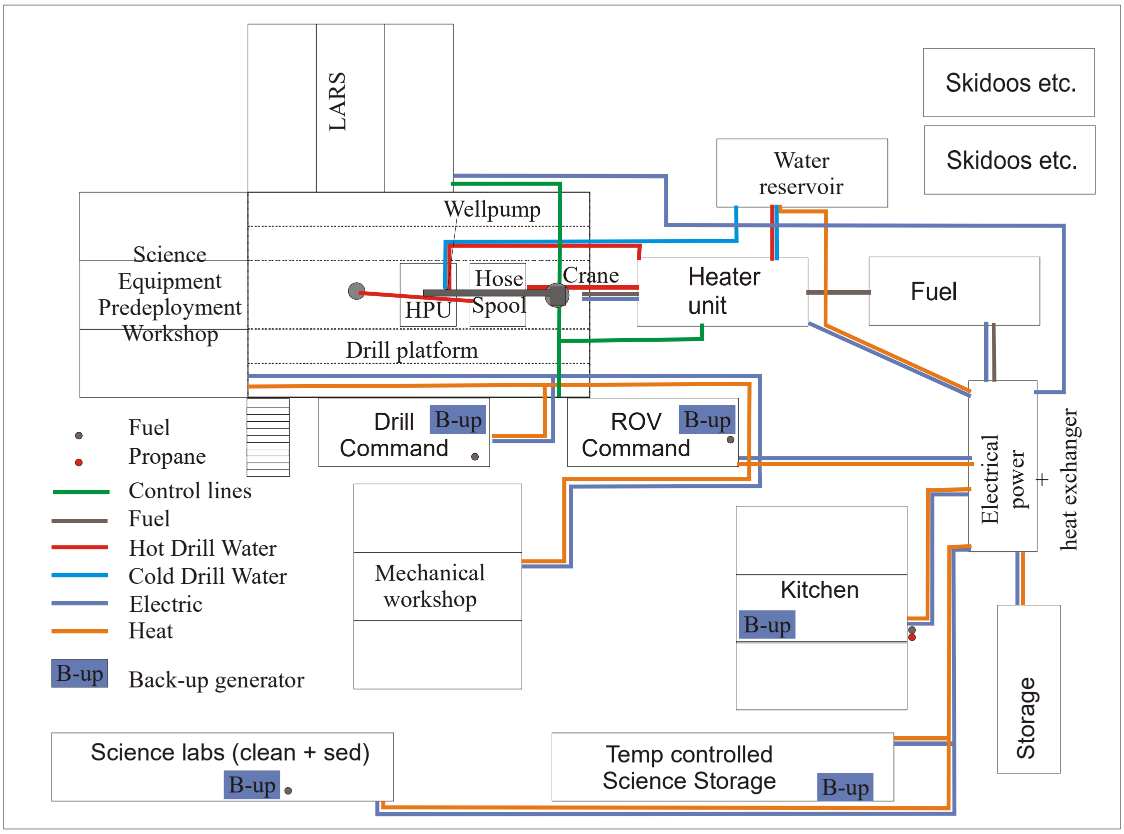


Figure 14 Drill Site Set-Up

Schematic drawing of drill site set-up showing connection for electrical power, heat and fuel between individual traverse units. Below earlier 20 ft container version

Facilities and Living Quarters

The suggested traverse system currently consists of 17 different components.

1. Field Laboratory
2. Drill Command Center (20 ft ISO Container – IDDO)
3. ROV Command Center (20 ft ISO Container – NIU)
4. ROV Umbilical and Coring Winch Platform (20 ft ISO flat rack - MECC type wings forming platform – NIU),
5. Science Equipment Predeployment Workshop (MECC)
6. ROV Storage and Maintenance Facility (electrical workshop for ROV) (20 ft ISO Container - NIU)
7. Science Storage, for example Oceanographic mooring, rock corer, sediment corer, ice corer (undetermined size -Raytheon)
8. Drill Platform with Hose Spool, Hydraulic Power Unit and Injector System and a lifting capabilities (crane) (suggestion 40 ft long 24 ft wide - NIU design may be part of the HWD system or part of the logistic component, IDDO)
9. Hot Water System - Heater Pump Unit (two (2) 20 ft MECC ISO Container-IDDO)
10. Melt tank (undetermined size, may be transported on the roof of one of the containers - IDDO)
11. General Mechanical Workshop (ROV/Drill/Camp) (20 ft MECC ISO Container)
12. Electrical Power and Heat Unit (undetermined size - Raytheon)
13. Temperature Controlled Sample Storage (undetermined size -/Raytheon)
14. General Storage Unit – Food (undetermined size - Raytheon)
15. Kitchen Living Facility (undetermined: suggestion: 20 ft MECC ISO Container - Raytheon)
16. Skidoo Trailers and additional transport sleds (2 -3 Lehman type sleds - Raytheon)
17. Fuel sleds (undetermined size – Raytheon)

This is a concept developed over the past years, which can provide the basis for detailed discussions of all involved parties, science, drill developers, instrument developers, Antarctic logistics group and contractor. Details of the type and amount of logistics available will factor into the design of the smart HWD system and drill requirements will factor into the logistic concept. Therefore the development of all units should occur coordinated to ensure smooth operation and functionality of the entire traverse system.

The Fuel consumption for electrical power supply for generally used units may be lowered by using solar panels installed on the roof and sides of the container units. This may make a back-up generator for some units unnecessary. Additional energy savings may come from using waste heat from the electrical power plant for heating purposes (hot water drilling and heating of containerized units during drill operation).

Field Laboratory

The Science conducted as part of will require some sort of lab facility/ies. S. Vogel at NIU has developed a concept for a containerized lab facility, which could provide a clean environment for sample handling and preparation and subsampling of ice, water and sediment samples. The clean field laboratory will be equipped with:

- Polypropylene, metal free, seam-welded construction. 100% Clean Air with HEPA filtered laminar airflow,
- UV lights for lab sterilizations,
- water filtration system (Milli-Pure or similar)
- high speed centrifuge and pore water press for pore water sampling
- and analytical equipment for analytical work like measurement of dissolved Oxygen, pH, electrical conductivity measurements, and
- equipment for subsampling of ice and water samples for He isotope or similar analytical measurements, which require instant subsampling.

in addition it would be desirable to have analytical equipment for

- organic and inorganic carbon measurements
- ion chromatography
- and others

Microbiological and geochemical investigations require sample handling, sub sampling and on site analytical work in a clean environment to prevent or at least minimize post acquisition sample contamination. Suggested equipment for the clean lab are:

- laminar fume hood,
- high speed centrifuge
- Milli-Q water
- sink,
- microscope,
- microbiological sampling equipment

In addition to a clean room environment, there exists also the need for a sediment and rock laboratory for general sample handling and preparation as well as initial on-ice core characterization. Equipment suggested for the sediment and rock laboratory are:

- core logging equipment
- rock cutting and thin section preparation
- ultra sonic bath
- sieves
- particle size analyzer
- petrographic, fluorescence microscope
- stereoscope
- digital imaging system

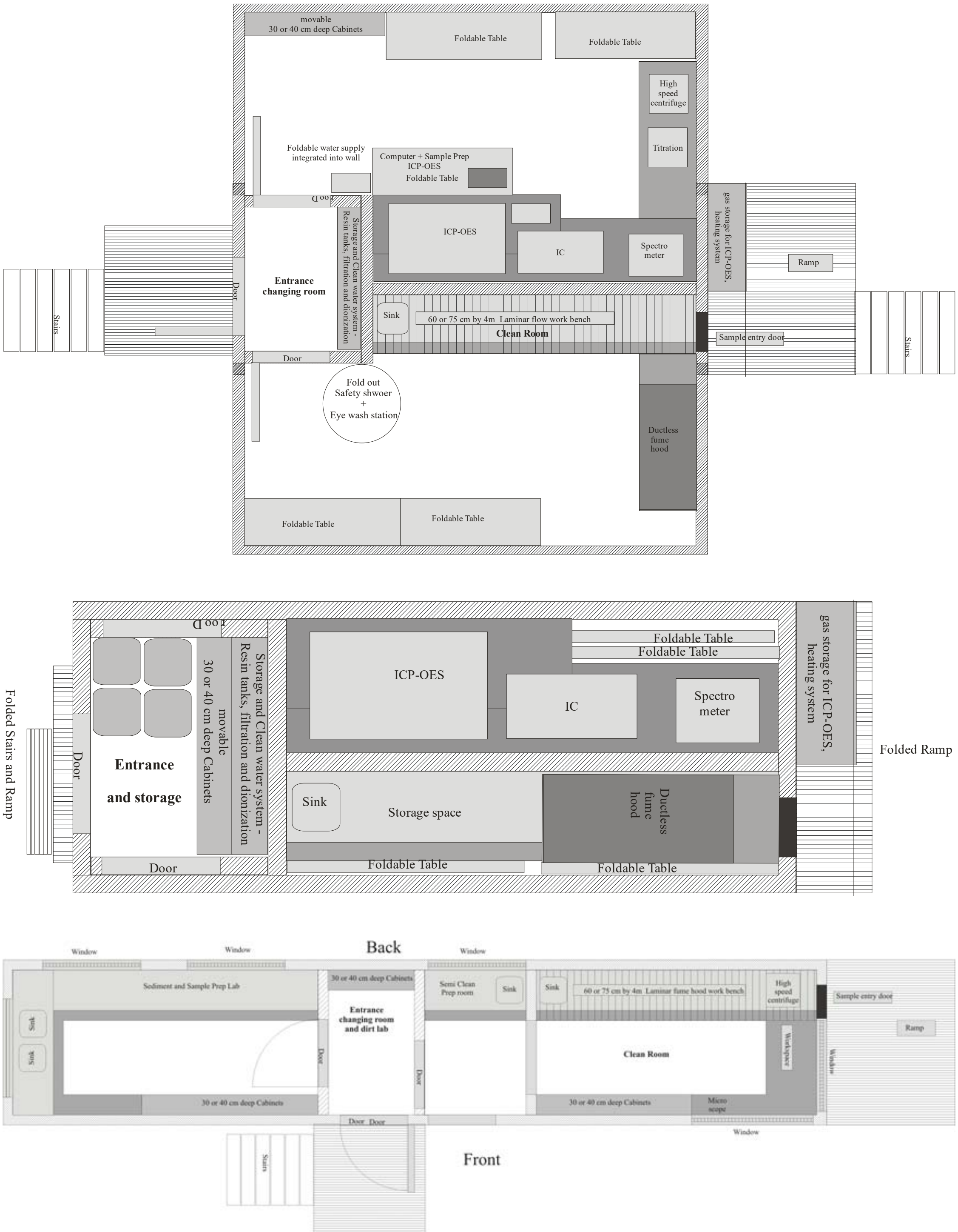


Figure 15 Field Laboratory

Schematic drawing of field laboratory Top & Center) 20 ft MECC container environmental field laboratory with clean room and analytical facility, Bottom) 40 ft ISO container with general sample prep lab and clean room. Clean room equipped with laminar fume hood, sink, microscope, high speed centrifuge and other equipment needed for sample preparation and subsampling of samples for biological and geochemical investigations.

In the field the field lab needs to be placed appropriately to avoid air pollution from hot water drill heat or electrical power exhaust. The field lab may therefore be placed at a distance from the drill site, which likely will be a compromise between accessibility and distance up wind from exhaust.

ROV Command Center (NIU, DOER))

The ROV command center provides shelter for the ROV personnel and equipment to operate the ROV. The ROV command center is equipped with i) the power supply for the ROV, ii) computers to control and operate the ROV, iii) data acquisition and data back up systems. The ROV command center will have a power back up system in case of power failure in the central power supply unit. The usage of solar panels is suggested and would substitute a diesel fueled back-up generator, which otherwise would be required if work would be conducted during traversing.

Drill Command Center (IDDO)

The drill command center provides shelter for the drilling personnel and all equipment to operate the hot water drill system. This includes the controls to monitor and control the drilling progress like the controls for the heating and pumping system, the smart hose winch, the drill rig system and the injector system. The drill command center will also provide general office space. It could provide significant weight savings if one combines the ROV and drill command centers and for example house it jointly in a 40 ft container.

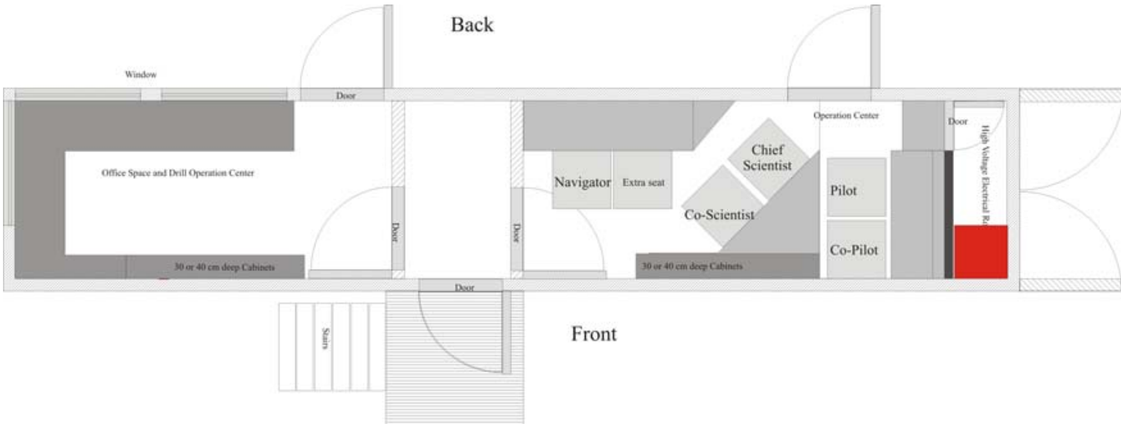


Figure 16 Example layout of a 40 ft ISO container used as combined ROV and Drill Command Center.

ROV Launch and Recovery System (LARS) (NIU/DOER)

The LARS houses the umbilical winch system and a steel cable SIR deployment winch as well as a multi-purpose winch system used to deploy the GIPSIE and sediment coring system.. The LARS is housed on a 20 ft ISO flat rack. On each sides a walk way can be attached, which enables working around the winches when the united is mounted on its sled base. See also Equipment section.

Science Equipment Predeployment Workshop (Raytheon?)

The Science Equipment Predeployment Workshop provides shelter for preparing science and drilling equipment prior to their deployment in the borehole. This unit may be housed in an expandable MECC container with removable front door and tent structure. The unit will include an extendable overhead crane allowing easy pickup of heavier equipment from an adjacent sled in the back and transfer of this equipment (e.g. ROV, oceanographic mooring system, etc.) to the drilling platform. During traversing sciene and drilling equipment can be stored in this unit. Movable shelving which can be fixed for traversing and universal fix and tie down points should be installed for this purpose.

ROV Storage and Maintenance Facility (NIU)

The ROV storage and maintenance unit will house the electronic workshop for the REST traverse and will allow general maintenance and repairs of the ROV as well as for assembling and preparing the long term observatories for deployment. In conjunction with the mechanical shop, which will house a variety of tools like hydraulic press etc.. The ROV storage and maintenance facility will also provide storage space for ROV spare parts. Additional spare parts may be stored in the general separate storage container. During drill set-up the ROV storage and maintenance facility will be connected to the ROV and Drill workshop, which will allow easy transfer of the ROV from the drilling platform into its storage during traversing.

Drill Platform with Hose spool, Hydraulic Power Unit and Linear Motion Drive (NIU design/IDDO)

The drill platform is the center piece of the drill system and also the largest and heaviest unit of the entire traversing system. The design of the drill platform is based on the foot print of three 40 ft containers. The center piece is a 40 ft ISO container platform with two 4 ft wide attachments on each side. Two of these attachments are fixed and bolted to the center piece, providing a solid rigid platform in the field. Together with the detachable side walk this provides a 16 ft wide 40 ft long drill platform on which will be mounted the spool and winch system for the smart hose, the linear motion drive, a hydraulic power pack and a hydraulic boom crane. During traversing the outer two attachments fold upwards, while during drill operation they provide an additional walkway around the center mounted drilling equipment.

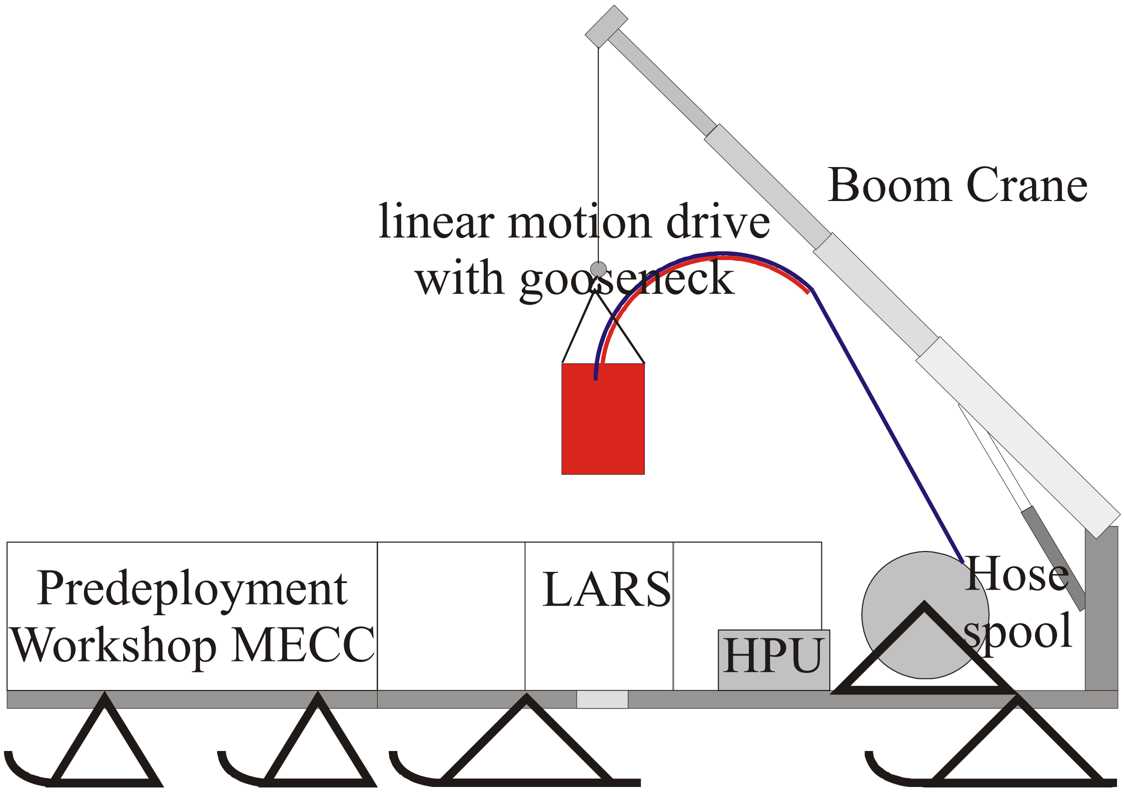


Figure 17 Drill plat form with boom crane in drilling and traverse mode

In the drill set-up the drill platform connects directly with the ROV LARS and science instrumentation predeployment workshop. Both of these units are MECC type units with down foldable side walls. In addition the fabric of the tent structure facing the drilling platform can be removed as well as the front doors. This allows easy access to equipment housed in these structures and extends significantly the space around the drilling platform during operation. The drill platform will have a variety of fix points to anchor other tooling and science equipment, like winch and spool system to deploy englacial analytical sensor string, water sampler etc. . A 1 meter diameter moon pool is installed in the center of the platform 12 ft from the front end (the end facing the predeployment workshop). Beneath the platform a borehole cover is attached. The cover is square and extends across the width of the platform. The borehole cover can be lowered to the snow surface. From the cover a series of telescoping rings extends to the moon hole shielding the borehole sides and preventing people and equipment to accidentally fall into the borehole. For safety reasons the borehole cover and moon pool have hinged lids with different sized holes, which covers the borehole during operation while allowing tubing and equipment being deployed and recovered. For safety reason the drill platform will also have anchor points to attach fall arrests, which are used to prevent personnel from falling into the 30” wide extended science borehole (see operational requirements for details).

The boom crane will be used to move heavy science and drilling equipment. The required boom tip height is dependent on the length of the longest science or drilling equipment. The deployment of the ROV requires at least a 12 m (~40 ft) boom tip height above the drilling platform at the borehole. A boom tip-height of 15 m to 20 m would be desirable allowing the deployment of the sediment coring system to recover sediment cores with a length of up to 10 m. A height of 15 m to 20 m would also allow assembling of drilling equipment above the platform rather than in the borehole, significantly reducing the risk to personnel and the risk of losing expensive drilling or science equipment by dropping a part into the borehole.

Heater Pump Unit (IDDO)

The heater and pump unit houses the hot water heater and high pressure pumping system as well as the hot water distribution system (manifold). This unit will be located next to the drill platform supplying hot water to the smart hose spool and receiving cold water from the clean tank.

In the current anticipated design the heating system is a glycol based heating system with a titanium heat exchanger. The heating system together with the clean access and samping system, the high pressure pumps and a titanium heat exchanger houses in two MECC containers. Each of the shelters would house one independent heating and pump system supplying ~80 and 160 for a total of 240 liter per minute. Weatherhaven has a interconnector kit which allows two MECC containers to be connected to each other, allowing people to walk between the two structures without having to get outside.

Water Reservoir (IDDO)

The water reservoir contains at least three tanks. The first tank is the melt tank to melt snow. From the melt tank water will be pumped through a prefilter to the storage tank and from there through the clean access and sampling system to the clean storage tank. When connecting to the marine sub ice environment, the clean access and sampling system can be bypassed. From the clean storage tank the water will flow through the high pressure pumps to the heat exchanger and onward to the manifold.

Clean Access and Sampling System (IDDO)

Without significant modification a system similar to Thorsteinsson et al. (2008) could be expanded into a two or three stage particle filter system, allowing filtration down to 1 μm, and an expanded UV-radiation system. To remove microbes from the water a microfiltration system (Doran et al. 2008) could be added. Figure 8 shows a schematic of such a system.

In addition to sterilizing and filtering the drilling fluid additional considerations need to be given to disinfecting the drill system prior to use as well as to appropriate testing methods and documenting all aspects of the clean access and sampling system.

The filtration system can likely be allocated within the structure which houses the heating and pumping system.

Mechanical Workshop (ROV/Drill, Traverse) (NIU/IDDO, Raytheon input))

The traverse requires a workshop equipped to handle most repairs. A 20 ft MECC container with down foldable sides would be most suitable for this purpose.

If half o container is used for tools and fixed equipment than other half could be used for maintenance and repair etc. The tent structure should have a opening so that larger equipment can be move in and out of the workshop area. A heated tent structure adjunct to the workshop which can be easily set-up and removed in which vehicles and other extra large equipment could be maintained and repaired may be of consideration.

Details about space required for spare parts, science, drill and traverse related spare parts, need to be discussed and the number for each field season adjusted.

Possible equipment for this workshop are:

- drill press with milling capability
- lathe
- hydraulic press for press fittings

A small mill and lathe as well as heavy duty cabinetry was purchased for the SIR and other instrument developments at NIU with the thought of incorporating these items into a containerized field deployable workshop facility. This equipment could be made available to incorporate it into the facility workshop.

The workshop will carry a variety of spare parts for repair of all science and drilling equipment as well as traversing equipment. After a spare is used a replacement part will be ordered instantly.

General Storage Unit (Raytheon)

On the traverse we need space for storage of science equipment, samples, spare parts and personnel belongings

Sample Storage (NIU/Raytheon)

During the traverse a variety of samples will be acquired, which require appropriate storage at temperatures above and below freezing. As temperature conditions on the Ross Ice Shelf can reach temperatures above freezing all samples should be stored in a temperature controlled storage unit. Water samples, sea, fresh and pore water, may be frozen and could be stored with acquired ice samples at sub freezing conditions preferable -20ºC. To preserve the structure of sediment and rock samples these samples should be stored at subglacial ambient temperatures just above freezing. A 20 ft insulated ISO container should provide enough space for both freeze and non freeze storage. Samples may be flown mid season to Mc Murdo. See further logistic and field season discussions below.

Kitchen Living Facility (Raytheon)

The kitchen and living facility has to provide space for up to 20 to 25 people. The kitchen facility will provide space to prepare food and for part of the crew to eat meals and spend some of their leisure time. Food storage will likely be in a separate temperature controlled storage unit. The food storage may be combined with the sample storage unit. Both units however even possibly contained within the same container unit require separate entrances to avoid contamination.

Containerized Kitchen

The US Army has purchased over 600 Weatherhaven containerized kitchens for field use.

- Easy to transport and set up in the field.
- Uses stainless-steel furnishings, making it robust and hygienic.
- Highly productive, with 280 sq. ft. (25.2 square metres) of food preparation space, 80 sq. ft. (7.2 square metres) of serving-line space, and a 30 sq. ft. (2.7 square metre) mechanical room.
- Kitchen staff can prepare three fresh, basic meals daily for at least 650 soldiers.
- Can be used as a stand-alone unit or linked to a dining hall.

Figure 18 Example of kitchen facility installed in an MECC shelter. (Source Weatherhaven)

For the traversing part of the project berthing for people participating in the traverse may be set-up across all containerized units. Sleeping otherwise may be in tents in a short distance to the drill site, which can easily be set-up and torn down at each drill site location. The sleeping camp set-up may be built from a combination of mountain, Scott and endurance tents.

Propane is likely the preferred fuel source for the kitchen stove.

For each participant of the expedition there needs to be some personnel storage space for personnel belongings. If possible this space should be in conjunction with a personnel berthing. However due to the nature of the expedition and round the clock operation it may be necessary to share berthing if space is an issue in order to accommodate all participants. Shared berthing during traversing could be supplemented with tent space during camp operation.

Skidoo Trailer (Raytheon)

Skidoos and other equipment may be transported on regular transport sled. Some equipment may also find space on the roof top of containerized structures or the drill platform.

Electrical Power and Heat Unit (Raytheon, NIU& IDDO - requirements)

General Consideration

Electrical power is needed to operate a variety of equipment. The main power consumers are ROV-operation, the hot water drill system and the field laboratory.

Each container needs to be equipped with a light and heating system. Power back-up systems are needed for units with electrical power sensitive equipment, like ROV and Drill operation. Power back-up systems should be designed to allow regular operation during traversing (non-drilling and non ROV operation) where the general camp power-supply is not available. Power back-up is also needed in ROV and Drill operation to ensure continued data collection and archiving during drilling and ROV operation in case of power failure. Solar panels may be used as power back up systems as field work will only be conducted during the Austral summer when solar energy is available 24 hrs a day. Utilizing solar energy, while initially more expensive, could potentially provide substantial savings of operation costs due to fuel savings in the field. For example substituting a 20 kW generator with solar energy would make a saving of $18,360 during a 90 day field season with 24 hr operation, fuel consumption of 1.7 gallons per hour and fuel costs of $5+ per gallon of fuel.

To reduce the overall fuel consumption of the traverse it may be possible to use waste heat produced during the electrical power generation for heating purposes. Electric power generation in general has a fuel efficiency of ~30 %. In addition approximately 50 to 60% of the fuel energy can be gained through heat exchanger and would be available for heating either buildings or preheat drilling water. This could increase the overall fuel efficiency up to 90%. This however would require the installation of radiators in each of the containers.

Bruci Koci previously suggested the use of diesel burning microturbines (http://www.microturbine.com/prodsol/products/index.asp) instead of diesel generators. Microturbines propose to be more fuel efficient (up to 82% when including heat recovery) and to require less maintenance. (Link for liquid fuel 65KW micro turbine http://www.microturbine.com/_docs/C65%20&%20C65-ICHP%20Liquid%20Fuels.pdf)

Specific Power Requirements:

The project requires a central power supply unit for drilling and science operation. The anticipated power requirements are in the order of 100 to 150 KW. For general electrical appliances 110 V and 220 V single phase power is needed. ROV operation and likely hot water drill operation will require 110 V, 240 V and 480 V three phase. Integration of solar power into the traverse design may in part substitute fuel power back up systems. Fuel-powered back up systems are otherwise required for each traverse unit which will be operated during traversing.

Individual power requirements for drill site camp operation:

Voltage:

ROV – 110V, 240 480V

Camp – 110V, 220V

Field laboratory, 110V, 240V or 480V (laminar fume hood)

Drill System likely 110V, 240-480V

Wattage:

ROV operation ~60 KW

Drill system	not yet determined - likely same order)
General camp requirements for computer, light fixtures etc.	~20KW
Temperature controlled storage	not yet determined

Back up generators* are requested for

- Field laboratory
- ROV and Drill command center
- Temperature controlled storage
- Mechanical workshop
- ROV workshop
- Kitchen

* may be substituted in part with permanently installed Solar Panels

Communication

It is anticipated that a wireless network will be set-up to be available for science during camp operation.

Outside communication with Mc Murdo and connection to the WWW may be provided during the regular NSF-OPP logistics. Details need to be worked out.

Possibilities include and Iridium satellite telephone and long wave radios

Local communication between camp and science team operating outside of camp occurs through regular VHF-radios.

Navigation

GPS supported navigation.

Crevasse detection radar

Weight estimate for facility structures

Table 4 Weight estimates for facility structures

Item	**Weight estimate [lbs]**	
General weights	**lower**	**Upper**
20 ft ISO Standard Container	5,000	10,000
http://www.seabox.net/web/catalog/sb1/sb8620/SB8620%20TYPE%202.pdf		
MECC Container Steel - empty	8,500	
MECC Container Alluminum - empty	5,500	
http://www.weatherhaven.com/military/products/expandable_container_shelters.asp		
Lehmann Sleds for 20 ft containers	7,000	8,000
http://www.lehmann-maschinenbau.de/web/index.php?id=34		
Total Estimate	**342,000**	**443,000**

Items		
Field Laboratory (MECC container with laboratory equipment)	8,000	12,000
Drill Command Center (20 ft ISO Container – IDDO)	7,000	10,000
ROV Command Center (20 ft ISO Container – NIU)	7,000	10,000
ROV Launch and Recovery System (20 ft ISO flat rack - MECC type wings forming platform – NIU),	30,000	40,000
Science Equipment Predeployment Workshop (MECC- empty)	10,000	12,000
ROV Storage and Maintenance Facility (electrical workshop for ROV) (20 ft ISO Container - NIU)	8,000	10,000
Science Storage, for example Oceanographic mooring, rock corer, sediment corer, ice corer (undetermined size -Raytheon) Empty 20 ft ISO container + shelving	6,000	8,000
Drill Platform with Hose Spool, Hydraulic Power Unit and Injector System and a lifting capabilities (crane) (suggestion 40 ft long 24 ft wide - NIU design may be part of the HWD system or part of the logistic component, IDDO) 40 ft Flat rack ~11,000 lbs http://www.seabox.net/web/catalog/sb4/SB4754/SB4754.pdf Winch, HPU, linear motion drive ~30,000 lbs Individual components may be transported on separate sled.	50,000	60,000
Hot Water System - Heater Pump Unit I -80 l/min (20 ft MECC ISO Container- IDDO+ Caltech weight estimate)	15,000	20,000
Hot Water System - Heater Pump Unit II 160 l/min (20 ft MECC ISO Container- IDDO)	15,000	20,000
Melt tank (undetermined size, likely plastic tubs and foldable water storage - IDDO)	1,000	5,000
General Mechanical Workshop (ROV/Drill/Camp) (20 ft MECC ISO Container) + workshop equipment	20,000	30,000
Electrical Power and Heat Unit (3 x 65 KW - Raytheon) 65 KW Microturbine 2,000 to 3,000 lbs each MECC container or regular container – 8,500 lbs	16,000	20,000
Temperature Controlled Sample Storage (undetermined size - Raytheon), based on 20 ft ISO refrigerating container + shelving http://www.seabox.net/web/catalog/sb2/SB5350/SB5350.pdf	6,000	8,000
General Storage Unit – Food (undetermined size - Raytheon)	6,000	8,000
Kitchen Living Facility (undetermined: suggestion: 20 ft MECC ISO Container - Raytheon)	12,000	20,000

15 sleds for containerized units	105,000	120,000
Skidoo Trailers and additional transport sleds	20,000	30,000
(2 -3 Lehman type sleds - Raytheon)		
Fuel sleds with fuel (undetermined size – Raytheon	???	???

Fuel

Fuel (Diesel, Gasoline) is needed as for the operation of the traverse vehicles, for electrical power production and to melt snow and heat water for the hot water drilling. Propan will be used for cooking purposes. Fuel consumption for electrical power production may be reduced if solar panels will be incorporated into the design of the individual traverse units. Solar panels could for example substitute fuel powered back-up generators, which otherwise would need to produce electricity for the general usage during traversing.

The exact amount of fuel required will be in the order of several thousand gallons and is dependent on the specs of the new hot water drilling system, the traverse vehicles and the overall traverse system. Rough estimates developed for the REST proposal are given in Table 6. Table 5 provides a rough estimate for the WISSARD site survey group.

Table 5 Estimates for the site survey traverse in year one and two are (from WISSARD ORW doc):

	Barrels
Shot hole drilling	
JP8 - 2 gallons per shot hole ~100 holes	4
Mogas – 1 gallon per shot hole	2
Mogas for Skidoos	
based on 7 km/gallon and	
2000 km per season for 4 skidoos	
1000 km preseason for 2 skidoos	32

Table 6 Rough estimates of fuel consumption for science traverse and drilling based on calculations made for the REST project in 2006 are:

In gallons	Yr 1	Yr 2	Yr 3
Diesel for traversing			
based on 5 Pistenbully 300 at 5.8 gallons/hr and a speed of 11.2 km/hr	829	2460	3884
Diesel for Drilling			
two 200m deep 0.7m and 0.3m diameter boreholes yr 1,			
three 0.7 diameter and five 0.3m diameter 300m deep boreholes yr 2			
four 0.7m diameter and 6 0.3m diameter 500m deep boreholes yr 3	1373	2769	8547
Generator usage 100 KW max			
Based on 60 day continuous operation at 60 KW and a 1.7	3672	7344	7344

gallon/hr fuel consumption for one 20 KW generator			
Mogas for Skidoos			
based on 7.5 miles/gallon and round trip 1600 km	275	275	558
Mogas for Drilling			
see diesel consumption	380	767	2367

Implementation

There are several groups involved in the implementation of this fast drill traverse system. Vogel et al. (NIU) has developed concept for traversable scientific fast access drilling facility. NIU is developing a number of new science instrumentation for the exploration of subglacial environments in West Antarctica. Some of the work is done at NIU in the facilities of the Analytical Center for Climate and Environmental Change. Most of the sub ice instrumentation will be developed by S.Vogel in collaboration with DOER-marine at their facilities in Alameda, Ca. It is anticipated that IDDO will be tasked to develop the proposed smart hot water based fast access drill system und will at least partly be responsible for the integration of the drilling system with the traverse system. IDDO has the appropriate technical expertise and facilities (machine shop, workspace) needed for the fabrication and assembly of the proposed drill system as well as the integration of science instrumentation and drill system components into a coherent traversing system. It is also anticipated that NSF-OPP will task Raytheon Polar Services with the purchase of traversing equipment, which includes heavy tracked traversing vehicles (e.g. Pistenbully, tracked Caterpillar tractors), general and specialized transport sleds and transport containers as well as basic living facilities like kitchen, electrical power unit.

It is desired that prior to deployment to Antarctica the entire traversing system is assembled and tested. A central location for the pre-deployment assembly and testing would be the facilities at IDDO at the University of Wisconsin Madison, WI. IDDO is especially suited for this task as it not only provides the space and facilities for such a pre-deployment test, but also is located centrally within the US.

Drill system

Joint ROV-Drill-Traverse System workshop (joint NIU, IDDO, Raytheon venture)

ROV-Drill command center (NIU - IDDO)

Drill Platform with hose spool, hydraulic power unit and injector system (IDDO with Science input, current design S Vogel)

Heater Pump Unit (IDDO – based on Project specific and FASTDRILL specifications)

Melt tank (IDDO)

Traverse system

ROV-Storage and Maintenance Unit (NIU)

ROV-Launch and Recovery System Unit (NIU)

Geochemical, Microbiological and Sedimentological Field Laboratory (???)

Temperature Controlled Sample Storage Unit (Raytheon)

General Storage Unit(s) (Raytheon)

Electrical Power and Heat Unit (IDDO/Raytheon, to simplify its integration this unit could possibly be fabricated at IDDO)

Kitchen and Living Quarter Facilities (Raytheon based on traversing needs)

Skidoo Trailers and General Transport Platform Sleds (Raytheon)

Operational Requirements

Personnel

All participants share equal responsibility to contribute to the success of the expedition by helping as good as possible with camp management and camp scores.

Fast Access Investigation

Total number of personnel may vary dependent on specific scientific objectives and related tasks:

20 to 30 for drill operation with ROV deployment

15 to 25 for drill operation without ROV deployment

Table 7

			Shift 1				Shift 2				Shift 3			
Time line	Task	# personnel needed	Job #1-I	Job #2-I	…	Job #X-I	Job #1-II	Job #2-II	…	Job #X-II	Job #1-III	Job #2-III	…	Job #X-III
0:00	XXX	5												
1:00	YYY	8												

Individual tasks and job description

Camp manager

Traverse safety person who may possibly be at the same time cook

2 mechanics

Chief scientist and/or technical director (responsible for technical operation)

12 – 15 people ROV personnel with 3 to 6 people shared with drill and science operation

6 to 9 people drill personnel with 3 to 6 people shared with ROV and science operation

3 to 6 people science personnel and technology specialists

4 to 12 dedicated lab personnel for time critical geochemical/ biological work

1 to 3 education and outreach people.

ROV Operation

All ROV personnel will also be involved in Drill and Science operation as well as camp and traverse activities. Model 2 is preferred.

Model 1

8-10 people for 24 hour operation with two shifts of each 12 hours,

2 Pilots , 2 Co-Pilots, 2 Navigator (optional), 4 Science Personnel.

People will rotate and work on all positions. People will only be limited available for other tasks like sample handling and processing, drilling, camp management during on and off time dependent on the priority of operation. 1 to 2 people could help at other tasks like drilling and science experiments during operation.

Model 2

12-15 people for 24 hour operation with three shifts of each 8 hours,

3 Pilots, 3 Co-Pilots, 3 Navigator (optional), 6 Science Personnel.

People will rotate and work on all positions. People will be available for other tasks like sample handling and processing, drilling, camp management during off time for 2-4 hours. 1 to 2 people could help at other tasks like drilling and science experiments during operation.

Model 3

8-10 people for 24 hour operation with one main shift (5 people) for 12 to 14 hours and a maintenance shift to keep ROV operational and intervene in case of emergency (2 to 3 people) 10 to 12 hours,

3 Pilots, 3 Co-Pilots, 3 Navigator (optional), 6 Science Personnel.

People will rotate and work on all positions. People will only be limited available for other tasks like sample handling and processing, drilling, camp management during off time. People would not be available for other tasks like drilling and science experiments during operation.

Drill Operation

6 to 9 people drill crew with 24 hour operation and 8 hour shifts (2 or 3 person shifts). At any time during operation 1 people on drill watch and at least 2 people stand by for immediate help and two additional for extended operation. Possible overlap with ROV crew.

Chief driller – overseeing drill operation,

Lead driller – lead drill shift,

Drill hands – support lead driller, can be scientists or other people, which will be trained in the field (see Caltech operation).

Science Operation

Individual tasks for science operation are:

- surface and borehole geophysical measurements, including GPS and other surveying work.
- deployment of instrumentation and sampling, including preparing of instrumentation and sampling equipment for deployment
- general data acquisition and storage
- clean sampling and sample processing with time critical analytical work.
- other project related activities

General task:

Most of the general tasks like preparing equipment for deployment, acquire specific data and conduct borehole experiments will be done by the drill team with support of one or two additional people under the supervision of the specific PI or a representative. An advantage of operating on a 3 shift/8 hr shift model is that people which rotate of their shift will be available for part of the following shift for additional tasks if additional labor is needed. Therefore no significant additional personnel resources need to be considered. For planning purposes one may increase the number of deployments by 3 people which will be available for general science tasks (included in numbers above). Science personnel will be integrated into Drill operation and ROV operation.

Specific tasks:

Specific tasks like setting up a GPS network, may be performed by general field personnel as part of regular operation. However a detailed operation and science implementation plan is needed to evaluate whether time and personnel resources will allow such work. If down time and time for regular drilling tasks will not permit such work than additional members may be deployed on a temporary assignment. This may either be done through the general field deployment logistics of the fast access drill operation or as a small independent operating field team unconnected to the fast access traverse facility (see surface geophysics below).

Geochemical and biological sample handling and analytical work:

Aside from ROV-operations the most time consuming tasks will likely be clean sampling and sample processing for on-ice and off-ice analytical work. Time critical analytical work that preferably is conducted on-ice directly at the drill site requires a well trained and coordinated team of 3 to 4 people per shift (12 to 16 total – 8 hr shift) to process sample and conduct time critical analytical work within one to two days following the acquisition of samples. The team would consist of a chemist and assistant chemist, a biologist and assistant biologist.

For the time critical analyzes it is very important to have good lab facilities onsite in the field, which provide a temperature controlled clean environment for sample processing and analytical work. The recovery of samples from depth initiates changes in chemistry. Best illustrated is this on hand of temperature and pressure field. Changes in pressure and temperature, changes gas content in water as well as directly influence pH. Changes in pH on the other hand initiates a variety of chemical. The closer we conduct analytical measurements to the sample recovery the better will measurements represent the insitu conditions beneath the ice sheet.

Geophysical Site Survey Activities

6 people site survey crew operating out of an independent remote field camp

GPS network set-up

2-4 people GPS network set-up crew operating out of an independent remote field camp, possibly combined with geophysical site survey activities. This work may be combined with geophysics survey. In this case only one or two additional people would join the geophysics party.

Total Number of deployments.

The total number of deployments will likely range between 40 and 60 (includes surface geophysics and drill operation) as a mid season change over will be requested for a number of science and technical personnel. Dependent on the timing of operation people from the GPS-network set-up group will be able to join the Fast Access Investigation Group.

Traversing and Field Operations

The current design of the field activities is deployment of the drilling and major science equipment by over ice traversing. For this a limited number of people are necessary to drive vehicles and operate equipment during the traverse.

Individual jobs are:

Drivers,

Mechanics,

Crevasse radar operation,

Camp and traverse management,

Limited science operation.

The majority of science personnel as well as small/light weight, sensitive science equipment will be flown in by Twin Otter or Basler for the start of drilling operations at the first drill site.

Dependent on operation radius, a central camp may be set-up and utilized as sleeping and living facility. In this case the drill and science moves from one drill site to the other within the vicinity of the central camp. The time and logistical resources need to commute daily from and to the drill site needs to be weight against those needed to relocate the sleeping and living facilities with the drill site.

If larger distances are traveled between individual drill sites camp facilities should be well integrated within the traversing system allowing high mobility and fast set-up and break down of camp. In any case a tent is requested for each participant. Set-up and break down of tents should be possible within a few hours, if kitchen and living quarters are sled mounted and therefore shouldn't impact overall mobility of the traverse facility. However some dedicated space/ storage space for personnel belonging should be included in the space allocation plan. This may include space within different science components of the facility. Dependent on the tasks of individual people they may utilize dedicated space in the ROV operation center or workshop areas.

Most of the scientist will leave the field by airplane. Midseason change over for a number of scientists and engineers will be requested.

Specific air support is necessary to transfer samples from the deep field to storage facilities and the lab facilities for additional analytical work not able to be performed in the field. This include samples, which require to be kept frozen (ice cores, sediment samples) and samples which should not be frozen, but kept cool (water and sediment).

Resupply of fuel and equipment at beginning and end of season, could either be done by traversing back to McMurdo or by air drop.

Traversing would allow to conduct additional science on the way, drop off and pick up of science parties or servicing and collection data from long-term observatories.

Calculations

Fuel consumptions

Heating system at full operation: 20 to 30 gallons per hour

High pressure water pump system: hydraulic/electrical/fuel motor driven – not yet determined

Smart hose winch system: hydraulic/electric – not yet determined

ROV winch system: hydraulic/electric – not yet determined

Linear motion drive: hydraulic/electric – not yet determined

Electrical power production: heat recovery – not yet determined

Skidoo: 7 km (miles?) per gallon of fuel

Electrical

Hydraulic pressure loss

Drilling speed, Drilling control program

Abbreviations

NSF-OPP – National Science Foundation –Office of Polar Programs
USAP – United States Antarctic Program

Appendices

Appendix 3: Concordia Traverse Report
Appendix Information to Solicit Quotes for Environmental Field Laboratory

References

Swift, J., E. Link, et al. (2005). Report of the Subcommittee on U.S. Antarctic Resupply, National Science Foundation - Office of Polar Programs Advisory Committee: 80.

Thermoplastic Composite Coiled Tubing

White Paper

1 Introduction

The variety of operations for which Coiled Tubing is being considered now is greater than ever before. Where Coiled Tubing traditionally featured mainly in well intervention & well servicing type of operations, now Coiled Tubing is now seriously being considered for many well side-track drilling programmes.

For most well intervention operations the coil is used as a means to apply circulation (stimulation, well cleaning), drive a down-hole motor (downhole milling) or enter highly deviated wells. For these operations accurate depth reading (e.g. through casing collar location) is important and knowledge on downhole pressures and temperatures greatly improve success rate.

For coiled tubing drilling operations, research and development efforts are aimed at increasing rate of penetration, reducing total drilling time and cost. The combination of having electrical power downhole with high communication rates is essential in improving Rate of Penetration. Current solutions whereby a multi-conductor wireline or E-line is used in conjunction with steel Coiled Tubing address some of these issues but leave others unresolved.

This white paper addresses some of the remaining challenges faced in Coiled Tubing drilling and proposes an alternative in a Composite Coiled Tubing. It endeavours to outline the benefits but also to discuss the operational limitations and requirements. It will review some of the advances made in composite coiled tubing design in comparison to earlier attempts made in the industry.

2 Challenges in Coiled Tubing Drilling

With rig-rates increasing and reservoirs getting smaller, increasing rate of penetration, reducing total drilling time as well as increasing accuracy are essential in bringing total drilling cost down whilst maximizing recovery. These two aspects are influenced by the following parameters:

1. Knowledge of downhole pressures and temperature. Knowledge of downhole conditions would allow for real-time adjustments to be made in the drilling operation.
2. Force (including torque) and vibration. Vibration of the BHA has a major influence on rate of penetration.
3. Borehole stability influenced by fractures and permeable sands.
4. Circulation rate. Circulation and well cleaning capability determine the number of wiper trips to be made.
5. Cementing. Cementing and necessity of removing E-line or multi-conductor wireline increase total drilling time.

Besides the challenges in drilling time and accuracy, in offshore operations the development where offshore cranes are constantly downgraded in lifting capacity constantly reduce or limit the operational envelope and make operational planning more complex. Airborne has been engaged in "offshore spooling" projects on a consulting basis, advising on reeling operations of a coil from a reel on supply vessels onto a reel on offshore platforms.

Figure 1: Composite Coiled Tubing

3 Solutions

Airborne Composite Tubulars proposes to apply thermoplastic Composite Coiled Tubing (CCT) with integrated electrical conductors and optical fibres as opposed to a combination of Steel coiled tubing and E-line or multi-conductor wireline. See also Figure 1 and Figure 2. This alternative to steel CT presents the following unique advantages:

1. Integration of power conductors and optical fibres. Power conductors can be integrated into the coil, providing up to 3 times the amount of power compared to wireline cable. Also, a number of optical fibres can be integrated, providing unprecedented data communication capability, the ability to monitor temperature across the complete well trajectory and strain monitoring capability.
2. The data communication capability provides the possibility for continuous acquisition of petrophysical and drilling dynamics data during drilling operations, resulting in logging passes for each bit trip.
3. In addition to the petrophysical data, borehole stability data can be assessed through combining downhole data with surface weight information. This can help identify, prevent, and cure fractures and permeable sands that are responsible for poor borehole stability.
4. The real-time information availability of the drilling, pressures, temperatures, forces and vibrations conditions downhole allows for a step change in real-time tool-face change leading to higher rates of penetration.
5. The tool-face control can be automated, resulting in automated drilling, predictability, controllability and ultimately elimination of waste.
6. The absence of a cable inside the coil simplifies operating the coil:
    a. No slack wire management required.
    b. No risk of bird nesting.
    c. No reversed pumping required for moving the slack up the coil.
7. The absence of a cable makes it possible to proceed with cementing operations without first having to remove the cable or change coil.
8. The absence of a cable inside in conjunction with the lower friction of the composite increases the circulation rate, reducing the required number of wiper trips. Also the pressure requirements at surface are lower as the pressure losses are reduced.

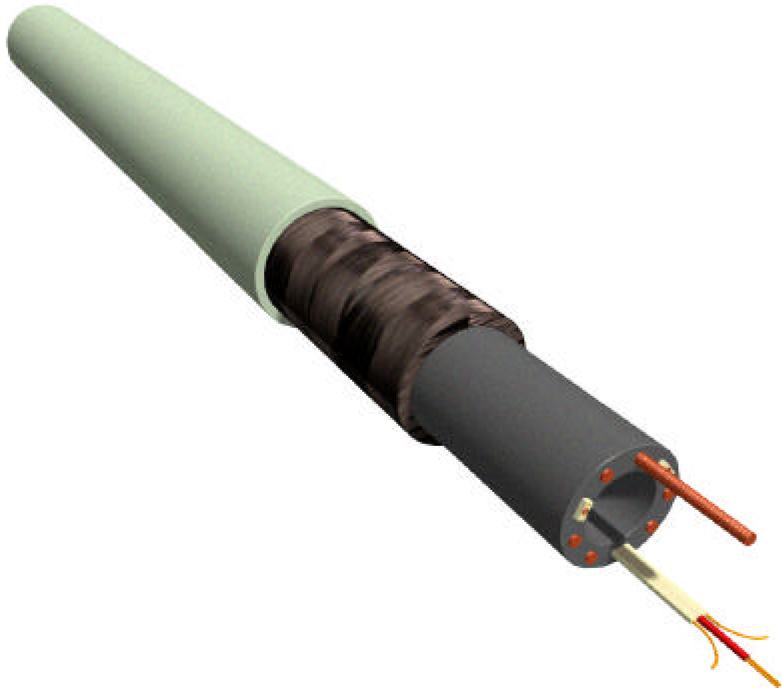


Figure 2: Composite Coiled Tubing with integrated power conductors and optical fibres

The unique mechanical properties of Composites in the Coiled Tubing application offer a number of other opportunities:

1. Weight. The weight to strength ratio of Composite is much better than steel:
    a. For a Composite Coiled Tubing typically the coil plus reel is half the weight of the steel coil plus reel. The reel can be designed to be lighter and cheaper due to the lower loading of the coil. This offers opportunities especially offshore where offshore cranes are downgraded.
    b. The much lower weight of the coil in mud (up to 80 % lower then steel) in combination with lower friction coefficients, strongly reduce the surface weight when pulling out of hole. Simulations have shown typically weight reductions of more then 50%. This now only allows for smaller injector head systems to be used, also makes the CCT interesting for extended reach drilling.
2. Fatigue. Composite Coil Tubing has excellent fatigue life, depending on the material applied. This results in longer coil life compared to steel. Current designs apply 10.000 cycles.
3. Superior chemical resistance. Materials such as PEEK show total chemical resistance, making them suitable for harsh environments such as H_2S, CO_2 etc.
4. Impervious to corrosion. One specific element in chemical resistance is that composites are impervious to corrosion.
5. Tapered tubing. The thermoplastic composite materials applied by Airborne allow for special tubing designs to be developed such as tapered tubing or tubing with different strength and stiffness characteristics along the tubing.
6. Controllable electrical properties. The CCT can be made completely magnetically and electrically insulating if required.

4 Operational considerations

Bottom Hole Assembly and surface equipment configuration

Using composite coiled tubing does affect the operation. It allows for new possibilities but also puts additional requirements to the operation. The most important consideration is that the coil is more flexible than steel. This results in a longer life for the coil, however it also results in earlier lock-up in highly deviated wells when a compressive force is applied to the CCT downhole. Airborne has performed extensive simulations with Coiled Tubing simulation software available in the industry (Figure 3) which showed the following results:

1. In Coiled Tubing Drilling operations with a certain weight on bit, the CCT locks-up earlier than steel CT as steel is stiffer. This means that use of a downhole tractor requires consideration.
2. Due to the fact that the CCT does not include a wire inside, there is much less pressure drop along the tubing, resulting in lower pressure levels at surface (at a certain downhole pressure).
3. The CCT has lower friction levels and much lower weight in mud than steel, resulting in lower Pull Out Of Hole forces and lower loading on the coil.

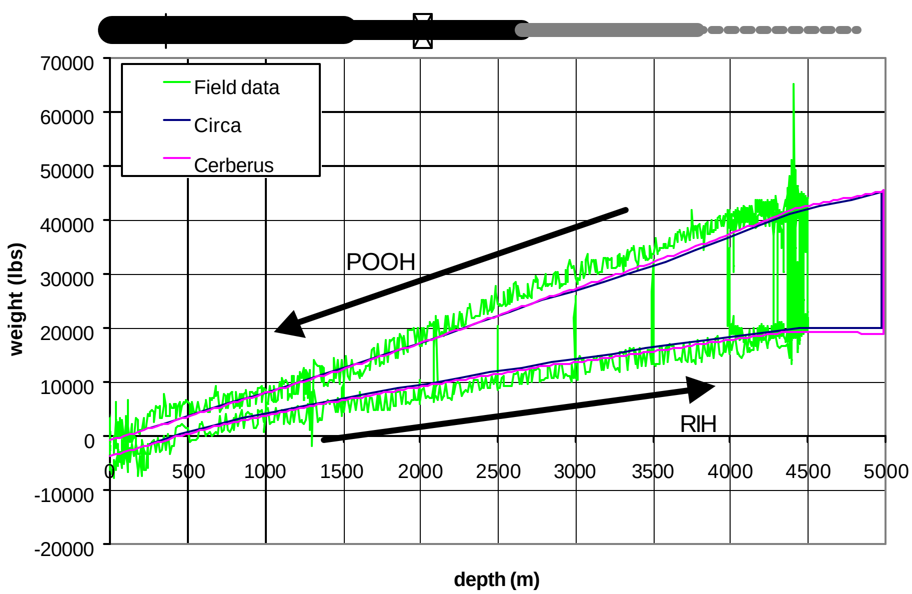


Figure 3: Example of weight gauge comparison plot

Job preparation and simulation considerations

In contrast to steel, the mechanical tubing strength characteristics are determined by the matrix, the fibre choice and angles in the composite lay-up, and can be designed fit-for-purpose. This results in different characteristics per coil that allow the user to tailor the coil to a certain application. This has consequences for job preparation and simulations made using conventional software simulation packages. Some examples:

1. Composites do not show yield stress levels as steel does. The failure criteria depend on the load situation and can be fibre or matrix dominated.
2. The modulus of elasticity differs from bngitudinal to circumferential direction. The torsion stiffness again is different.
3. The spoolability is determined by fibre lay-up and fibre itself. Application of glass results in higher spoolability, higher electrical insulation but lower strength and stiffness.
4. The friction coefficient of the CCT is lower than steel, both in cased hole and open hole.

5 Feasibility

Technology

The industry has seen developments in the area of Composite Coiled Tubing in the past 10 years. These developments were based on a thermoset matrix system rather than a thermoplastic system as proposed by Airborne.

Airborne has selected the thermoplastic matrix system as opposed to thermoset for a number of reasons which alleviate or resolve earlier drawbacks identified in earlier composite coiled tubing developments:

1. Higher allowable strain. Current fatigue testing shows strain levels possibly up to 1.5 - 2%, reducing reel diameter to acceptable sizes whilst maintaining stiffness, strength and fatigue properties. Thermoset does not show this level of allowable strain. See also Figure 4 and Figure 5.
2. Greater toughness and superior impact resistance. Thermoplastic material is more ductile than thermoset, thereby showing much higher impact tolerance. A second aspect related to the toughness and ductility is the superior residual strength characteristics of thermoplastic materials compared to thermoset. This is deemed essential especially in downhole applications where contingency is a must.
3. Superior Rapid Gas Decompression characteristics, due to the “one material concept” which results in optimal bonding between layers (liner – fibre reinforcement and coating).
4. Welded connections. The thermoplastic material allows for welded connections to be made. See Figure 6.

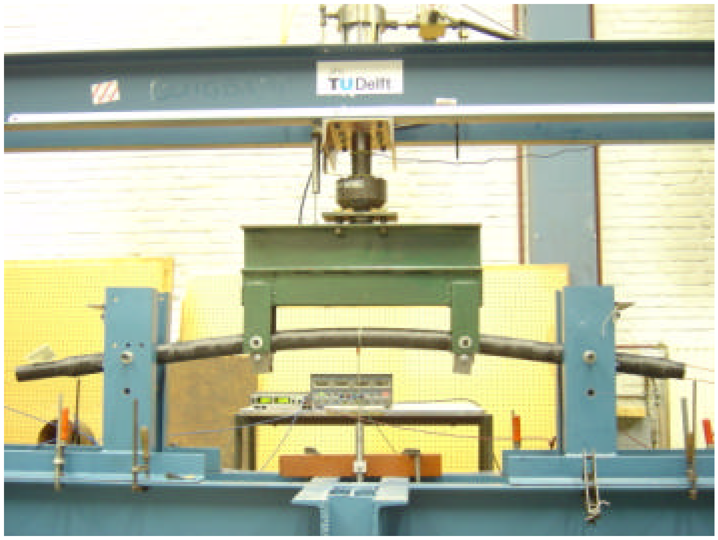


Figure 4: Four-point Bending testing

Figure 5: Airborne's in-house pressure test facility

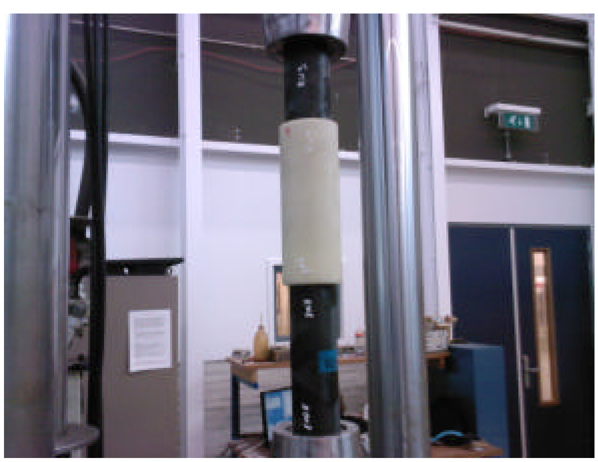


Figure 6: Welded connection

Production

The production technology required for manufacturing thermoplastic tubulars has been developed in-house by Airborne. A production test-bed has been constructed and used to qualify the production techniques. The first production line has been designed in concept, the detailed design phase has commenced. An artist impression is shown in Figure 7 below.

Figure 7: Thermoplastic composite tubulars production facility

Economical viability

Composite Coiled Tubing is significantly more costly than steel. Airborne is working towards proving the extended fatigue life of a coil in the projects we are currently engaged in. Still it is expected that, when evaluating and considering composites in coiled tubing for a specific application, the full operation needs to be considered:

1. Total service life.
2. Impact on drilling performance.
3. Impact on operational aspects such as equipment, space usage, offshore cranes etc.

6 More information

Airborne is committed to the successful introduction of thermoplastic composite coiled tubing in the Oil & Gas industry through material research, knowledge development on industry specific requirements and fit for purpose designs, yielding technically and economically viable solutions (see also appendix A). Other industry applications currently being developed are Pipe In Pipe (insulated subsea flowline), Flowline and various specialty projects on a confidential basis.

For more information contact Martin van Onna MSc., General Manager Airborne Composite Tubulars B.V.

M.vanOnna@airborne.nl

Appendix A: Background Airborne in Composite Tubulars

Airborne has been active in the field of composite structures since 1995 and has been working on continuous tubulars development since 2000. The following milestones describe the development of composite tubulars in Airborne:

1. Shell International Exploration & Production and Airborne started the development of the required technologies for composite coiled tubing in 1999.
2. In 2000 this project was extended into a joint European technology programme. This was spit into two phases:
    a. Research and development phase (2000 – 2002).
    b. Demonstrator phase (2003 – 2005).
3. The development programme resulted in the following technology capabilities:
    a. Thermoplastic continuous winding techniques.
    b. Integration of power conductors and optical fibres.
    c. Basic material selection.
    d. In-house analysis software for design optimisation, including linear, non-linear, stress, stiffness, fatigue, and creep analysis.
4. In 2006 Airborne continued with the in-house development of the production technology, resulting in a conceptual design for a production pilot line.
5. In 2007 the company Airborne Composite Tubulars was established:
    a. Three baseline products have been defined, Flowline, Composite Coiled Tubing and Pipe In Pipe.
    b. Several baseline development projects commenced in close co-operation with large operators such as Shell Houston. Other specialty application projects were started as well with clients on a confidential basis.
    c. A production test-bed was constructed and made operational, on which all production techniques are combined, tested and optimised.
    d. Testing facilities have been constructed such as pressure testing facilities.

Papers:

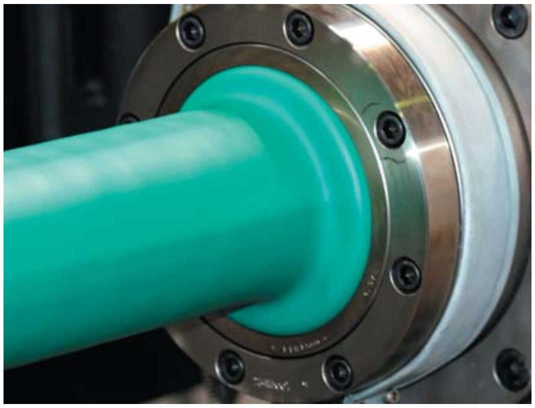
M.A.I. Kremers, W.S. Leenders, and A. van Mourik, “PDT-COIL, a Power & Data Transmission Composite Coiled Tubing”, Fourth International Conference on Composite Materials for Offshore Operations, Houston, TX, October 4-6, 2005.

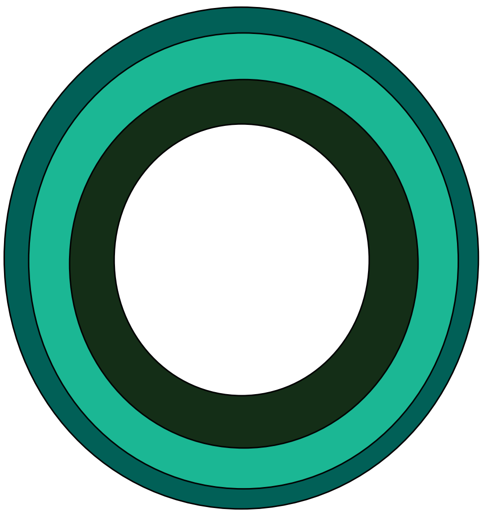
Daniele Inaudi and Branko Glisic, “Integration of Fiber Opti Sensing Systems into Composite Structures for Oil & Gas Production and Transport” Forth International Conference on Composite Materials for Offshore Operations, Houston, TX, October 4-6, 2005.

Appendix Fiberspar tubing

FIBERSPAR® Tech Notes

Product and service information from the leader in spoolable pipeline technology





HDPE or PEX Pressure Barrier

Glass Fiber Reinforced Epoxy Laminate

HDPE Extruded Outer Wear Layer

Introducing Fiberspar 750 Series LinePipe:

The world's leading spoolable pipeline technology is now available for ANSI 300 applications.

With more than 1.5 million meters in service, Fiberspar LinePipe is the world's most widely accepted spoolable, high-pressure pipeline technology. Nothing else comes close. Now, this proven technology is available in new Fiberspar 750 Series LinePipe for low-pressure, ANSI 300 applications.

The best technology at the lowest cost.

A rugged external HDPE wear layer protects Fiberspar 750 Series LinePipe in tough installation environments. Fiberspar 750 Series LinePipe eliminates corrosion, has far fewer joints, and is much faster and safer to install.

The unique performance advantages of LinePipe, Fiberspar's unsurpassed spoolable flowline expertise, and strategically located deployment centers combine to deliver LinePipe 750 at a lower cost than steel, stick fiberglass, or other composite products.

Fiberspar 750 Series LinePipe meets CSA and EUB regulations.

Fiberspar 750 Series LinePipe, like all other LinePipe, meets or exceeds CSA Z662-03 Specifications and is approved for routine permitting by the AEUB. Fiberspar 750 Series LinePipe is qualified for oil, water, gas, or multi-phase service and is available in temperature ratings up to 60°C or 82°C for gathering and injection applications.

750 Series LinePipe uses proven connectors and ANSI 300 flanges are standard on service-end fittings.

750 Series LinePipe fittings are the same easy-to-install LinePipe connectors that are field proven in thousands of high-pressure LinePipe installations. LinePipe connector strength actually exceeds pipe strength. Standard service-end fittings for 750 Series LinePipe are coated for corrosion protection and come with ANSI 300 flanges. Threaded, stainless, or other specialized fittings are available on request.

FIBERSPAR® LinePipe™

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Phone: 403 265 9900 • *Fax:* 403 266 7111 • *E-mail:* info@fiberspar.com

Fiberspar LinePipe LLC
12239 FM 529 • Houston TX 77041
Phone: 713 849 2609 • *Fax:* 713 849 9202 • *E-mail:* info@fiberspar.com

www.fiberspar.com

See specifications on reverse side

Specifications - Metric

Fiberspar LinePipe (FS LP) is intended for corrosive gathering and injection applications including general and sour produced fluids and gases. FS LP is available with high-density polyethylene or cross-linked polyethylene pressure barriers with temperature ratings to 140°F and 180°F respectively. **Other pressure ratings and diameters are available upon request.**

						HDPE (E)		PEX (X)	
Product Identity	ID (mm)	OD (mm)	Nominal Wt/m in Air (kg)	Minimum Operating Bend Radius (cm)	Recommended Maximum Operating Pressure** (MPa)	Nominal Ultimate Burst Pressure (MPa @ 60°C)	Recommended Maximum Tensile Load (kg @ RT)	Nominal Ultimate Burst Pressure (MPa @ 82°C)	Recommended Maximum Tensile Load (kg @ RT)
750 Series									
FS LP 2 1/2" 750(*)	52	65	1.51	99	5.17	24.8	1,570	23.4	1,570
FS LP 3" 750(*)	64	79	1.99	123	5.17	20.0	1,990	19.3	1,990
FS LP 3 ½" 750(*)	75	91	2.59	143	5.17	20.0	2,700	19.3	2,700
FS LP 4" 750(*)	88	106	3.36	167	5.17	19.3	3,610	18.6	3,610
FS LP 4 1/2" 750(*)	101	120	4.28	192	5.17	19.3	4,730	18.6	4,730

*Represents thermoplastic barrier material.

**Pressure ratings are based on minimum 20-year service life using ASTM D2992 long-term test procedures. Recommended maximum operating pressure is Fiberspar recommendation for general oilfield water, gas, low-vapor pressure hydrocarbon, and multiphase service conditions at the maximum rated temperature. Consult Fiberspar for a recommended maximum pressure rating for other service conditions.

E = High-density polyethylene (HDPE) rated from –34°C to 60°C (–29°F to 140°F)

X = Cross-linked polyethylene (PEX) rated from –34°C to 82°C (–29°F to 180°F)

All products are hydrotested to 1.5 times maximum recommended operating pressure. Material selection is based on the desired operating temperature and chemical compatibility of FS LP constituents with fluids.

Specifications - Imperial

						HDPE (E)		PEX (X)	
Product Identity	ID (in)	OD (in)	Nominal Wt/Ft in Air (lb)	Minimum Operating Bend Radius (in)	Recommended Maximum Operating Pressure** (psi)	Nominal Ultimate Burst Pressure (psi @ 140°F)	Recommended Maximum Tensile Load (lb @ RT)	Nominal Ultimate Burst Pressure (psi @ 180°F)	Recommended Maximum Tensile Load (lb @ RT)
750 Series									
FS LP 2 1/2" 750(*)	2.03	2.54	1.02	39	750	3,600	3,480	3,400	3,480
FS LP 3" 750(*)	2.54	3.09	1.33	48	750	2,900	4,400	2,800	4,400
FS LP 3 ½" 750(*)	2.97	3.58	1.74	56	750	2,900	5,960	2,800	5,960
FS LP 4" 750(*)	3.48	4.16	2.26	66	750	2,800	7,960	2,700	7,960
FS LP 4 1/2" 750(*)	3.99	4.73	2.87	76	750	2,800	10,440	2,700	10,440

*Represents thermoplastic barrier material.

**Pressure ratings are based on minimum 20-year service life using ASTM D2992 long-term test procedures. Recommended maximum operating pressure is Fiberspar recommendation for general oilfield water, gas, low-vapor pressure hydrocarbon, and multiphase service conditions at the maximum rated temperature. Consult Fiberspar for a recommended maximum pressure rating for other service conditions.

E = High-density polyethylene (HDPE) rated from –34°C to 60°C (–29°F to 140°F)

X = Cross-linked polyethylene (PEX) rated from –34°C to 82°C (–29°F to 180°F)

Fiberspar pipe is covered by one or more of the following Canadian patents: pat. 2,076,391; pat. 2,233,295; and pat. 2,282,358; and one or more of the following U.S. Patents: pat. 5,921,285; pat. 5,908,049; pat. 5,913,337; pat. 6,004,639; pat. 6,016,845; pat. 6,148,866; pat. 6,286,558; pat. 6,357,485; pat. 6,361,299; pat. RE 35,081; pat. 6,604,550; pat. 5,176,180; pat. 6,706,348; pat. 6,663,453; pat. 6,764,365.

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FIBERSPAR

FS LP 1 1/4" 2,500 (E)

1 1/4 Inch Nominal, 2,500 Series Fiberspar LinePipe w/HDPE Pressure Barrier

Product Data Sheet (Imperial Units)

ASTM 2996 Designation: RTRP-11HZ1-4112

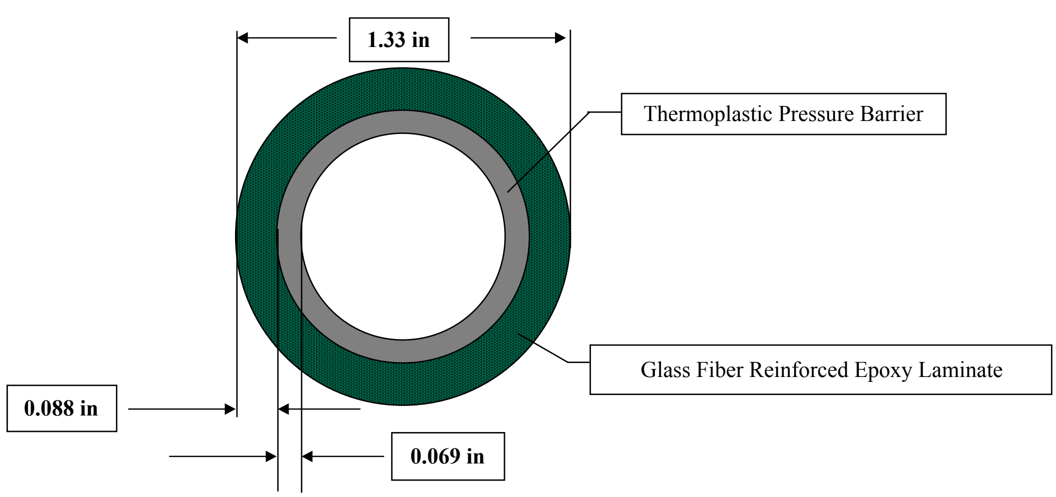
Fiberspar s/n: LEGN012524

Physical Properties:

Geometry		**Tensile Modulus**	
Outside Diameter (in)	1.33	Axial (psi)	9.75E+05
Inside Diameter (in)	1.02	Hoop (psi)	1.26E+06
Inside Flow Area (in^2)	0.81	**Poisson's Ratio**	
Total Wall Thickness (in)	0.16	Major	0.49
C/S Area (in^2)	0.58	Minor	0.63
Linear Weight		**Thermal Exp. Coeff.**	
Linear Weight - Air (lb/ft)	0.40	Axial (in/in -°F)	1.16E-05
Linear Weight - Water (lb/ft)	0.15	Hoop (in/in -°F)	6.69E-06
Net Density (lb/in^3)	0.057	**Thermal Conductivity**	
Flow Coefficients		(BTU/hour/ft^2- in/°F)	1.92
Hazen - William's	150	**Resin T_g**	
Darcy-Wiesbach	0.0004	(°C)	125°
Manning	0.009	(°F)	257°

Mechanical Performance:

Maximum Operating Temperature	**140 °F**		
Minimum Operating Temperature	**-29 °F**	**78 °F**	**140 °F**
Max. Recommended Operating Pressure (psi)		2,500	2,500
Nominal Ultimate Burst Pressure (psi)		9,700	6,900
Maximum Recommended Tensile Load (lbs)		2,120	1,800
Nominal Ultimate Tensile Load (lbs)		5,300	4,600
Nominal Ultimate Compressive Load (lbs)		-6,100	-5,000
Nominal Ultimate Collapse Pressure (psi)		2,200	2,200
Minimum Operating Bend Radius (in)		22	22
Minimum Spooling Diameter (in)		38	38



FS LP 1 1/4" 2,500 (X)

1 1/4 Inch Nominal, 2,500 Series Fiberspar LinePipe w/PEX Pressure Barrier

Product Data Sheet (Imperial Units)

ASTM 2996 Designation: RTRP-11HZ1-4112

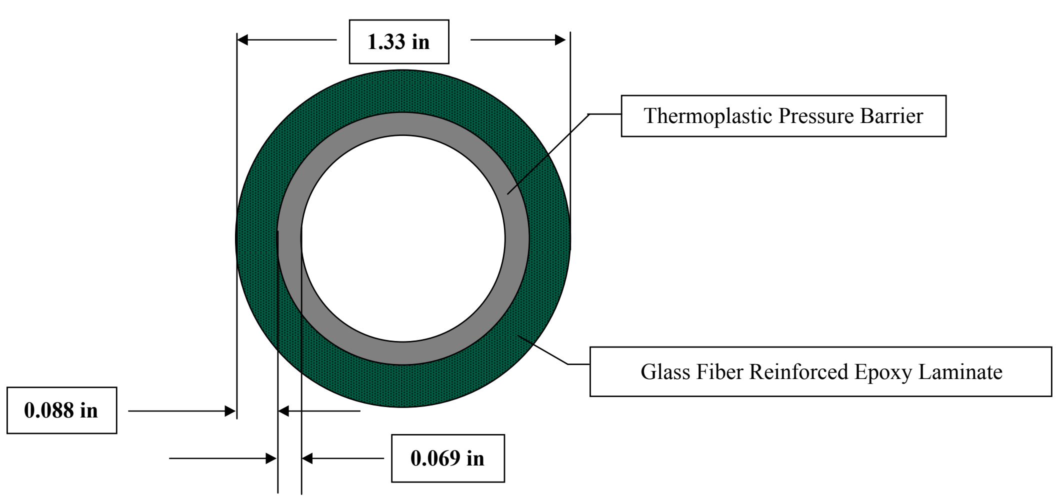
Fiberspar s/n: LXGN012524

Physical Properties:

Geometry		**Tensile Modulus**	
Outside Diameter (in)	1.33	Axial (psi)	1.10E+06
Inside Diameter (in)	1.02	Hoop (psi)	1.39E+06
Inside Flow Area (in^2)	0.81	**Poisson's Ratio**	
Total Wall Thickness (in)	0.16	Major	0.47
C/S Area (in^2)	0.58	Minor	0.59
Linear Weight		**Thermal Exp. Coeff.**	
Linear Weight - Air (lb/ft)	0.40	Axial (in/in -°F)	8.11E-06
Linear Weight - Water (lb/ft)	0.15	Hoop (in/in -°F)	5.00E-06
Net Density (lb/in^3)	0.058	**Thermal Conductivity**	
Flow Coefficients		(BTU/hour/ft^2- in/°F)	1.92
Hazen - William's	150	**Resin T_g**	
Darcy-Wiesbach	0.0004	(°C)	175°
Manning	0.009	(°F)	347°

Mechanical Performance:

Maximum Operating Temperature	**180 °F**		
Minimum Operating Temperature	**-29 °F**	**78 °F**	**180 °F**
Max. Recommended Operating Pressure (psi)		2,500	2,500
Nominal Ultimate Burst Pressure (psi)		9,700	6,700
Maximum Recommended Tensile Load (lbs)		2,120	1,800
Nominal Ultimate Tensile Load (lbs)		5,300	4,500
Nominal Ultimate Compressive Load (lbs)		-6,600	-5,000
Nominal Ultimate Collapse Pressure (psi)		2,200	2,200
Minimum Operating Bend Radius (in)		22	22
Minimum Spooling Diameter (in)		38	38



Product and service information from the leader in spoolable pipeline technology

Fiberspar LinePipe™ technical advantages over alternative composite products

Fiberspar LinePipe and Connector Design

Fiberspar LinePipe and connectors start with proven oilfield pipeline technologies and adds patented design advances. LinePipe technology is a unique combination of advantages unavailable from any other source.

Reinforcement/Strength Member - Fiberspar LinePipe uses glass fiber-reinforced epoxy resin to provide strength. This proven technology has been used for more than 30 years in GRE or stick fiberglass pipeline applications.

Pressure Barrier - Fiberspar LinePipe's internal pressure barrier is either HDPE 3408 (used extensively in the industry) or cross-linked, high-density polyethylene for higher temperature applications. LinePipe's pressure barrier is integrally bonded to the structural layer, and fluid compatibility with this material is well established. Fiberspar manufactures both HDPE and PEX LinePipe pressure barriers completely in-house.

Integral Structure - Fiberspar LinePipe's inner thermoplastic pressure barrier is permanently chemically bonded to the epoxy matrix and glass fiber reinforcing layers. An integrally bonded structure is essential to manage the effect of permeation and to ensure that that the liner does not collapse upon decompression even in the presence of highly permeable gases such as CO_2 and H_2S. Fiberspar LinePipe is qualified to ensure the inner barrier does not collapse or blister based on operating conditions and chemical compatibility in compliance with API17J.

Alternative Composite Spoolable Pipe

Other composite spoolable pipe designs now being introduced in the market use a variety of reinforcement and strength members including dry-glass fiber, aramid, carbon, or steel reinforcing. Some of these new products are fully un-bonded, or only partially bonded. Although these new products are all generically being called composite spoolable pipe, there are fundamental differences between the design, construction, and qualification required of these alternatives compared to LinePipe.

Reinforcement/Strength Member

- Dry-wound glass fiber (no matrix) is subject to time-dependent loss of strength due to environmental stress corrosion and abrasion damage from even minor changes in loads or temperatures. Bare glass fiber will become damaged over time with even minor cyclic changes in pressure, temperature, or axial loading. As a result of these damage mechanisms, dry-glass fiber is not considered suitable as reinforcement material in structural applications where the dry-glass fibers would be exposed to water through permeation, or where the glass fibers are in direct contact with one another and there is any cyclic loading.

- Aramid fiber reinforcement is subject to time-dependent loss of strength from hydrolysis, which can become significant in applications beyond 50°C.

- Steel reinforcement in a multi-layer composite structure would generally be suitable in applications where steel would ordinarily not experience significant loss of strength from corrosion.

Pressure Barriers

- Pressure barriers in alternative products include the same or similar grades and materials used by Fiberspar, as well as alternative materials. Establishing proper chemical compatibility as well as operating temperature limits for pressure barrier materials is essential in any spoolable composite pipe design.

Bonded/Un-bonded Structures

- Some alternative composite spoolable pipe designs have multi-layer, un-bonded structures, and in some cases structures that are partially bonded. Permeating fluids, including extremely small quantities of gas common in virtually all production or injection "liquid" applications, will eventually build up and accumulate at the interface between any un-bonded multi-layer structure. Managing pressure and volume

Continues on reverse side.

of fluids present between layers in multi-layer, unbonded structures is essential to prevent either external jacket rupture, or inner pressure barrier collapse.

LinePipe pressure & temperature ratings, qualification, and performance record

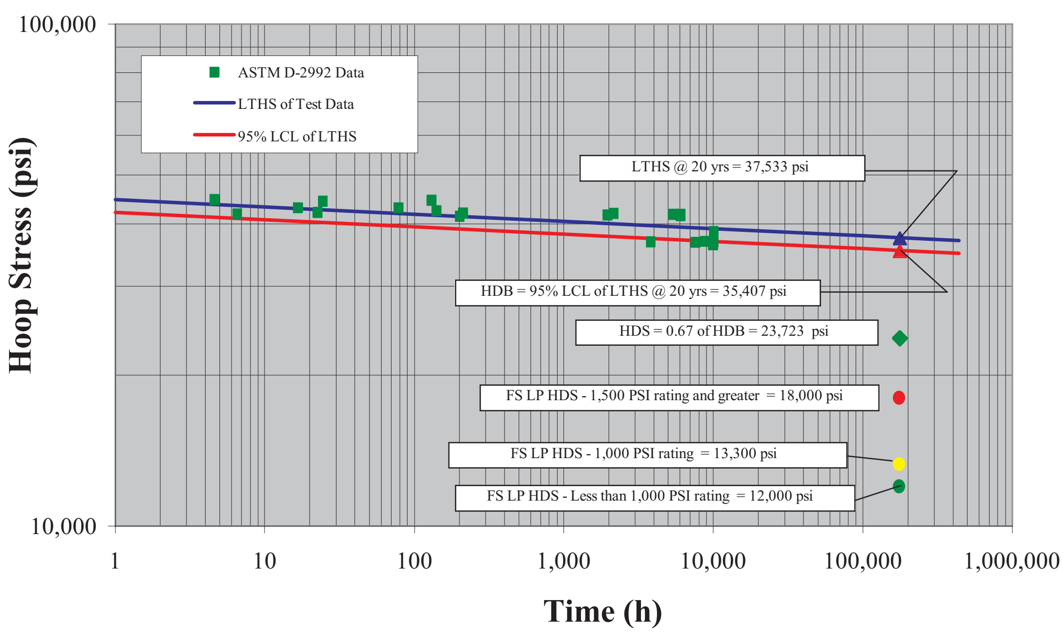
Pressure, Temperature, Design, and Safety Factors

- Fiberspar LinePipe qualification has been conducted in compliance with ASTM D2992, API 15HR, and CSA Z662-03 requirements. Fiberspar LinePipe pressure and temperature ratings are based on full qualification, and safety factors recommended by Fiberspar in all cases are more conservative than required by these industry specifications. Fiberspar qualification testing has been audited by CSA and Shell Global Solutions.
- In cooperation with the Alberta Energy and Utilities Board, an extensive experimental harvesting program was conducted that included harvesting more than 39 samples from working LinePipe installations that had been in service for a minimum of two years. One hundred percent of the samples met or exceeded the requirements of new pipe after testing.
- Fiberspar has an installed base of more than 4 million ft (1,200 km) of Fiberspar LinePipe in service for more than 100 operators. Customer references are available upon request.

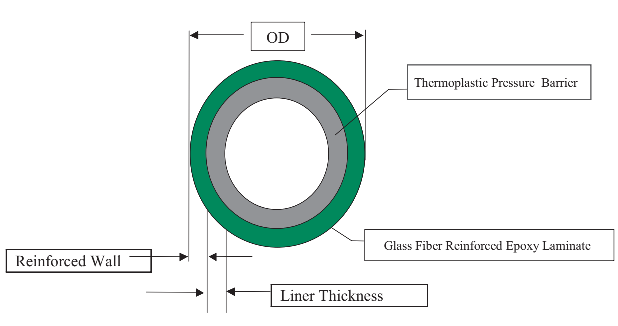
Fiberspar LinePipe Deployment

Fiberspar LinePipe can be installed with the support of Fiberspar employees using Fiberspar-designed installation equipment located throughout North America. In addition, Fiberspar LinePipe installation can be supported by more than thirty Fiberspar LinePipe Certified Installers.

Regression curve for FIBERSPAR LinePipe per ASTM D2992-96, Procedure B



LinePipe Product Geometry



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Anaconda drilling system nears commercial rollout

John Kennedy, Contributing Editor

IN LATE SUMMER, **Halliburton Energy Services** will move its field-tested Anaconda Advanced Well Construction System to the Gulf of Mexico to drill its first commercial well.

The Anaconda system is undergoing extensive testing at the Halliburton Research and Development Center in Duncan. The first full-scale test well was drilled with the system in Duncan, Okla; a second began in early May.

THE FIRST PHASE

Halliburton developed the first phase of the system with **Statoil** of Norway to exploit inaccessible reserves in Statoil's mature North Sea fields. First commercial use of the system will be offshore where the cost savings potential is high, but Halliburton plans to apply versions of the Anaconda system to a variety of drilling, completion, and well service operations.

Major components of the digitally controlled system are a high-tech surface control center, a carbon fiber coiled drill string with embedded conductors, and an advanced bottomhole system.

"Anaconda utilizes state-of-the-art information technology for system control, telemetry, and real-time communication which enables the oil companies to make rapid decisions in real time from either the drilling location or remotely," said **Jim Terry**, inventor and director of the Anaconda Project.

"This makes possible the efficient real time collaboration of multidisciplinary teams regardless of the proximity to the drilling operation such that reservoir assets are optimized through better decisions."

Mr Terry said this development project, which began in early 1998, was the most intensive in Halliburton's history. "It was also the most secretive," he added.

He will discuss the Anaconda system in a presentation at the IADC Annual Meeting 27-29 September in Houston.

In addition to providing a new approach to drilling, the Anaconda system will be a "platform for continued technical development." And it can be integrated with other Halliburton technologies.

Until the system has some commercial history, quantifying savings will be difficult. But Mr Terry says the system could reduce the cost/bbl to develop a field by as much as half.

At least in the beginning, Halliburton personnel will operate the system while it is on location.

THREE SYSTEMS PLANNED

Halliburton expects to develop three systems from the basic platform, each building on what is learned in the previous system. The first is a slim-hole system for which future applications will include well stimulation, testing, completion, and logging/perforating.

Continuous coil of carbon fiber laminate drill string is a feature of Halliburton's new Anaconda well construction system.

System 3, on which development will begin soon, will be capable of constructing larger well diameters and reaching measured depths of up to 50,000 ft.

System 3 will be able to minimize the number of offshore structures and associated capital expenditures, drill exploration wells in deepwater environments, and be used for subsea development wells and minimum-diameter, high-rate production wells.

In addition to the advantages of the composite drill string, the ability of this system to transmit data at high speeds and integrate other data with drilling information is one of its leading advantages, according to Halliburton. "Ultimately," said Mr Terry, "real-time seismic-while-drilling will be possible."

THE INCENTIVE

"Anaconda's breakthrough technology will enable our customers to increase recoverable reserves while reducing the cost," said **Dave Lesar**, **Halliburton Company** president.

He added that Halliburton embarked on this development project to overcome limitations of existing systems, to improve data gathering and analysis, and to lower costs.

Today's well construction techniques are constrained because the use of steel limits the well path to around 5 miles, said Mr Terry. Steel drill strings restrict both the path of today's wells and their departure from the surface location.

The ability to reach farther from a platform location with a well may mean that one or more platforms can be eliminated. In some cases, this might save as much as $1 billion in field development costs, said Mr Terry. Being able to build a longer horizontal well path with smaller and lighter equipment will require fewer structures. And reducing the force needed to direct the hole improves steering and well control.

System 1 marks the first use of composite material for a drill string and the first use of downhole self propulsion. Data rates using the system's telemetry are 2,000 times faster than existing data transfer techniques such as mud pulse.

THE PIPE

Anaconda's SmartPipe™, jointly developed by Halliburton and **Fiberspar Spoolable Products**, is manufactured in a continuous coil using a laminate of carbon fiber. Embedded in the pipe are conductors that relay data between the control center and the subsurface assembly.

Under most drilling conditions, the pipe is nearly buoyant, an advantage in extended reach drilling operations. Fatigue is not a problem, says Mr Terry.

SmartPipe can withstand 800 times more flexing cycles than steel. And the reeled pipe eliminates many of the hazards of pipe handling.

The first composite drill string for System 1 is $2\frac{7}{8}$-in. OD, developed to meet Statoil's requirements in the North Sea where the system will work after its commercial debut in the Gulf of Mexico. System 3 will get a 5½-in. drill string.

Larger drill string sizes will use more than one reel, with a connector applied in the field to connect the reels. Steel connectors are now used for field connections, but a composite connector is being developed.

BOTTOMHOLE ASSEMBLY

The system's Advanced Drilling, Evaluation, and Propulsion Tool (ADEPT) measures borehole and formation parameters, orients the borehole in 3D space, provides the mechanical forces to drill the hole, and incorporates the industry's first open system subsurface propulsion system. The system uses a standard mud motor and standard drill bits.

With the propulsion system, no mechanical force is required from the surface equipment to move the pipe into or out of the well. Instead, the pipe can be propelled by downhole hydraulic forces applied by the ADEPT assembly.

An electronically sequenced tractor provides controlled weight on bit while drilling and pulls the tool into high angle and horizontal wells.

SURFACE EQUIPMENT

The surface system includes a control center, SmartPipe injector and reel, a tower and pipe handling system, blowout preventers, and a digital control and data acquisition system.

A three-man team operates the system: a "pilot" runs the equipment, a systems engineer maintains system integrity, and a "navigation engineer" interprets the sensor data, builds a detailed subsurface map and guides the well path.

Basically, the system "is run with a mouse," said Mr Terry.

All downhole data are available for real time decisions. Real time transfer of sensor data to the office enables geophysicists, geologists, and reservoir engineers to update their interpretations in real time using their familiar interpretation tools. The Earth Model that is the well plan is available to the drilling engineer who can re-design the wellbore geometry in real time as needed to reach the target.

The navigation system uses existing seismic data along with the downhole data through a link to Halliburton's satellite system. "This means the drilling engineer has data in time to steer *this* well," said Mr Terry.

THE IMPACT

Halliburton expects the system to have a significant impact on hydrocarbon recovery, cost, and efficiency.

According to Halliburton, the flexibility and capability of Anaconda systems will improve access to reserves and enhance drainage patterns, providing increased recovery.

Appendix Oyo GeoSpace

Appendix Concordia Traverse Report

INSTITUT POLAIRE

CONCORDIA PROJECT
INFORMATION ON THE SURFACE TRANSPORT SYSTEM
SET UP FOR SERVICING THE DOME C SITE

French Polar Institute
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CONCORDIA PROJECT
INFORMATION ON THE SURFACE TRANSPORT SYSTEM SET UP FOR SERVICING THE DOME C SITE

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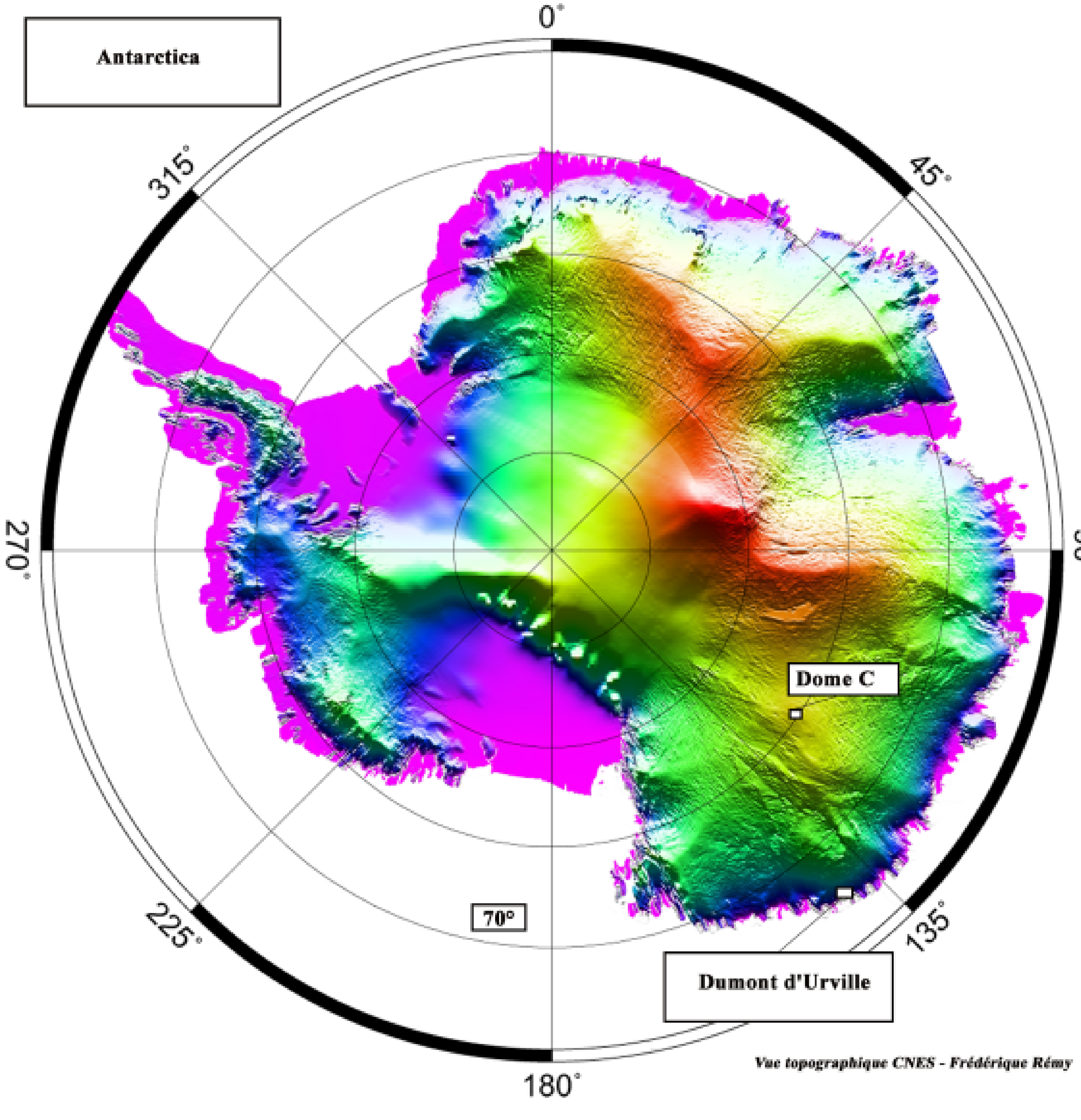

Antarctica
0°
45°
90°
135°
180°
225°
270°
315°
70°
Dome C
Dumont d'Urville
Vue topographique CNES - Frédérique Rémy

CONCORDIA PROJECT
INFORMATION ON THE SURFACE TRANSPORT SYSTEM SET UP FOR SERVICING THE DOME C SITE

This document presents the elements that guided IFRTP and its partner ENEA in their initial choices of traverse equipment and the results obtained.

A. Background

The French Polar Expeditions, parent organization of the current French Antarctic Program Operator IFRTP, had in their time acquired a reputation of excellence in the organization of traverses for scientific surveys or 'scientific' traverses. The object of these traverses servicing Dome C is different. These are 'logistic' traverses. The project to build a wintering station at Dome C (CONCORDIA) and the associated deep European ice core program (EPICA) involve the initial transportation of about 2,700,000 Kg of equipment to the site, 1,120 km inland. Then every year the normal operation of the site will require the transportation of about 300,000 Kg of supplies (food, fuel, various equipment).

B. Initial Requirements

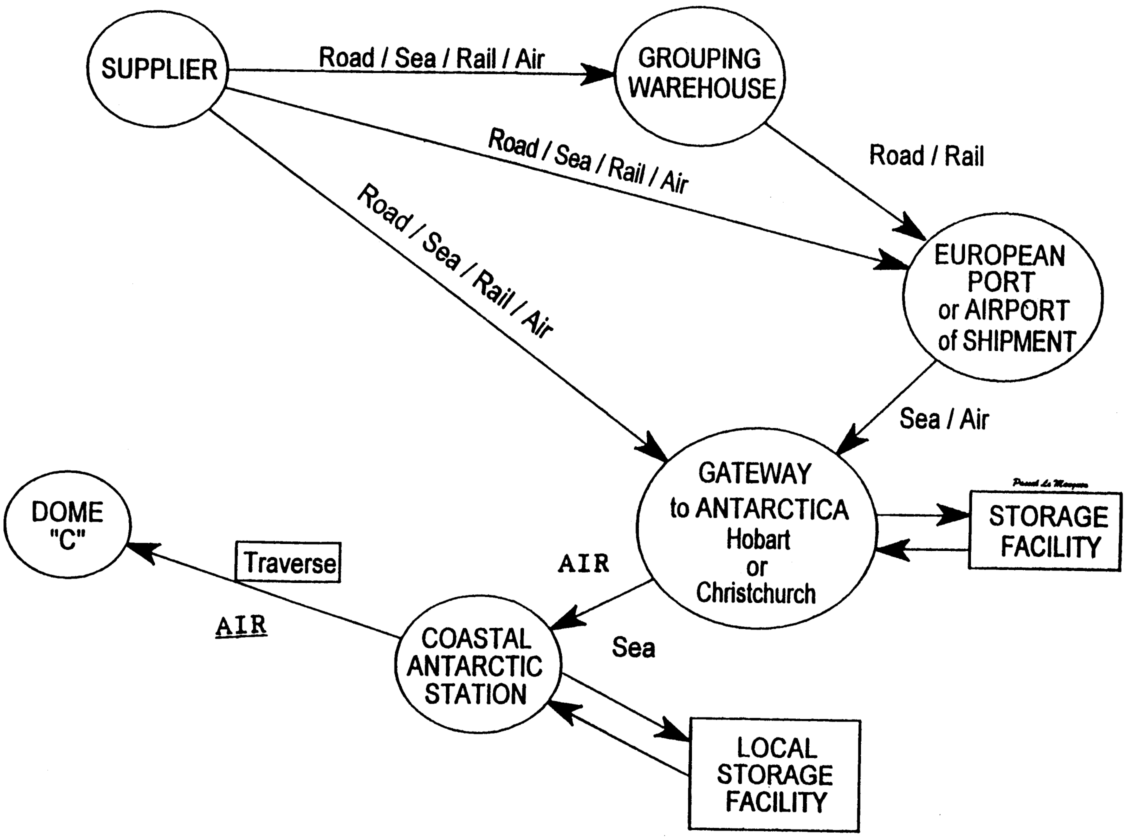
For several reasons, IFRTP and its partner ENEA made the choice of setting up a "traverse" surface transport system to service the Dome C working site. The characteristics of this surface transport system were dictated by:

- The acceptable net delivery rate;
- The departure point;
- The route used;
- The intermediate passage points;
- The point of delivery;
- The nature of goods to deliver;
- The transport personnel;
- The safety conditions.

The organization of the global transport operation, all the way from the manufacture or production site to Dome C is outlined in next page's diagram.

The operation of surface transport convoys on the Antarctic continent relates to the last step of this diagram. The logistic traverses can be assimilated to commercial transport operations in the sense that they have to:

- Deliver cargo **ON TIME**, and **IN GOOD CONDITION**;
- Provide a reliable routine service;
- Achieve the best **COST PRICE**.



Organizing the traverse operation involves finding proper answers to the following questions:

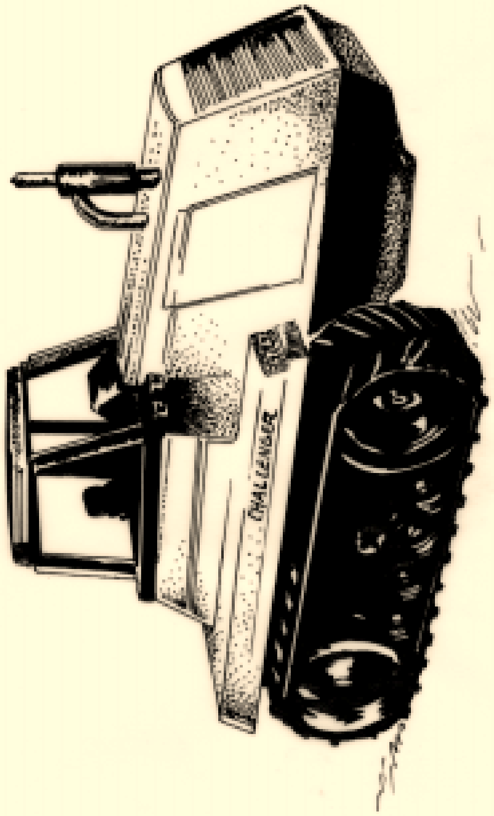
- What will the cargo be composed of, and what will the packaging be ?
- What transport vehicles will be used? What is the optimum delivery rate ?
- What drivers? How to satisfy their needs ?
- What solutions to the maintenance problems ?

C. Choice of Equipment

C1 – Basic packaging unit

To maximize efficiency, the basic packaging unit preferred for the traverse is the standard 20 foot shipping container. The sleds, trailers and handling equipment, including the unloading installations on the shore, were designed for the manipulation of such containers. Upstream, the items to send to Dome C are designed or selected for inclusion in 20 foot containers whenever possible.

Caterpillar Challenger Tractor



C2 – Vehicles

Two options were possible: load the cargo on the deck of a self-propelled vehicle, or load it on sleds or trailers towed by a tractor. In either case, there were no vehicles readily available on the world market for traverse operation. Our choice criteria were:

- Adaptability to the environmental conditions;
- Ease of use;
- Reliability;
- Ease of finding and obtaining spare parts close by (in Australia and New Zealand);
- Usability with respect to ground conditions (ground pressure, operational speed, ground leveling requirements);
- Load capacity, towing capacity;
- Fuel consumption.
- Costs

To allow a quick implementation of the transport system it was decided not to engage into designing a prototype, but to look for commercial vehicles to adapt to our requirements. We didn't find any suitable self-propelled decked vehicle responding to our requirements and the the choice of tractors useable on snow and ice in low temperatures is quite limited. Our search for tractors concentrated on:

- Civil engineering tractors ("pushing");
- Agricultural tractors ("towing");
- Ski field snow grading tractors;

while our search for towable load carriers concentrated on:

- Sleds;
- Tracked trailers.

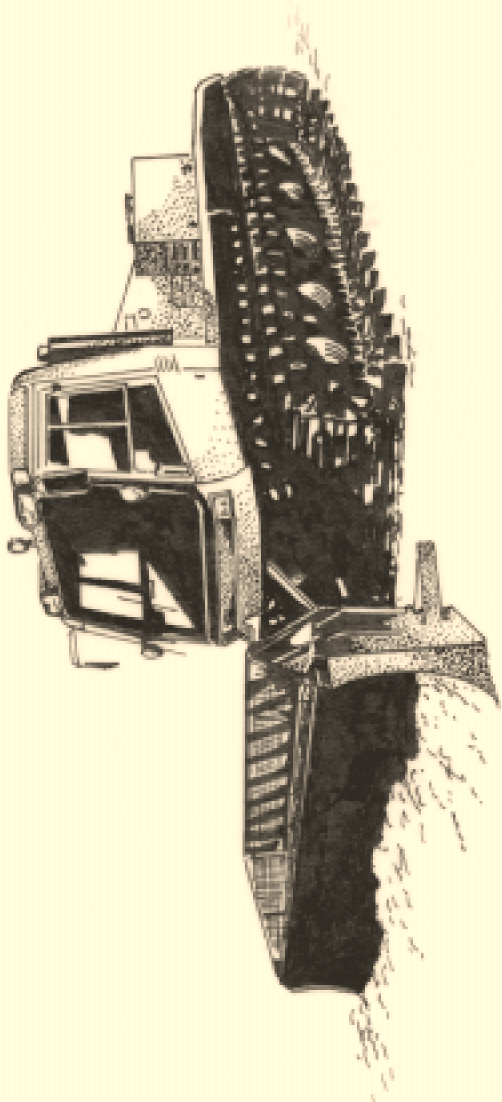
Tractors

At the time we started our investigations only 3 categories of tractors available on the world market called our attention:

- The Caterpillar D series "pushing" tractors (bulldozers);
- The Caterpillar Challenger series agricultural "towing" tractors;
- The Kassbohrer Pisten Bully (PB) series "snow grading" tractors.

The Caterpillar D series tractors, although being excellent machines, ended up being ruled out because of their high price and their low speed. The Caterpillar Challenger series tractors are agricultural tractors with rubber tracks designed to tow loads on soft ground. Simple modifications allow their use in summer on the Antarctic continent. The Kassbohrer PB series tractors are not towing machines. They are built to grade snow on ski fields and have an incomparable ability to work with their blade. They have a very low ground pressure.

levelling vehicle
Kassbohrer PB 330



The Caterpillar Challenger series tractors take advantage of the Caterpillar savoir-faire in civil engineering machinery. They have a low ground pressure (300 hPa), a powerful engine (215 to 230 kW), and a simple robust design. It is a conventional direct drive powershift transmission (hydraulic clutch, semi automatic gear box). The Challengers have an operating weight of 15,500 kg, a maximum speed (with no load) of 30 km/h and an operational cruising speed of 6 to 15 km/h when towing loads. They are designed to tow loads and it is possible for them to tow loads continuously without any durability problem. But they can lose some towing capability in dry "little-cohesive" snow. Being of simple robust design, they are low maintenance. They are not originally equipped with a blade, and attempts to fit one were not successful (pitching too important, lack of visibility). They can (mechanically) safely tow at maximum capacity as track slip will occur before any excessive mechanical stress. Towing at maximum capacity can occasionally cause the tractor to get bogged in irregular ground (bumps, Sastrugis...).

The Kassbohrer PB series tractors are snow grading machines designed for use in the ski fields. The PB 330 units are powerful (240 kW) to be able to push large amounts of snow and light (9,000 kg) to be able to go up steep slopes. The ground pressure is extremely low (60hPa) so that the machines won't compact snow too much on the ski runs. Transmission is via hydrostatic pumps and motors, with electronic controls. The blade, very easy to handle, is designed for snow. The maximum speed is of about 15 km/h with no load. They are designed to move on all types of snow, but lose some towing capability because of their low ground pressure on very light snow. Their technical sophistication makes them fragile for such a use far from well equipped workshops. The interval between major service operations, in Antarctica, is only of about 1,500h. Experience shows that towing heavy loads with a PB is damaging to the hydrostatic transmission.

Both types of tractors use under load about 6 litters of diesel fuel per kilometer. Under no load, the Challenger uses about 2 litters per kilometer while the PB, because of its hydrostatic transmission, uses about 4 litters per kilometer.

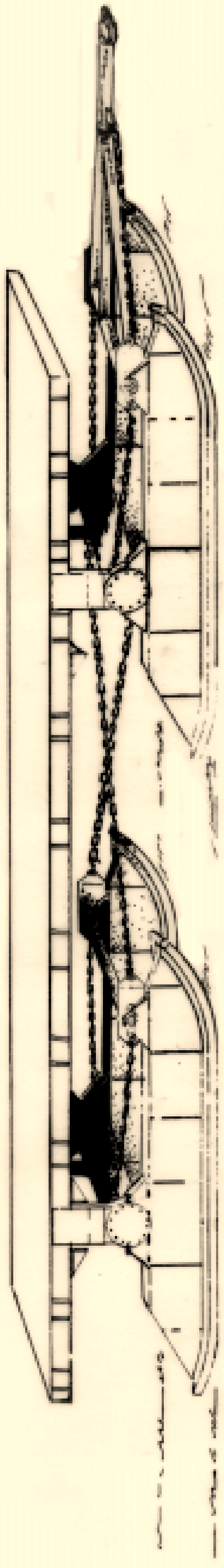
In summary: despite our desire to standardize equipment to simplify maintenance on the convoys, we concluded that these two tractors were complementary and we use them both: the Challenger to tow loads and the PB to grade snow and tow light loads in specific conditions.

Sleds

The traditional tow used to carry loads on snow or ice is the sled. The sled was invented in prehistoric times and preceded the wheel. By instinct the first designers had conceived a simple low ground pressure device taking advantage in snow fields of the low friction of the snow.

All traverses on ice caps have used sleds. If about every expedition had its own design of light sled, there are only few heavy sled designs. We have used Otaco and Aalener articulated models. We now use models of our own design: an articulated decked sled of 15 t capacity and a "tank sled" for bulk fuel. The tank sleds are dedicated to fuel, the product most transported on the traverse. The relatively small 12 m3 tank sits on a single pair of articulated

Classical decked sledge



skis via elastic devices. The tank sleds get a good net weight / gross weight ratio. In addition the tank sleds, with no moving components, save on mechanical problems.

Tracked trailers

If sleds are typically rustic devices, hence considered generally solid, they become fragile as you increase their size, capacity and moving speed (10 km/h is a high speed). Increasing reliability along with performance requires to list all points subjects to stress loads and either limit the number of fragile points or find technical solutions to avoid stress concentrations. This leads to a heavy design. The sled stops to be a reasonable option when you have to carry heavy loads.

Historically, rolling succeeded sliding. It makes sense to try to replace skis by a rolling system involving less towing resistance. Rolling on soft ground can be achieved using tracks. The tracks make the link between rotating wheels and the soft ground, spreading the weight over a large area to achieve low ground pressures. Tracks are a well known solution for traction in self propelled vehicles, but were practically unknown as passive option in towed vehicles.

The spread of passive tracks was triggered by the availability of continuous rubber tracks, appearing in the late eighties in catalogues of several manufacturers. Until then only existed tracks made of steel elements connected together or tracks made of elastomer strips placed side by side and mechanically connected. The continuous rubber track came with high mechanical reliability and on hard ground a lower resistance to motion than skis.

Facilities and living quarters

Traverse operation requires 15 to 16 hours of work every day and the personnel needs comfortable accommodation. Three units are assigned to personnel living needs:

The "Living" module is divided into two sleeping cabins, one surgery/radio room, one kitchen/dining room and one cold porch.

The "Store" module is divided in two rooms, one for provisions and one for spare parts. For a one month traverse, 1,200 kg or 2 m3 of food and drinks are needed.

The "Energy" module houses the generator set, the water production (snow melter) and distribution systems, the workshop, the bathroom and a warm store for medical supplies. The generator set rated at 65 kW powers the two "Living" and "Energy" modules as well as the tractor engine heaters during stops to keep machines warm.

A fuel pumping unit is located on the outside of the module and is used for refueling the tractors which need 4 m3 a day. The unit includes filtering and metering of the fuel.

12m decked trailer

Telecommunications

Each tractor as well as the "Living" module have fixed VHF transceivers for local communications within the traverse or with close parties. The fixed transceivers are completed by individual hand-held VHF radios.

The traverse has three different systems for long distance communications. An INMARSAT C is used to send by Telex position reports and other general work messages. An INMARSAT M is used for phone and fax, for both work and private communications. Traditional HF radio is used as back-up for INMARSAT but also for regular HF voice communications with the stations when out of range of the VHF system (about 20 km). There are three HF radio units, one in the "Living" module and two in different tractors.

Navigation

All of the tractors being equipped with GPS . There is also a theodolite, a solar compass and a Radar on the traverse.

C3 – Equipment at both ends of the traverse route

Each container or cargo bundle over 10 ton is loaded on a special, rudimentary "handling sled" in preparation for its loading on the convoys. A handling sled allows to handle and manoeuvre the load locally without the need for expensive or delicate equipment. The handling sleds are either loaded on the convoys with the cargo or left on the loading site which means that some units are needed at the delivery site.

Departure point (Cape Prudhomme – loading)

Dumont d'Urville, situated on an island, is separated from Cape Prud'homme, departure point of the traverses on the edge of the continent, by about 5 km of sea free of ice in summer. The personnel preparing the convoys is most of the time isolated from the station and must be self-sufficient. A base was created at Cape Prud'homme and includes living quarters, a powerhouse, two workshops, a 200m2 store, a 300m3 fuel farm and a 300m2 underground garage to shelter the vehicles in winter.

The personnel at Cape Prud'homme maintains the traverse equipment when not in use on a convoy and prepares all the cargo loads for the next convoy. Preparation of the loads is usually made using a 15 ton capacity electric gantry crane but can alternatively make use of the cranes mounted at the back of the Challengers.

Transfers of cargo between the ship's unloading area and Cape Prud'homme are usually conducted over the ice in winter by Dumont d'Urville Station personnel but can also be conducted in summer using a 50 ton displacement barge unloaded using a fixed electric gantry crane installed on the shore.

Delivery point (Dome C – unloading)

All unloading operations are conducted by traverse personnel using the cranes mounted at the back of the Challengers and a Cat 953 track loader stationed at Dome C. If a load is too heavy for the cranes or the loader, the sled or trailer is placed in a pit with its deck flush with the snow surface and the load still on its handling sled is towed out onto the snow.

D - Organisation, personnel

The choice of the number of tractors in the traverse transport system was made on three different grounds: technical, psychological and financial.

Technical criteria included considerations such as convoy length, maintenance operations during stops, personnel accommodation requirements and breakdown probability.

Psychological aspects concentrated on the organization of a wandering group subject to a rhythmic routine. Both technical and psychological evaluations used our past traverse experience.
Large groups are more difficult to manage which hopefully combines well with the fact that too a large number of vehicles is difficult to operate and maintain. Our typical convoys include 7 load towing tractors and 2 snow grading tractors operated by a team of 9 to 10 persons. By experience this is manageable both in terms of personnel and in terms of vehicles.

D1 – The traverse team

The traverse team requires a specific personality and profile. It must be able to perform many duties: drive, level the ground, determine its position and navigate, eat well, communicate, maintain and fix equipment, attend patients and form a coherent, responsible team.

The work on the traverse

Some of the duties have to be fulfilled by all members of the team while some other duties only need to be fulfilled by one person.

- **Drive:** The team members must be able to drive a vehicle towing a load while being attentive to onboard indicators and instruments. They must in addition be intuitive and attentive to feel the machine and react promptly to any problem.

- **Level the Ground:** Four persons must be able to level the ground with the Kassbohrer's blade, continuously and well enough to provide a good track for the six tractors that follow. This leveling determines the speed of the whole convoy. It is an exhausting job and in normal conditions the operator should be replaced every four hours

- **Determine Its Position And Navigate:** Two persons must be able to navigate using GPS and understand simple astronomical phenomena. One person must be able to determine a position using a theodolite, the astronomical tables and a logarithm table.

- **Eat well:** One single person must be able to organise, proper meals for the team.

- **Communicate:** One person in charge of telecommunications must be able to use Inmarsat as well as HF radio equipment.

- **Maintain Equipment:** Seven persons (one per tractor) must be able to carry out basic maintenance on the tractors and their loads (refuel, clean, clear snow, maintain loads secure, check couplings).

- **Fix Equipment:** The traverse is a technical adventure with 220 kW tractors, a diesel generator set, 18 to 25 loaded sleds or trailers. Four persons must have sufficient experience to intervene on a fully loaded sled or trailer deck. At least four persons must be experienced diesel mechanics, one of them must have a good knowledge of the Kassbohrer's hydrostatic systems. One person must be a good welder, and another one an electrician/electronics specialist.

- **Attend Patients:** The presence of a medical doctor on the traverse is necessary.

- **Form a Coherent, Responsible Team:** In such isolation and difficult environment, the team must be coherent and responsible. This requires a careful choice of all members, but more importantly requires the presence of a very good assertive leader accepted by all, capable of taking initiatives and making decisions. This leader organizes the everyday life of the traverse and takes the decisions when problems occur.

Professional skills of the whole team

- **Four Diesel Mechanics,** for maintaining and repairing all mechanical equipment, with at least one skilled in hydraulics.

- **Four grading specialists** which can also have other skills (mechanic, navigator, etc…).

- **One Navigator and Telecommunications Officer,** capable of maintaining his equipment. This member is usually the electrician / electronician of the team. This position involves a fair amount of work during traverse stops.

- **One Medical Doctor,** who can possibly also be Navigator or leveling specialist. He is usually in charge of the cooking. It is common practice to keep the doctor away from dangerous activities.

- **One Traverse Leader,** It can be one of the Diesel Mechanics, but it cannot easily be the doctor. The traverse leader must have a good knowledge of the project. He must know all the equipment perfectly and be able to assess its condition in order to take the right decisions.

- **One "Open" Member,** who only has to be able to drive a tractor and have good physical abilities. This person can be a scientist doing en-route studies, a journalist that will report on his trip, a supplier of equipment, a VIP, a technician in training etc... He is usually there "au pair" rather than as a full staff member. It "opens" the traverse to the outside world by allowing various one-off members to join the team.

Social considerations

As previously mentioned, the traverse team must be coherent and cohesive. Its members must really work "together". The personnel turnover should be low while still allowing the creation of a sufficient pool of experienced traverse personnel. The problem is to create a pool of experienced, rigorous professionals and avoid the succession of strong personalities coming along for the adventure without caring for the group.

Both professional and personal qualities are essential. The cohesion of the team requires respect for each other, and the understanding that every action not carried out properly can result in extra work load, equipment failure and/or high risk situations for somebody in the course of future traverses.

Traverse work starts with the preparation of vehicles and loads before departing and ends with the conditioning of vehicles for the winter upon return of the last traverse of the season. Bad conditioning for the winter, rough operation of vehicles or postponed repairs will sooner or later show their due.

Training

It is difficult on the employment market to find people with personal and professional capacities that can make them good "traversers". There are no formal selection criteria, but we consider aptitude to the environment to be an important issue and we tend to give preference to people that have the requested professional abilities along with a successful wintering past in Antarctica or mountain work experience. Then, we complement their skills as required by additional specialized training sessions. Such sessions include specific training on the Kassbohrer PB and Caterpillar Challenger tractors organized by the manufacturers, navigation courses at specialized institutions such as the French National Geographic Institute or first aid courses.

D2 – Risk assesment

Identification of potential risks

Total safety can never be reached, but we are making every effort to reduce risks as much as possible. Risks can derive from:

- Crevasses
- Fire
- Loss of food stocks
- Loss of energy production systems
- A vehicle or the whole convoy getting lost

Bad weather and white out

- Cold, Altitude, Sun
- Exhaustion
- Psychological disorders
- Illness
- Physical accidents

Crevasses: There are hardly no crevasses between Dumont d'Urville and Dome C and all are concentrated in the coastal zone. We have very little experience in this domain.

Fire: Fire is the most serious risk as it can cause the loss of one of the three modules or one vehicle. To minimize risks, the main personnel facilities were divided into two modules that separate the energy production area from the living area. The two "Energy" and "Living" modules have no link and personnel has to go outside to get from one module to the other. The fuel tank for the generator set is on the outside of the Energy module. The third module is the "Store" which doesn't contain any dangerous combustible materials (no petrol, propane, diesel fuel...). The three modules are made of auto-extinguishing material classified "M0" or "M1". All electrical installations follow maritime regulations.

Loss of food stocks: This can be caused by fire or the accidental disconnection of the sled or trailer carrying the stocks. To prevent a total loss of the stocks, the food is usually divided in three lots placed in the living module, in the storage module and on a sled (safety stock).

Loss of energy production systems: This can be caused by fire or by a problem with the diesel fuel, such as congealing. To prevent total loss of energy production capabilities, the traverse has at least one 25 kva generator installed on a tractor, a separate propane stock, kerosene and petrol.
A vehicle or the whole convoy getting lost: The convoys now follow most of the time the old convoy trace made easy to follow. However, each tractor is equipped with a GPS receiver and each driver has had basic navigation training. In addition, one tractor is equipped with a radar and is always placed in a position where it can monitor the entire convoy.

In case there was a problem with the GPS system network itself and no visible old trace was available for reference, the navigator is capable to determine his position astronomically using the sun as reference.

Cold: The main risk is associated with the loss of heating capabilities following the loss of energy production systems. But there are also daily risks caused by loss of attention and risk awareness. *The briefing of new traverse members on this aspect is necessary. Clothes are appropriate and each person has sufficient amount of clothes to get changed as needed.*

Altitude: Altitude related risks are mostly for personnel reaching Dome C by plane, not by traverse. Nevertheless, there can be daily risks on the traverse caused by loss of attention and risk awareness, notably over-estimation of one's physical capabilities. *The briefing of new traverse members on this aspect is necessary. The traverse is equipped with a compression chamber since the 95/96 season.*

Sun: Sun related risks are mostly concerned with eyes and possible serious ophthalmia due to UV radiations, and personnel is provided with adequate sun glasses. *The briefing of new traverse members on this aspect is necessary. On the forward leg to Dome C, "night sun" is especially problematic for drivers as it is at windscreen height.*

Exhaustion: Exhaustion is highly dependent on the schedule adopted, the environmental conditions and the problems encountered. *The medical doctor and the traverse leader should assess the level of exhaustion of the personnel and the traverse leader has all latitude to adapt the schedule and work program to the situation.*

Psychological disorders: *These problems, or the possibility of their occurrence, should be detected beforehand in the selection process.*

Illness: Traverse personnel is subject beforehand to thorough medical tests. The first main risk is food poisoning. *Food stocks are checked and sorted every year, and storage temperature requirements for refrigerated and frozen products are carefully enforced.* The second main risk is an accident or illness requiring surgery under anaesthetic. The traverse doctor is capable of and has sufficient equipment to perform surgery under anaesthetics.

Physical accidents: It is one of the most delicate problems. Physical accidents that would have benign consequences in a normal environment can take dangerous proportions in the traverse environment. *Traverse personnel must be aware of their isolation and take special care in any activity.*

Associated Prevention Measures

Safety is absolutely essential. There are several methods to prevent accidents and minimize their consequences. The actions taken in this effect on the traverse are:

- Multiply the number of shelters in the convoy, spread clothes and sleeping bags.
- Spread food into several stocks
- Link all vehicles and shelters with VHF radio.
- Have several INMARSAT and HF telecommunication systems spread in the convoy and regularly check them.
- Have several GPS positioning receivers spread in the convoy.
- Have in the convoy enough Kerosene to refuel an aircraft coming for a rescue operation.
- Have a medical doctor on the traverse, have experienced personnel, train one or two traverse members at first aid techniques.
- Have medical facilities
- Have a radar

It is also worth mentioning an evident action: Use reliable vehicles and equipment that prevent to have the personnel living in permanent fear of breakdowns and being exposed to dangerous repair operations.

The traverse members have to be trained, informed and permanently aware of their situation. It can seem obvious, but we should still mention that on the traverse:

- In a blizzard, you should only go outside wearing sufficient clothing, and possibly attach yourself to a safety rope.
- You should never open the door of one of the modules while the traverse is moving (for the personnel on rest shift when the traverse operates on 24 hours a day mode).
- You should check before starting the convoy that every person is there and where they should be.
- You should respect the planned schedule for sending radio messages reporting the traverse position.

Safety can't be neglected but imposing excessive safety measures is not necessary as it could give a false impression of security. The environment is hostile and the traverse personnel should always feel it.

E – Technical Aspects – Improvements – Performance

E1 – Vehicle Pool

The pool of vehicles dedicated to the Concordia surface transport system is composed of:

- 7 towing tractors Challengers 65x
- 3 snow graders Kassbohrer PB 330
- 14 tank-sleds of 12m3 capacity for the storage and transport of fuel.
- 1 'living' caravan
- 1 'power supply / workshop / ablutions' caravan
- 1 'store' caravan
- 1 temperature controlled cargo van (kept either cold or warm depending on the content)
- 3 multipurpose cargo trailers with a 12 m long deck and 25 ton capacity
- 7 multipurpose cargo sleds with a 6 m long deck and 12 ton capacity
- 7 specialized sleds for the transport of 20 foot units

A standard convoy comprises 6 or 7 Challenger towing tractors, 2 PB330 snow graders, the three caravans, the temperature controlled cargo van and about 20 to 25 various sleds and trailers.

E2 – Adaptation of vehicles to Antarctic conditions and to desired function

E2.1- CAT Challenger 65x, main winterisation modifications

Engine compartment:

Installation of a fuel priming pump, a water separator and a fuel line heater in fuel system, Addition of a man hole on the fuel tank, a water collector at the bottom and a drain pipe and tap.

Installation of a 12/24 v alternator and a 50 MT starter motor
Installation of Fleetguard heaters in all oil compartments et and tank type heater to cooling system,
Installation of a 220V electric circuit to feed the engine heating elements when the convoy is stopped, with external connector and protection switchboard
Installation of an additional oil sump to increase oil capacity and hence intervals between oil changes.
Installation of a cerium oxyde catalytic converter which connects to the air intake of the turbocharger. This reduces the carbon deposits in the cylinders and lowers the exhaust gas temperature

Cabin

Installation of a marine type roof escape hatch with adjustable hinge, including external handle and lock facility;
Manufacture and installation of a double glazed front windscreen (original curved unit is replaced by 3 smaller flat units fitted in an adapted frame);
Installation of heating air pipes around front windscreens;
Replacement of the glass rear wind screen by a thick, clear plastic screen (it is too large to allow the installation of a double glazed glass panel);
Installation of a new locker and silicon seals on the cabin door;
Installation of a pyrometer to monitor the exhaust gas temperature and electronic tachometer on the right hand side of the cabin;
Removal of all levers not used in instruments panels and of their mechanisms (except on one vehicle);
Installation of a bench type driver seat, with 2 rewinding safety belts. The bench is mounted on a KAB seat base;
Installation of a road truck type rearview mirror, mounted on the external handle of the right side of the cabin;
Installation of supports for external GPS and VHF antennas.

Frame, body, belts and bogies

Manufacture and installation of a new bonnet assembly to improve engine compartment sealing and insulation complete. The bonnet assembly has large openings and lift off doors for easy maintenance;
Manufacture and installation of a heavy duty roll up blanket for the coolant radiator air intake;
Manufacture and installation of a sealed sump cover with relocated dipsticks and filters and transmission guard group;
Manufacture and installation of a heavy duty battery box with 2 x 210 AH batteries and Fleetguard battery blankets. Batteries will are filled with acid density 1.3 kg/dm3 and connected to an external 24 V starting/charging plug;
Insulation of the Hydraulic tank;
Manufacture and installation of ice scraper for drive wheels;
Installation of silicone seals in drive and idler wheels;
Installation of metallic hubs on wheels;

Challenger tractor pulling trailer and sled

Extension of the tracks grousers by vulcanization of an additional strip;
Installation of silicone seals in belt tension cylinders.
Removal of the external traffic and indicator lights

It must be noted the mixed track tension system combining springs and compressed nitrogen is still not operating satisfactorily in low temperatures as the cylinder then loses nitrogen despite the fitting of silicon seals. The alternative solution currently envisaged is to fill the pression chamber with hydraulic fluid, linked to a nitrogen accumulator..

E22 – Kassbohrer PB 330s

Engine compartment

Modification of the engine air intake and exhaust system to include snow separator,
Installation of heaters in all oil compartments and tank type heater to the cooling system,
Installation of a fuel circuit made of Caterpillar elements (with fuel priming pump, water separator …),
Insertion of an external cutout switch on the 24V circuit,
Installation of a 220V electric circuit to feed the engine heating elements when the convoy is stopped, with external connector and protection switchboard.
Installation of a cerium oxyde catalytic converter which connects to the air intake of the turbocharger. This reduces the carbon deposits in the cylinders and lowers the exhaust gas temperature,

Cabin

Installation of a roof escape hatch, including external handle and lock facility,
Installation of two road truck type rearview mirrors,
Installation of a hand operated accelerator,
Installation of supports for external GPS antennae,
Installation of a pyrometer to monitor the exhaust gas temperature.

Frame, body, belts and BOGGIES

Manufacture and installation of a sealed sump cover
Replacement of the original batteries by heavy duty batteries, batteries are filled with acid density 1.3 kg/dm3 and connected to an external 24 V starting/charging plug
Insulation of the Hydraulic tank
Installation of 2 x 300 l fuel tanks, 1 x 50 l buffer tank with a water collector at the bottom and a drain pipe and tap.
Replacement of standard blade hoses by silicone hoses
Manufacture and Installation of double glazed front windscreen (original curved unit will be replaced by 2 smaller flat units fitted in an adapted frame).
Manufacture and installation of 2 narrower (1400mm wide), symmetrical tracks,
Removal of the snow cutter’s suspension and installation of a towing hook
Replacement of the inflatable bogie wheels by new wheels filled with compressible foam

Challenger pulling trailer and sledges

E3 – Additional equipment common to all tractors

Fitting of a 20 ton Hyster winch on one Challenger;
Installation of 3 hydraulic cranes of 11 tm capacity at the back of 3 Challenger tractors;
Installation on one Challenger tractor of a '35 kVA / 50 Hz / 3 x 400 V' electric generator driven by the equipment socket, as a backup for the caravan's generator;
Installation on 3 Challenger tractors of 3 x '4 kVA / 50 Hz / 220V' electric generators driven by the hydraulic pump;
Installation on the 4 Challenger tractors equipped with a generator of 4 pairs of 1 to 2 kW 220V projector lights;
Installation of a special plough on the equipment arms of one Challenger tractor;
Installation on one Challenger tractor of a radar, with a second tractor to be equipped in the future.
Installation of two HF radio transceivers on two Challengers tractors.

E4 – Tracked trailers

The first two trailers were equipped each with two pairs of MTS 73 undercarriages, they all have idlers made of inflated tires, rubber belts and bogies. Several small problems appeared au début, technically minor but disrupting for the operations.

The MTS idlers were equipped with tubeless tires. This technique used universally around the world showed its limits in Antarctica. We are using now tires filled up with foam. The density and the elasticity of the foam would be equivalent to the tire inflation pressure required (we could not use rigid tires that would give too much resistance to deformation).

The rubber the belt are made of gets stiffer below - 35 Deg. Celsius. This in addition to the thickness of the belt, to the thickness of the pitched grousers and to the "winding radius" of the 850 mm idler increases the towing effort. We have consequently replaced the original belts designed for operation on abrasive ground by thinner belts and as the presence of the grousers increase the towing effort we have purchased thin smooth belts on which we vulcanized our own, smaller grousers. .

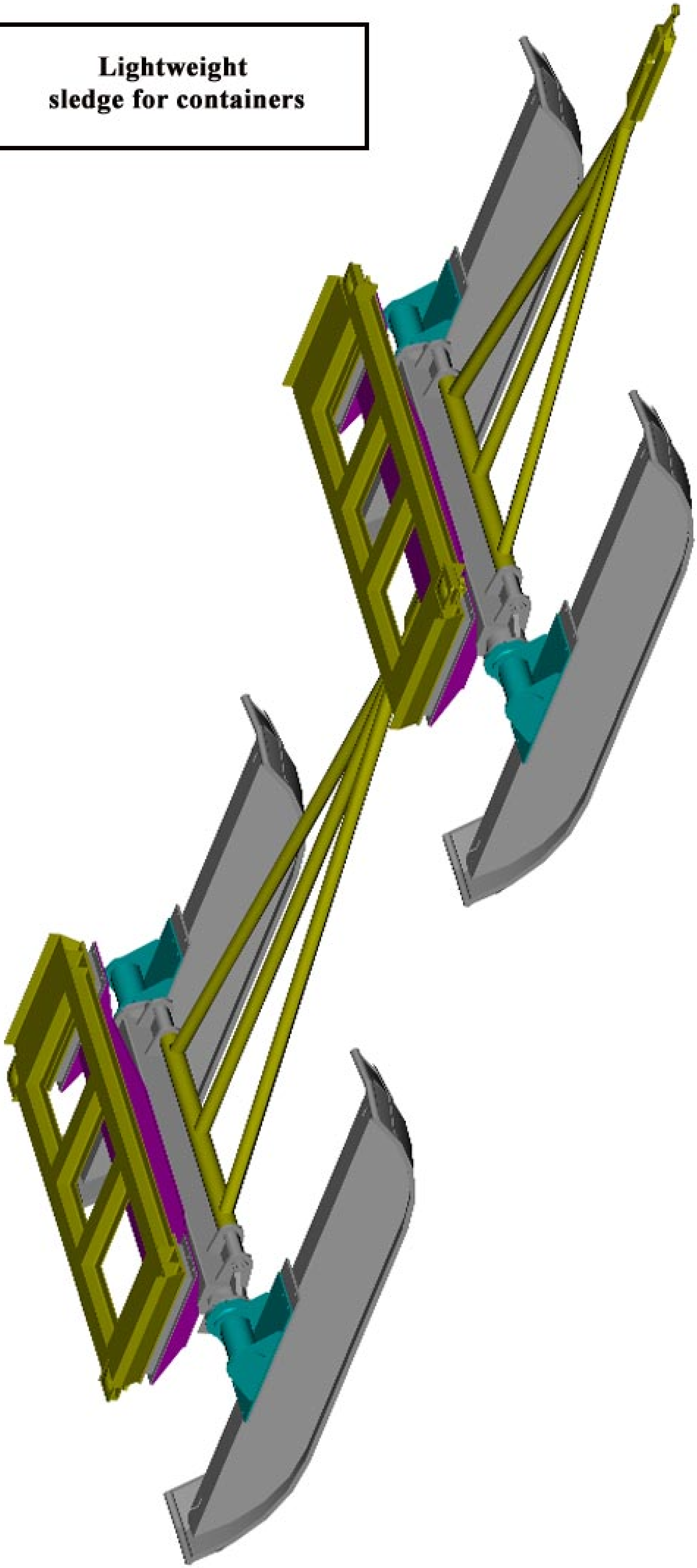
Note on the VFS 50 undercarriage

The 73 inch long MTS73 undercarriage used originally is too short to allow a low ground pressure when the trailer is sufficiently loaded. Therefore we installed MTS73 undercarriages at the front of all trailers and installed at the back longer 116 inch long MTS116. But the MTS116 showed some fragility in their main beam and they were replaced by 116 inch long undercarriages of the VFS50 series. The VFS50 units have been equipped with rubber bands on the steel wheels and silicon seals on bearings.

Another interesting advantage of the VFS units is their low price, half the price of the MTS116 units. The VFS series are manufactured by the Caterpillar Agricultural Division while the MTS series are manufactured by the Caterpillar Defense Division. It must be noted that while Caterpillar advised against the use of the VFS series in Antarctica, the VFS units have to date not presented any major problem.

The tracked trailers with their loads usually present a 2.0 net payload to deadweight ratio.

Lightweight sledge for containers



E5 – Sleds

Cargo sleds

Trailers are heavy and typically have a low net payload to deadweight ratio. Trailers should only be used for dense loads and there is place for improved sled designs to carry light loads (maximum 12 000 kg) such as empty construction modules or insulation panels.

The kinematics of articulated sleds requires the longitudinal mobility of the front ski assembly under the deck. Depending on the load, this movement can induce very high efforts in the axles. It is why we have designed sleds where the different components are linked with elastic couplings to allow relative movements during travel and to control efforts.

On one model of sled we have suppressed the deck to save weight and use the load itself, usually a 20 foot container, to provide structural strength. On this model, the front and back ski assemblies are linked by a drawbar instead of chains. This sled is one of the simplest ever built with only 12 different types of elements.

This type of sled with its load usually presents a 2.5 to 4.0 net payload to deadweight ratio.

Tank sleds

The principle behind this specialised sled is the use of the tank as structural element linking the front and back ski assemblies. The tank sits via 3 pairs of elastic articulations (each providing a three degrees of freedom link) on two articulated skis. This sled is also built with only 12 different types of elements.

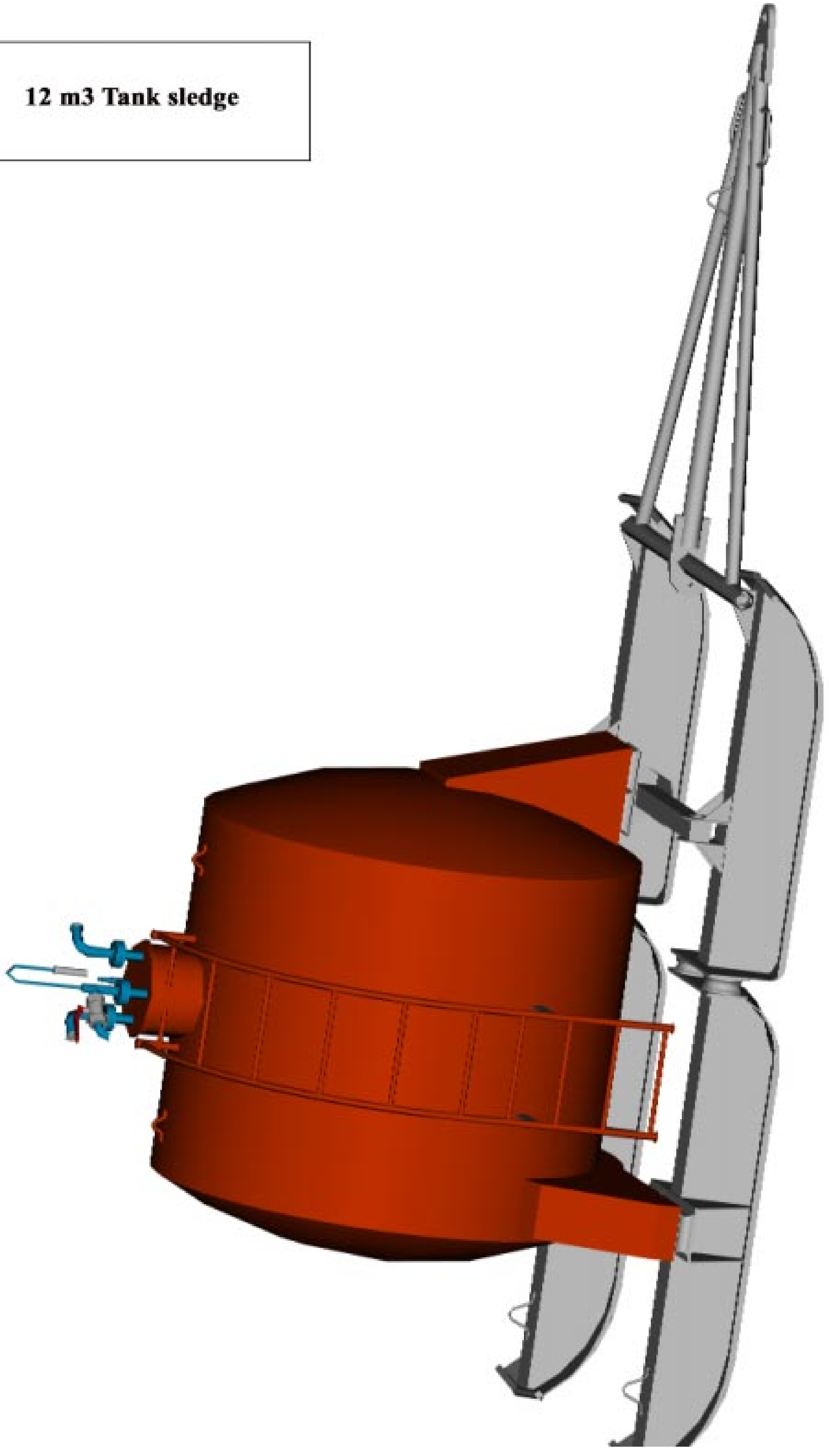
The 12 m3 tank is obtained by using standard components, with a 2,000 mm long, 2,400 mm diameter tube. The steel chosen for the parts that can suffer shocks and/or high stress is following French standard NF A48 FP (resilience measured at -50 deg C). The double skin configuration is achieved by deploying a flexible elastomer tank inside the steel tank.

The volume of fuel transported in each tank may seem low but it allows to leave behind near empty tanks very quickly and regularly, about one every day and a half, and to spread the fuel load equitably between tractors. Every tank left behind is still containing fuel to be used on the way back.

Leaving behind these tanks facilitates the progression of the convoy and automatically compensates for the loss of power linked to the increase of altitude and the loss of traction linked to the change of mechanical characteristics of the ground snow.

A full tank-sled presents a net payload to deadweight ratio of 3.5.

12 m3 Tank sledge



E6 – Cost and Performance

Performances :

13 return traverses have been already completed. The traverse reported here are traverses purely logistic not involved in any other works (glaciology, magnetism ...). The average duration of a return traverse to Dome C, including a 2 day stop on the site, is of 21 to 25 days (9 to 13 days for outward journey, 8 to 10 days the return).

The fuel consumption of a Challenger tractor depends a lot on the quality of the ground. Under full load the consumption varies between 5.5 and 8.0 litters per kilometer and while towing only empty sleds and trailers on the way back to the coast the consumption varies between 3.5 and 4.5 litters per kilometer.

Each season the cargo load delivered at Dome C is usually higher on the second and third traverses after the first traverse has compacted the track and improved traction conditions. It is then more meaningful to give a total cargo delivery figure for the season rather than give a figure per traverse. 407,500 kg were delivered to Dome C during the last season, and this total is currently increasing by about 10% every season.

The table shown on next page gives some statistics for past traverses.

Cost:

The analysis of the transport system costs makes a distinction between equipment and development costs. Development costs includes the cost of discarded equipment and the cost of modifications to equipment still in use. The costs are based on an average rate of 1 US Dollar (USD) for 6 French Francs.

Equipment cost:	4.2 Million USD
Development cost :	1.7 Million USD
Cost of Cape Prudhomme coastal installations:	2.0 Million USD
Cost of Dome C unloading installations :	0.5 Million USD

The cost of Cape Prud'homme coastal installations includes salaries costs for the construction of the installations, following French salaries rules. The operational costs of each season is not indicated as about half of it is made of salaries from France and Italy and the differences in rules and structures may not allow a meaningful comparison. It is the same for amortization costs.

When using the French calculation rules the overall transport cost is estimated at about 2.5 USD per kilogramme delivered at Dome c when excluding the development costs and about 3.0 USD per kilogramme when including the development costs.

GENERAL STATISTICS ON CONCORDIA TRAVERSE TRANSPORT SYSTEM

Traverse N°	Date pre transfer	Depart CPH	Arrive DC	Depart DC	Return CPH	Gross Weight (t)	Payload ex-CPH	Payload delivered at DC	Fuel used (m3-t)	Duration (days)	Net cargo flow (t/day)	Efficiency Payload / Gross
04		16-01-97	29-01-97	31-01-97	10-02-97	420	187	125	75/60	27.0	4.63	0.30
05		16-11-97	02-12-97	04-12-97	13-12-97	374	160	99	74/59	27.1	3.65	0.26
06		20-12-97	02-01-98	03-01-98	12-01-98	384	165	115	63/50	24.5	4.70	0.30
07		16-01-98	26-01-98	28-01-98	06-02-98	392	173	123	62/49	20.8	5.92	0.31
08	17-11-98	20-11-98	03-12-98	05-12-98	13-12-98	377	164	109	68/55	23.4	4.65	0.29
09	19-12-98	21-12-98	04-01-99	06-01-99	14-01-99	439	188	129	74/59	24.1	5.35	0.29
10	17-01-99	18-01-99	29-01-99	31-01-99	09-02-99	428	194	129	81/65	21.6	5.97	0.30
11	16-11-99	19-11-99	02-12-99	04-12-99	12-12-99	421	186	119	84/67	23.3	5.10	0.28
12	17-12-99	19-12-99	28-12-99	02-01-00	11-01-00	486	223	157	83/66	23.0	6.83	0.32
13	15-01-00	16-01-00	26-01-00	28-01-00	06-02-00	473	208	131	96/77	21.2	6.18	0.28

Notes:
- Weights are in metric tonnes (t), volumes in cubic metres (m3) and durations in days
- 'CPH' is short for Cape Prud'homme, 'DC' is short for Dome C

F – Ongoing technical improvements, efficiency increase

F1- Current system

The 10% annual increase in net cargo delivery was due as much to the improvement of the Challengers' traction (raising of grousers) than to the reduction of the resistance to traction exerted by sleds and trailers (general design, fine tuning). A special effort was also made towards the better distribution of the types of loads within the convoy, the use of tractors in tandem and the use of elastic liaison elements.

Each modification had to be tested and validated, then progressively extended to the rest of the vehicles. For example the raising of grousers took three seasons to complete. The alignment of all trailers and sleds on the latest standard should still take two more seasons.

The old convoy trace is usually found again every season through the use of marking tricks but its ground quality still fails to come up to expectations. A special effort will now be made towards the improvement of its consistency and macro-geometry. Work and tests in that direction started during the 1999/2000 season. The convoy now includes at the back a snow grader preparing the ground for the next passage. The time interval between the grading and the passage of vehicles should allow a good hardening of the surface. This should be reinforced by the introduction of a special plow to be used during the return trips towards the coast. The plow is designed to break and mix the upper parts of the soil at the back of the convoy just before the snow grader to obtain a more homogeneous ground.

The grading gives the trace a good geometry but it would obviously be even more effective if the trace was less pronounced. We are going to give some attention to methods reducing the impact of the convoy on the ground surface. We are mostly working on reducing the movements of tracks and skis and on coming back to a system guiding the head of the skis on rough terrain to prevent them from plunging into holes.

In the long run we are expecting with a harder and smoother surface an increase in convoy speed and a decrease in fuel consumption which will both contribute to an increase of the net cargo delivery capacity. This should also reduce wear and tear on the equipment.

Maintaining the schedule for 3 traverses per season requires a global organization were each action has been planned and timed in advance. This extends to the management of loading operations at the coast and unloading operations at Dome C, to the reduction of en-route maintenance operations (equipment reliability), to the organization of meals (all meals are prepared and divided in individual portions before the season in Europe and Australia). We are also currently testing several methods to raise the bad weather and visibility thresholds above which the convoy have to stop (powerful driving lights, glasses, marking of the edge of the trace ….)

F2 – 10 year plan

We did not want to start the setting-up of the existing transport system by the study of prototype powered vehicles because this process requires a lot of time and does not allow to mix design, validation and operation of the system.

Now that this system is operational we can in parallel work on the design of new vehicles. We are working on a concept mixing towed and self propelled vehicles where the head vehicle would produce electric power and feed it to electric motors fitted on the trailers under tow that would become partially self propelled.

This concept, used by railways, would allow an increase of the net cargo capacity per driver and a decrease in maintenance requirements by a reduction in the number of diesel engines. It would also significantly increase the potential for cleaner operations with minimum polluting emissions as it easier to prepare and control a single generator set unit than four vehicle engines housed under their bonnets.

Appendix Information to Solicit Quotes for Environmental Field Laboratory

Environmental Field Laboratory for Geochemical and Microbiological Subglacial Research

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Description and Specifications

Overview

The field deployable containerized environmental field laboratory will provide a clean laboratory environment for geochemical and microbiological research of subglacial environments. The Laboratory will be housed in a 20 ft Weatherhaven MECC container. The ~ 42 square meters (480 sq. ft) of laboratory space is subdivided into three entities:

- Entrance room (2.4 m by 1.8 m, 8 ft by 6 ft)
- Clean Laboratory (3.6 m by 6 m, 12 ft by 20 ft)
- Analytical Laboratory (3.6 m by 6 m, 12 ft by 20 ft)

A platform with stairs will be installed in the front and at the back of the container. The front platform will provide entrance to the laboratory. The back platform provides space to deliver samples through the sample entry door to the clean room. The back platform also houses a storage cage for gas bottles (i.e. Argon gas) needed for ICP-OES operation.

The rooftop of the container will serve as home for the backup generator and the laboratory air handling and heating system.

Laboratory

Entrance Room

The entrance room provides storage space and additionally will serve as changing room prior to entering the individual laboratories. It will also house the laboratories water storage and clean water supply equipment. In the transport mode, the entrance room will be accessible from the outside and used as storage for excess furniture from the two laboratories. A window is installed in the entrance door in order to avoid accidents while opening the doors.

Clean Laboratory (Clean Lab)

The Clean Lab is used for sample preparation and sub-sampling in a clean environment. The lab is equipped with a class 100 laminar flow workbench (based on Salare VLF 3000) and a self-contained ductless fume hood (based on Salare FCR-1500 or 1800). During transport the fume hood is stored on a table resting above the laminar flow bench. This tabletop is mounted to the side of the laminar flow bench and swings out 90 degrees for lab operation. The Lab also contains foldable tables for extra bench space. All furniture and the wall system are made of polypropylene. Metal free components will be used in the construction of the lab's interior. Only in case such components are not available for certain aspects of the construction, metal substitutes will be used. Each such component needs to be approved separately.

Sample entry is through a pass-through window at the end of the laminar flow bench.

Integrated into the laminar flow bench are a sink with ultra pure water supply (Millipore Element or Advantage system) and under the counter storage cabinetry. The Clean Lab will also be equipped with a safety shower, and will have heated and filtered air supply.

Analytical Laboratory (Analytical Lab)

The Analytical Lab will house a suite of analytical equipment. The lab will be equipped with a fixed installed lab bench with under the counter cabinetry and foldable movable tables (for additional bench space). Ultra pure water supply and an out-foldable sink will be integrated into the wall system. Alternatively, a portable water station with a sink may be acquired.

Incorporated into the fixed installed lab bench are a pull out computer table and a side bench top, which swings out 90 degrees during lab operation. Scientific equipment will be mounted on shock absorbent platforms on top of the fixed lab bench. Mounted on the wall above the bench top are down foldable wall racks on which additional equipment can be mounted for transport purposes.

Scientific Instrumentation

Anticipated analytical instrumentation (pending availability of funding):

- ICP-OES
- IC
- Spectrometer
- Titration
- High Speed Centrifuge

In consideration are:

ICP-OES:

- Perkin Elmer Optima 5000 DC series
- Perkin Elmer Optima 2100 DV

IC:

- Dionex
-

Spectrometer:

- ASD Inc. is/NIR spectrometer – LabSpec 5000
  with Multipurpose Fiber Optic Fixture
- Shimazu UV 3600 (likely not transportable)
- ??? Alternate ???

Titration:

- Methrom Titrando 836 with Software Tiamo, two dosing units and stirrer
  2ml and 5 ml burettes
  Alkalinity titration: pH electrode
  Chlorinity titration: silver-nitrate electrode

High Speed Centrifuge:

- Thermo Scientific Sorvall Stratos Benchtop Centrifuge
  Temp control -9° to 40° C, variable speed control 500 to max speed 23,300 rpm/ 50,377xG, Capacity 4 x180 ml
- Thermo Scientific IEC Multi and Multi RF High Performance Centrifuges.
  Temp control -9° to 40° C, variable speed control 500 to max speed 16,800rpm/ 30,300xG, Capacity 4 x 250 ml
- ??? alternate ???

Additional consideration:

Weighting table and scale for analytical work and sample prep.

Attachments

Rooftop

The rooftop will be used to mount a back up generator, external air handling and heating system (see below) as well as provide additional transport space. For this purpose the rooftop must be strong enough (ISO specs should be sufficient) and need to be equipped with multi purpose attachment points to mount the backup generator (towards the rear side of the container), air handling system (front side of container), and tie down points. The space between the backup generator and the air handling system will be used as storage cache for shipping containers of equipment used in the lab.

Front and Back Platform

The two platforms provide space for people to enter the laboratory or to deliver samples. Both platforms are detachable for shipping. For transport in the field, the two platforms can be flipped up and secured to the container. The back platform also provides space for a detachable gas bottle cage mounted to the container.

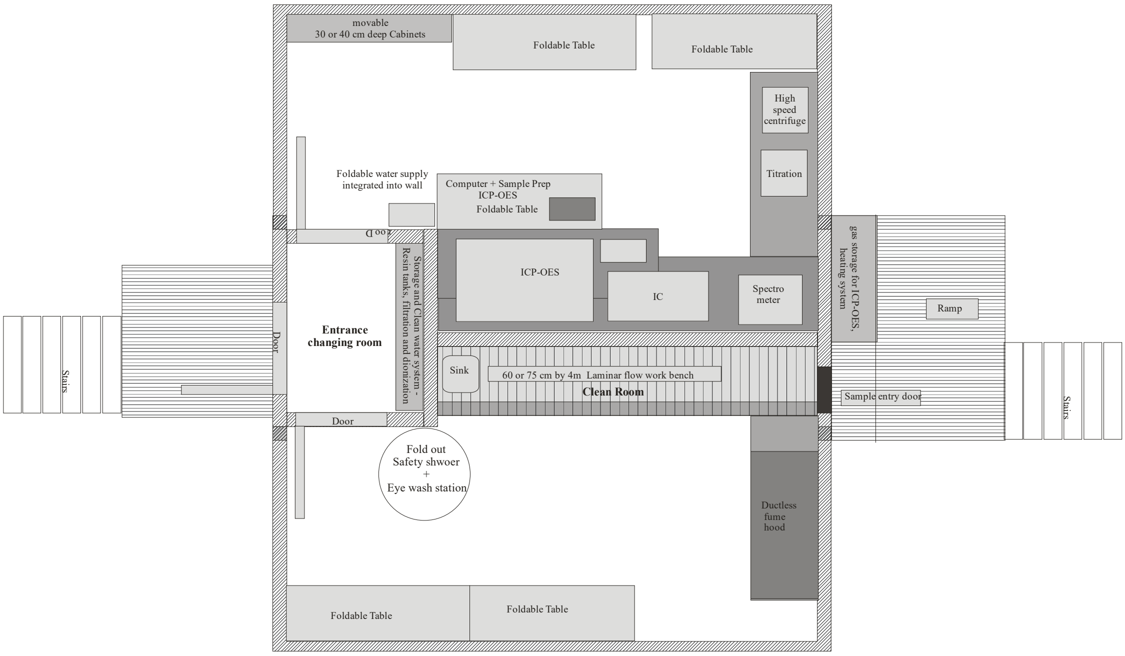


Figure 1: Field Lab in Operation Mode

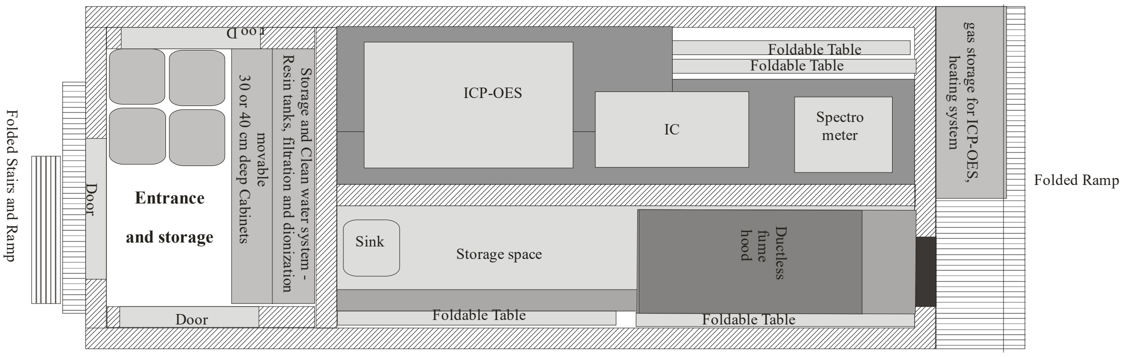


Figure 2: Field Lab in Transport Mode

Details

Container

The container should be equipped with one set of laden ISO forklift pockets. There should be at least 4 tie down points on the outside of the container. In front as well as the back of the building should be attachment points to install a platform and stairs (see attachments). The rooftop requires mounting points and possible reinforcement to accommodate the installation of a back-up generator for uninterrupted electrical power supply. Interior need to meet general clean lab requirements for microbiological and geochemical work (e.g. metal free fabrication). The floor needs to be non - skid. Exterior paint (4 walls & roof) may be fire retardant paint (optional). Insulation shall be sufficient to provide shelter and has to include floor, walls, doors and ceiling of the container and provide enough environmental protection at temperatures between 0ºC and -30ºC or lower (32ºF to -22ºF, see Environmental Conditions). Floor insulation shall not hamper the installation of lab furniture and equipment.

Lab furniture

Clean lab:

In the clean lab area a ~4 m long laminar flow bench with cabinetry will be installed, covering the entire area between the wall to the entrance room and the end of the container. The laminar flow bench is also usable as vertical flow fume hood. On the left side inside of the hood a sink with Milli-Q water supply will be installed. On the right hand side a sample door allows cores to be handed from the outside of the container directly into the clean space of the laminar flow bench.

The base cabinet should have one set of drawers (column) to the right of the sink cabinet. The remainder of the cabinetry has a row of drawers above door cabinets, which are suitable for acid storage. Pending further discussion one double door cabinet may be converted into a drawer cabinet. All drawers and doors should be latched, to prevent unintended opening during transport. On the left and right hand side of the flow bench a set of electrical receptacles shall be installed in the front panel of the cabinetry. Exact location and number of receptacles need to be determined.

Hinged at the right hand site of the flow bench is a polypropylene wall partition, which in the unfolded version will cover the tent structure of the container.

A polypropylene roof panel (~ 4 foot wide) is hinged at the top of the laminar flow bench, covering the transition between the container and the tent structure.

In operation mode, a portable ductless fume hood will be placed on a table in front of the polypro wall.

It may be discussed whether the above mentioned polypro wall partition and roof panel may be extended so that polypro paneling creates a solid walled room (87” x 215” x 75”-84”, depth x width x height) within the tent structure space. The roof panel would be hinged at the top of the laminar flow bench and the partition wall to the entrance room. The side panel would be hinged to the right and left of the room and the back wall would come in three to five parts. Latter would be stored in the entrance room during transport. The outside of the panels could be covered with 2” of solid styrofoam insulation significantly increasing the thermal insulation of the container.

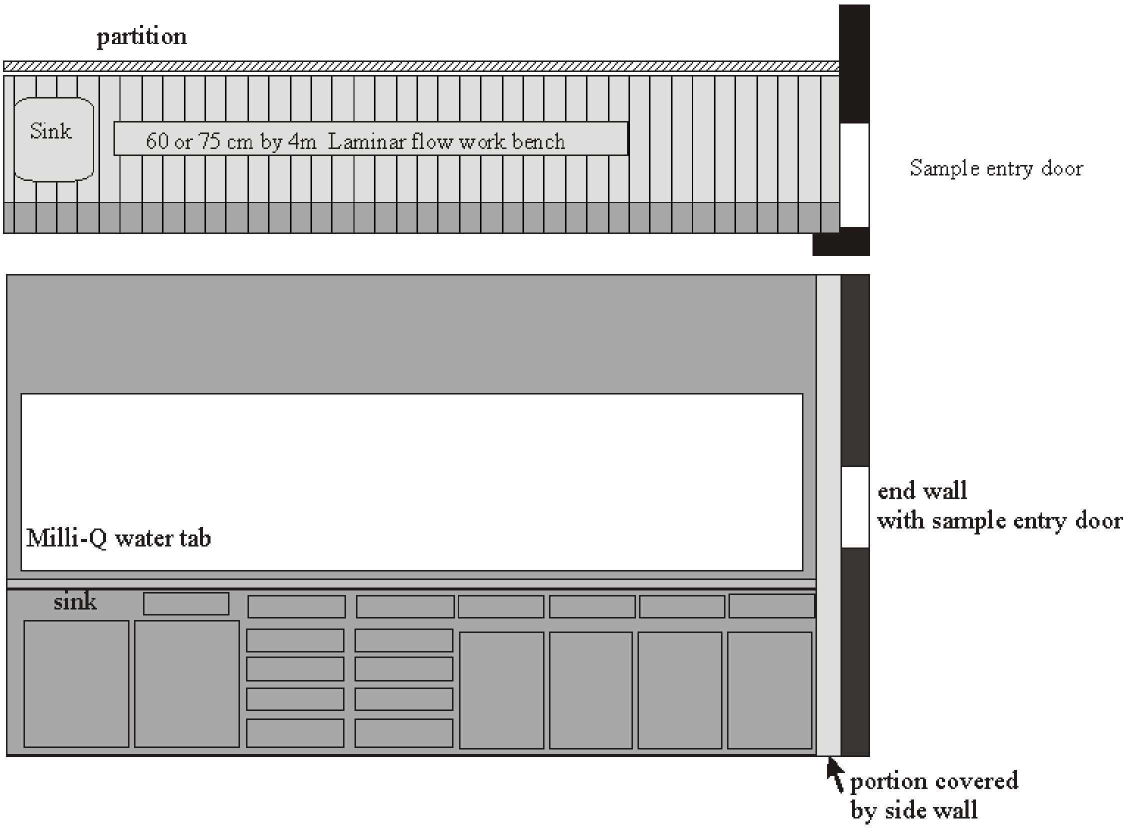


Figure 3. Sketch of laminar flow bench

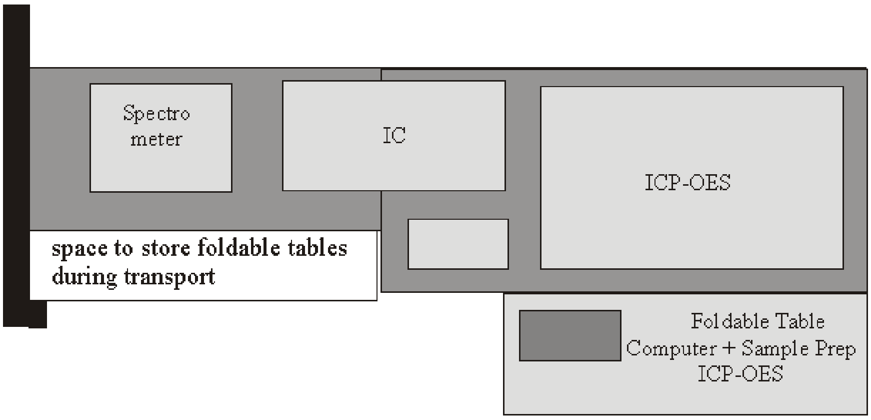
Analytical Lab

The main item in the analytical lab is a workbench covering the area between the partition wall to the entrance room and the end of the container.

The workbench consists of a series of double door and drawer cabinets (see attached drawing). A continuous workbench extend across the entire workbench. In front of the ICP-OES is table, which is hinged and can be folded up and down. Alternatively the table top may be slide out style and can be pulled out of a pocket in the cabinetry. The fold down version may allow one or two drawers to be placed between the surface of the fold down table and the regular counter top. A series of double gang receptacle will be located above the fold down table surface, providing power for laptops and other portable electronic devices.

On the left hand side two or three shelves will be mounted on the wall behind. The shelving must be designed so that all items on the shelf can be secured for transport to prevent that items may fall off the shelf and damage of instrumentation below during transport. Directly above the instrumentation down foldable shelves will be mounted at the wall, providing additional storage space during transport. Above the ICP an air filter may be installed providing a clean air curtain above the instrument.

In addition to the fixed installed shelving a row of down foldable shelving will be installed on the wall behind, providing additional storage in transport mode.



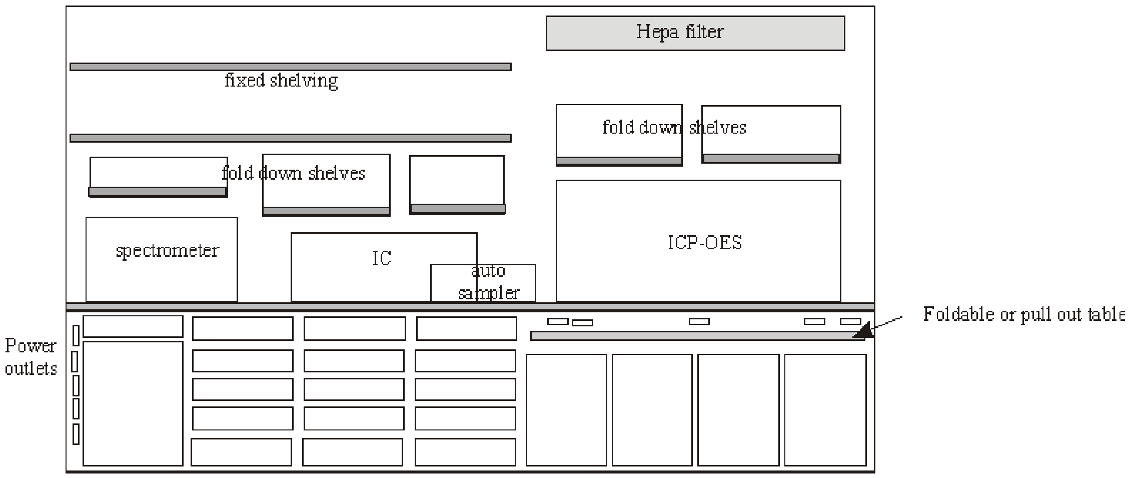


Figure 4: sketch of work bench in the Analytical Lab

Heating and Air Handling System

Air handling

Filtered air-handling system for entire Lab.

Positive airflow from Clean Lab to Entry Room and outside (Sample chamber)

Positive airflow from Analytical Lab to Entry Room desired; not required.

??? Can Laminar Flow Bench provide clean air supply for entire Clean Lab for desired positive airflow:

- Ducting of laminar flow bench from entry room?
- heated air supply through heat exchanger? (see heating section)

Heating:

Heating has to be sufficient to raise the temperature inside of the lab during occupancy to decent lab temperatures (what is an acceptable working temperature in the field? 15° C?). The temperature will be lowered during transport mode; however, heating has to be sufficient to prevent freezing.

Heating source:

Small autonomous furnace during transport (gas, diesel? Waste heat of generator or pulling vehicle?).

Heat exchanger and heat supply from hot water drill system or generator waste heat supplied via heat exchanger during operation mode.

Details need to be discussed.

Lighting

LED lighting system may reduce the power consumption of the container and may be operated by roof or side mounted solar panels. Example of LED lighting: http://www.ledpower.com/products.html

Electrical

The rooftop should contain mounting for solar panel sufficient for lighting and the operation of computers. External electrical power (220/240 V or 480 V entrance service) will be used as main power supply to operate the main equipment like laminar flow bench, fume hood or scientific instrumentation. A rooftop mounted back-up generator should provide if possible uninterrupted electrical power.

In each the analytical lab and the clean lab area five 110 V duplex outlets horizontally mounted should be installed above the doorway. At the rear end of each of the two rooms (the wall with the gas bottle storage) five 110 V duplex outlets shall be mounted vertically. The five duplex in the clean lab area may be integrated into the laminar flow hood. Each of the duplex strips should be on a separate 20 A circuit.

Water system:

1. Water source: snow melted in plastic tub with stainless steel heat exchanger
2. Water is stored in a 100 gallon entry reservoir tank (tank 1)
3. Water is moved from tank 1 into clean reservoir tank (tank 2, 100 gallon) and passes if necessary through scrubbing packs to remove any surface contaminates.
4. Scrubbing pack consists of:
    a. 0.1 um filter
    b. ??? 10 inch deionizer cartridge Resin Tech
5. Water flows into Milli-Q Advantage A10 or Milli-Q Element system and is dispensed over the sink above the laminar flow bench
6. passing through an Millipore BioPak Ultrafilter at the end point for micro biological application

The Millipore Milli-Q Advantage system can supply 3 remote stations: two stations are mounted above the sink in the Clean Lab, and one station is integrated into the wall-mounted sink located in the Analytical Lab. One remote station is equipped with a BioPak Ultra-filter for microbiological work; the other station is equipped with ultra-filtration specific for trace analysis work.

Storage tank vents include a hydrophobic nominal 0.2 um filter to prevent airborne contaminants to enter water system.

Clean storage tank includes UV radiation system to prevent bacterial growth.

Milli-Q water system installation

Dispenser arm over sink with System installed next to water tank

Safety Shower:

Water supply for the safety shower may come from hot water drill storage tank or the internal (100 gallon) water storage tank. If supplied from the hot water drill storage tank, water has to recirculate through insulated piping to avoid frozen pipes. Water from the safety shower may drain through a floor drain into a) the environment, or b) into an open plastic container below the floor.

Integration into Drilling and Traverse System

It is anticipated that the field lab will be deployed by over ice traversing. The container is a standard ISO container and can be mounted on the USAP container sleds, designed for the South Pole traverse route. The dimensions of the field lab however also allow deployment by LC-130.

While the Field Lab will be operable as a stand-alone unit using its roof mounted (backup) generator and furnace, the unit needs to fit into the drilling and deployment system. In order to increase the efficiency of the overall drilling and traverse system, the system is equipped with plug and play capabilities including standard connectors for electrical power supply, 110V, 220/240 V and 440/480V with a main switchboard in the entrance room.

Operational Consideration

1-year stock of non-perishable items.

Restocking of Raytheon supplies throughout the field season.

Demobilization

Fixed installations inside of the container and any equipment intended for over wintering in the field will be susceptible to extreme cold temperatures of up to -50° C (see environmental conditions for details). All equipment should be easily serviceable. At the end of the season all equipment left in the field must be demobilized including removal of any fluids. Therefore, fluids in any of the equipment left in the field must be easily removable in order to prevent freeze damage. In reverse, at the beginning of the field season all equipment must first be serviced before taken into operation. For this purpose a set of spare parts should be brought into the field. Most of the scientific equipment should be shipped back to McMurdo station for over-wintering in more environmental friendly conditions.

??? Temperature susceptibility of Polypropylene?

Environmental Conditions

West Antarctica	
Ambient working temperature:	-30˚C to 0˚C (-22˚F to 32˚F)
Ambient in field storage temperature:	-50˚C to -20˚C (-58˚F to -4˚F)
Polar Plateau	
Ambient working temperature:	-50˚C to -30˚C (-58˚F to -22˚F)
Ambient in field storage temperature:	-80˚C to -50˚C (-112˚F to -58˚F)
Home Institution	
Ambient temperature storage at home institution:	10˚C to 40˚C (50˚F to 104˚F)

Vendor contact info

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