

IceCube Upgrade Drill Overview

November 3, 2021

Terry Benson, Drill Systems Engineer



Enhanced Hot Water Drill (EHWD)

IceCube, South Pole 2004-2011



Seasonal Equipment Site (SES), aka Drill Camp



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IceCube Upgrade Drill Overview - T. Benson



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Enhanced Hot Water Drill (EHWD)

IceCube, South Pole 2004-2011



Tower Operations Site (TOS)



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Enhanced Hot Water Drill (EHWD)

IceCube, South Pole 2004-2011



REQUIREMENTS

- 86 holes, each ϕ 60 cm x 2500 m
- 7 field seasons to complete work
- Compatible with South Pole environment and logistics
- Simultaneously support deployment of instrumentation
- Minimize drill time and fuel consumption
- Maintain safe and predictable operations

SPECS

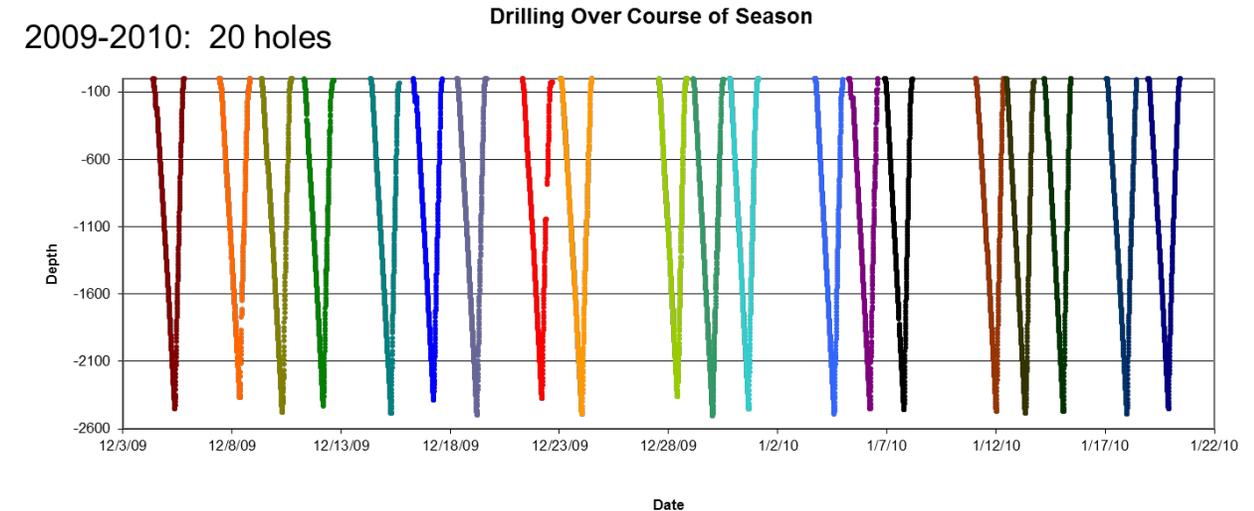
- 5 MW capacity (4.7 MW thermal, 0.3 MW electric)
- 92% thermal efficiency for main heating plant
- 200 GPM (760 LPM), 88°C (190°F), 1100 psig (76 barg)
- 2.2 m/min maximum drill speed
- 1.2 million lb
- 24/7 operation, total crew of 30

PERFORMANCE (per hole)

- Average: 30 hr drill/ream, 5500 gal (21,000 L) AN-8, 48 hr hole turnover
- Peak: 27 hr drill/ream, 4000 gal (15,000 L) AN-8, 32 hr hole turnover



Hole Profiles (depth vs. time)



Papers:

[IceCube Enhanced Hot Water Drill functional description](#), 2014, Benson et.al.

[Modeling hole size, lifetime and fuel consumption in hot-water ice drilling](#), 2014, Greener et.al.



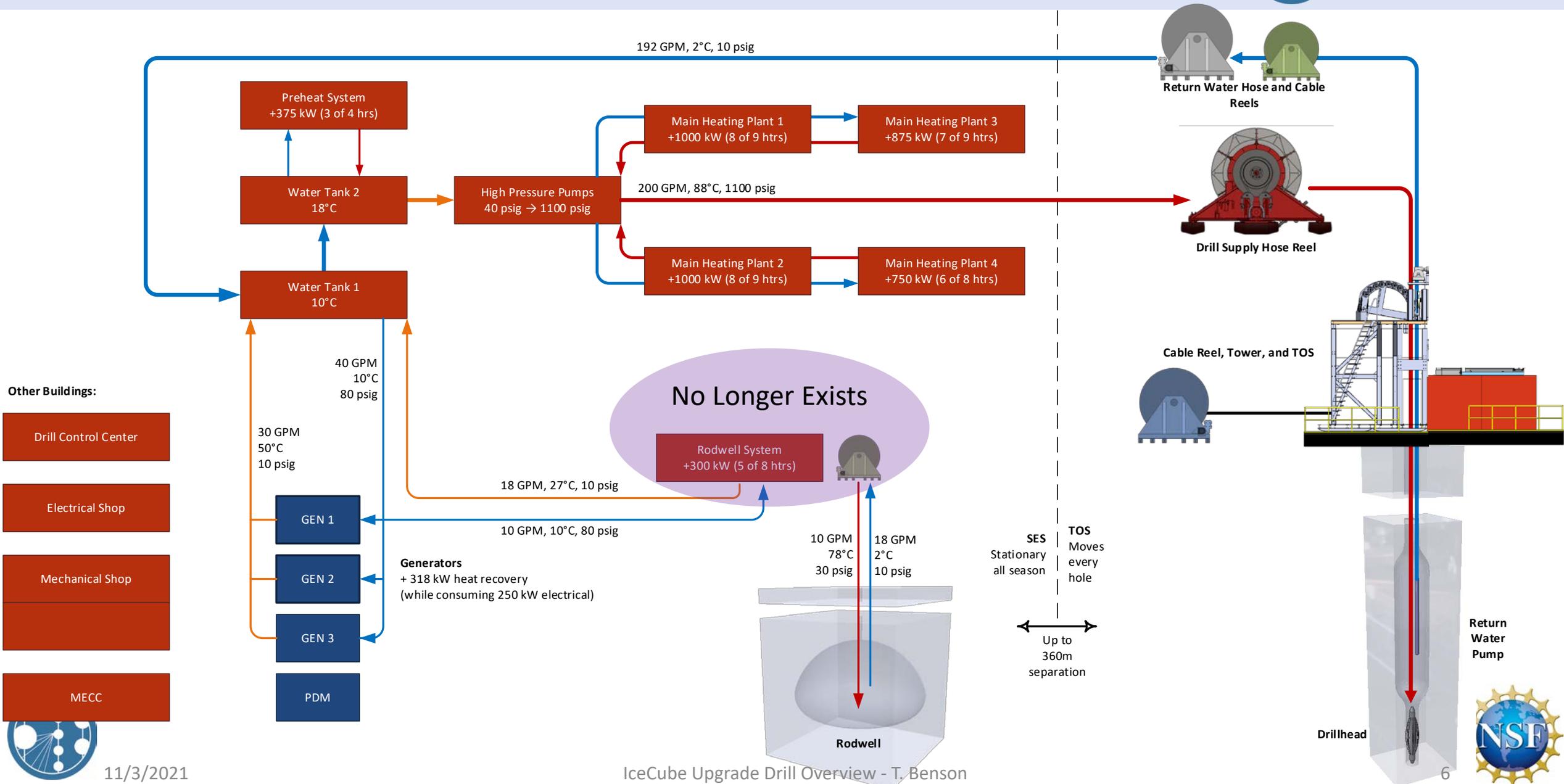
ICU DRILL System Requirements



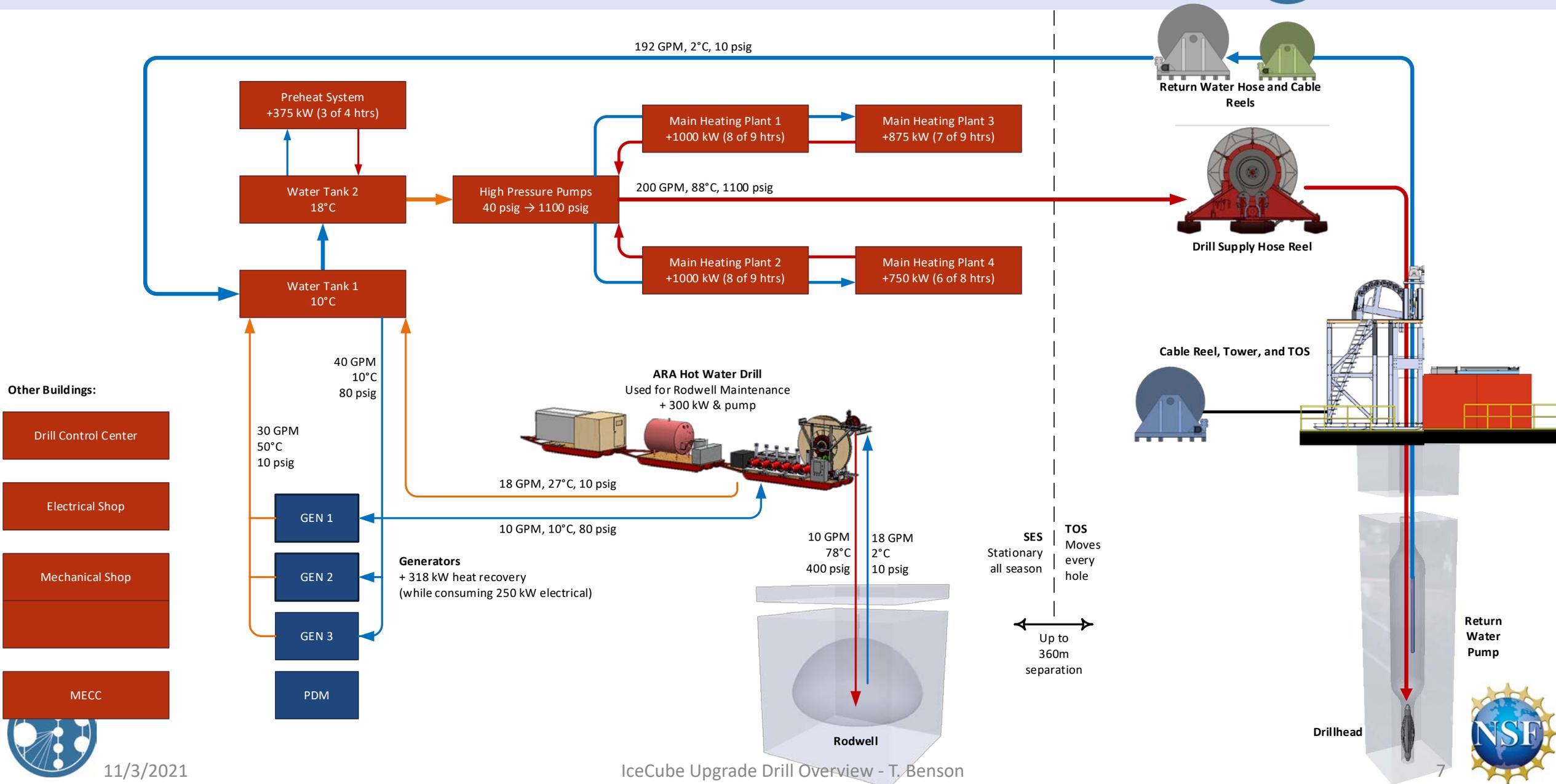
	EHWD (Gen1)	ICU
HOLE DEPTH	2450 m	2600 m
HOLE SIZE	45 cm dia for 37 hr lifetime	52 cm dia for 45-55 hr lifetime
ARRAY	125 m hole spacing	22 m hole spacing, center of IceCube
ICE QUALITY	NA	Better and less bubbles
HOLES	86 holes in 7 seasons	7 holes in 1 season
DRILL TEAM	30	28
LOGISTICS	LC130, primarily	Vessel and Traverse, primarily



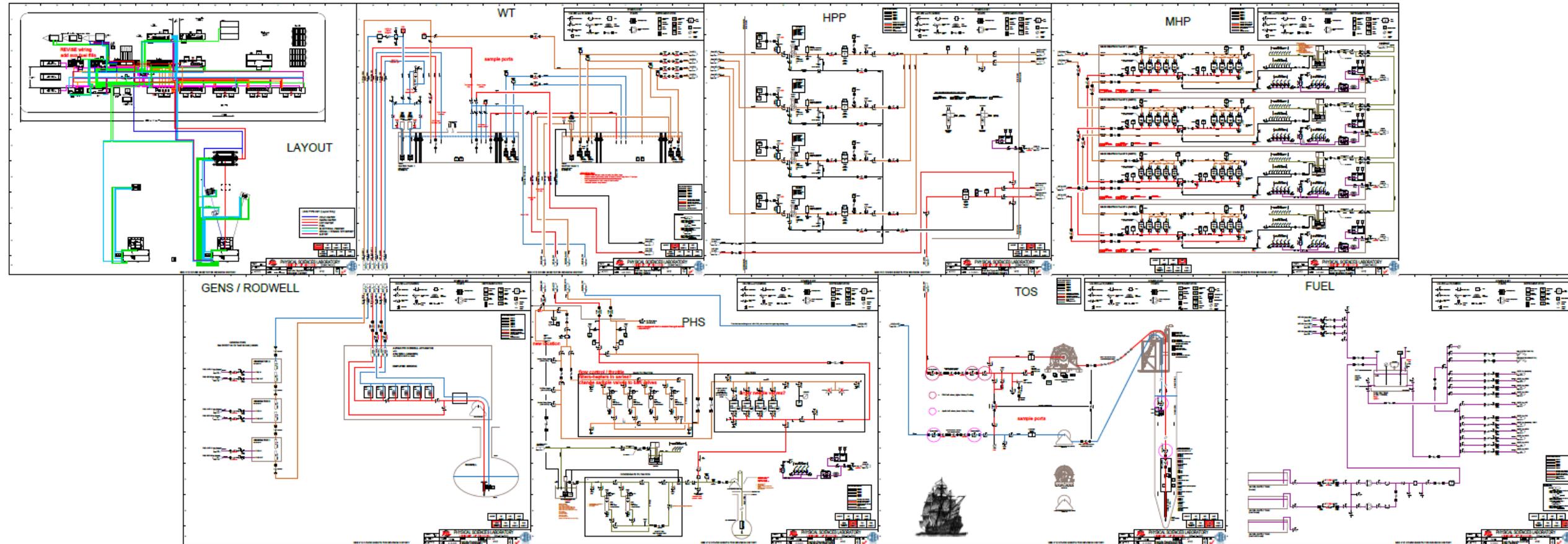
ICU Drill



ICU Drill



ICU Drill – P&ID



*33 motors drives
500+ sensors/actuators*

From EHWD to ICU Drill

Drill subsystem starting status at beginning of Upgrade project.

Subsystem	Starting Status
Water Tanks	Fair
Pumps	Moderate Refurb
Main Heating	Fair
Preheat/Filtration System	Moderate Refurb
Tower & TOS	Fair
Hose Reel	Fair
Cable Reel	Significant Refurb
Return Water System	Fair
Support Buildings	Fair
Independent Firm Drill	Fair
Drill Hose	New Required
Drill Cable	New Required
Rodwell System	New Required
Generators, PDM	New Required
Control System	New Required

Fair
Moderate Refurb
Significant Refurb
New Required



Water Tanks (WT1 & WT2)

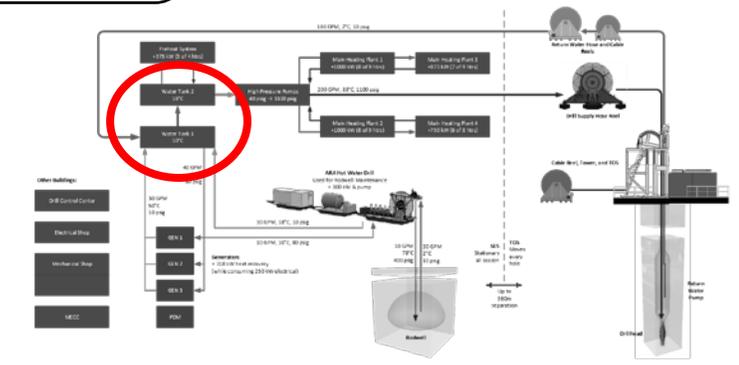
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Port Heuneme
McMurdo
Spole
Mix
As of Nov 2021



2x Tanks, 10000 gal capacity each

What's shipping?

- Pumps: 3x Vertical Turbine Pumps, 8x Charge Pumps, 4x Transfer Pumps
- Railings, Ladders, and Doghouse building materials
- Plumbing and instrumentation



WT2

Vertical Turbine Pumps, WT1



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Main Heating Plants (MHP)

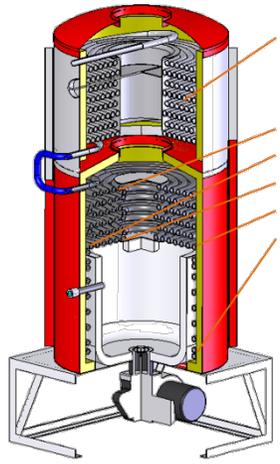
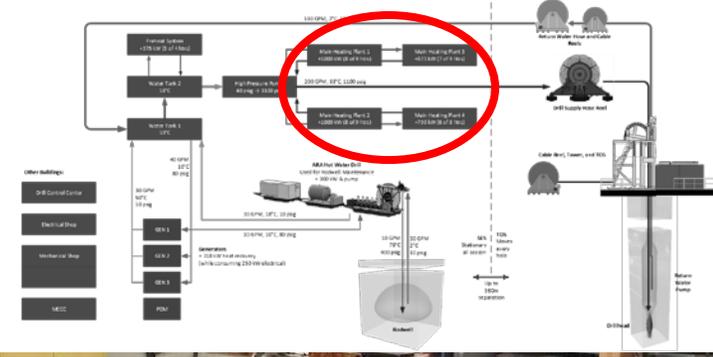
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4 buildings, 34x Custom High-Efficiency Fuel-Fired Water Heaters, 125 kW each; Plumbing, Instrumentation, and Controls

What's shipping?

- Heater outlet flowmeter assemblies
- Heater local control boxes
- Condensate collection systems
- Plumbing replacements
- Network/PLC/Estop control panels



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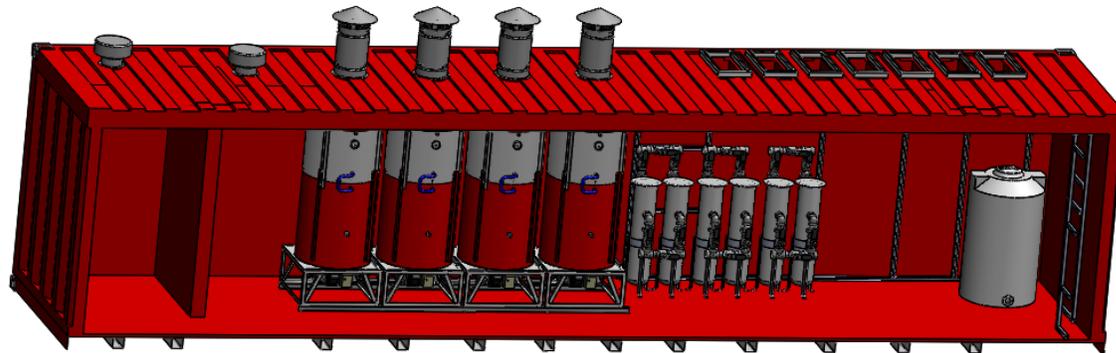


PreHeat System (PHS)

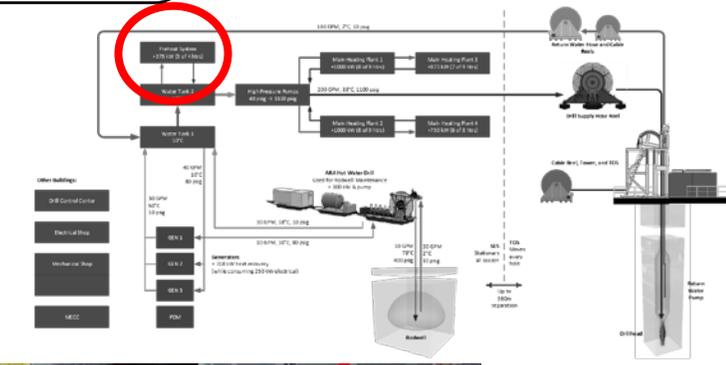
4x Water Heaters and 3x Pump Control Systems maintain WT2 level and temperature; Main system filtration; Condensate collection and handling system

What's shipping?

- Heater outlet flowmeter assemblies
- Heater local control boxes
- Main system filters and plumbing
- Condensate collection/handling system
- Plumbing replacements
- Network/PLC/Estop control panel
- 3x Motor drives



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Rodwell & Makeup Water Strategy

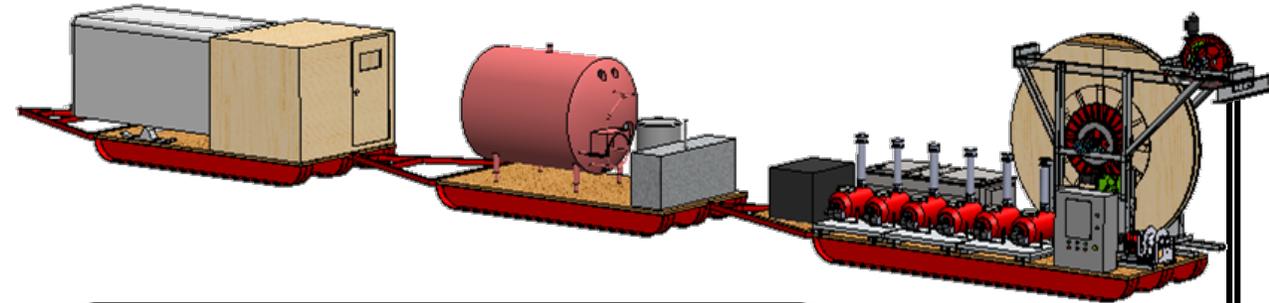
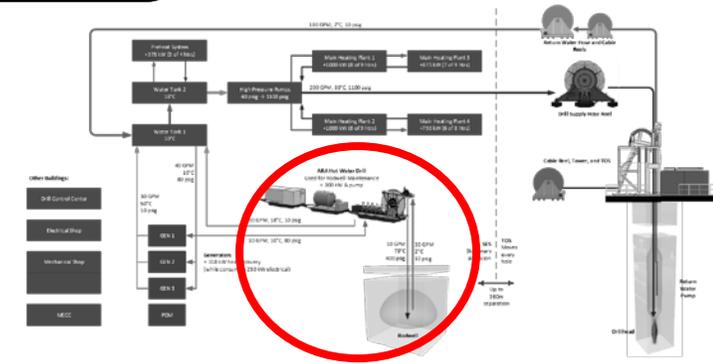
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Existing ARAHWD drill system at Pole, to be integrated into ICU drill as Rodwell support system (original Rodwell system no longer exists)

What's shipping

- “White Generator” and electrical distribution sled
- ePump – main pumping system
- ePump control panel
- Downhole pumps and nozzle stems
- Downhole pump control panels
- Network/PLC/Estop control panel
- Downhole camera
- Sensors and controls



ARA HOT WATER DRILL SPECS

- Hot water to make dry holes
- Drill/pump-out simultaneously
- 3-sled train configuration, 34klb (15t) dry weight
- 300kW thermal power, requires 30kW electrical
- 12gpm (45 lpm), 85°C, 1000psi (7Mpa) local supply
- OR, supply from main ICU Drill thermal plant
- 30 gpm return from hole capability



Tower Operations Site (TOS)

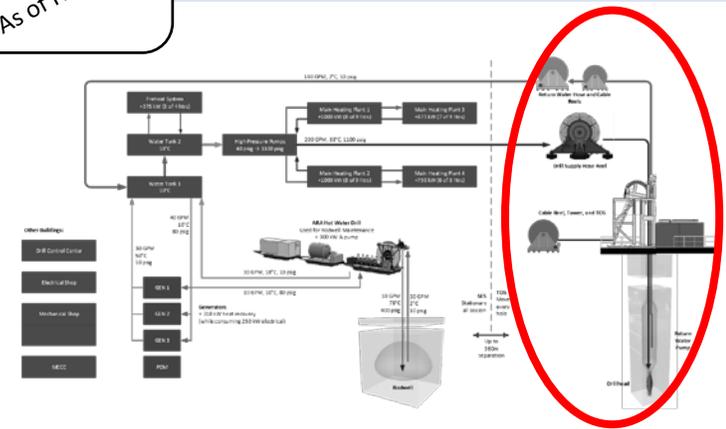
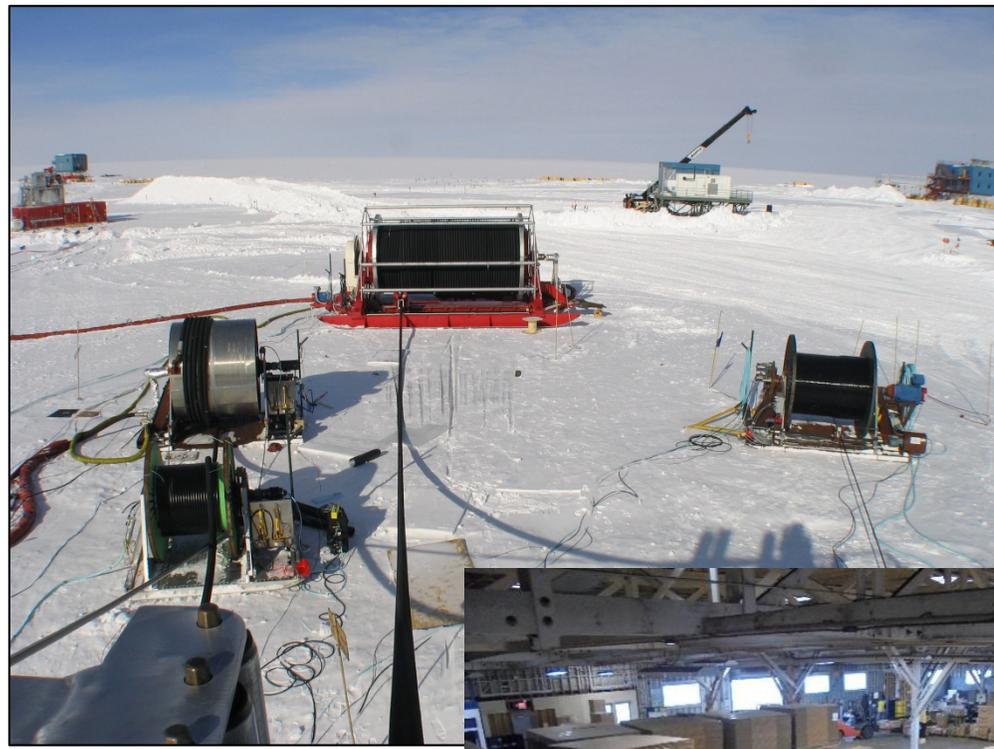
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Tower (2x), Tower Operations Structures (2x), Drillheads (3x), Reels and winches (9x), Main drill cable and hose, motion control system, Instrument Installation Support

What's shipping?

- Drill Hose
- Drill Cables
- Return Water Combo Cables
- Main Hose Reel Manifold and Repair Parts
- Main Cable Reel
- Return Water Cable Reel
- Return Water Hose Reel Repair Parts
- TU-20 Winch Repair Parts
- PO5 Reel
- Bullwheel Tensioner
- Spare Tower Hoist
- Tower/TOS Repair Parts
- Weightstack
- I/O Control Panels
- Network/PLC/Estop Control Panels
- 16x Motor Drives
- Pendants
- Computer Rack and Peripherals



Independent Firm Drill (IFD)

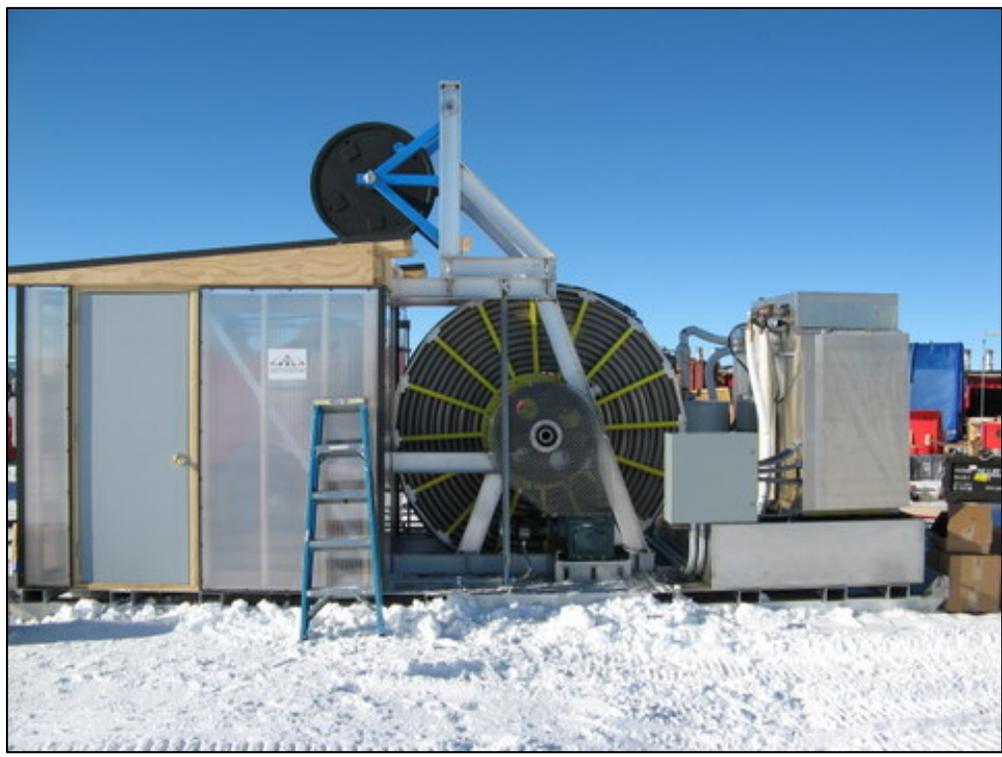
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Makes the firm holes needed to commence deep drilling independent of main drill system, closed loop electrically-powered glycol system

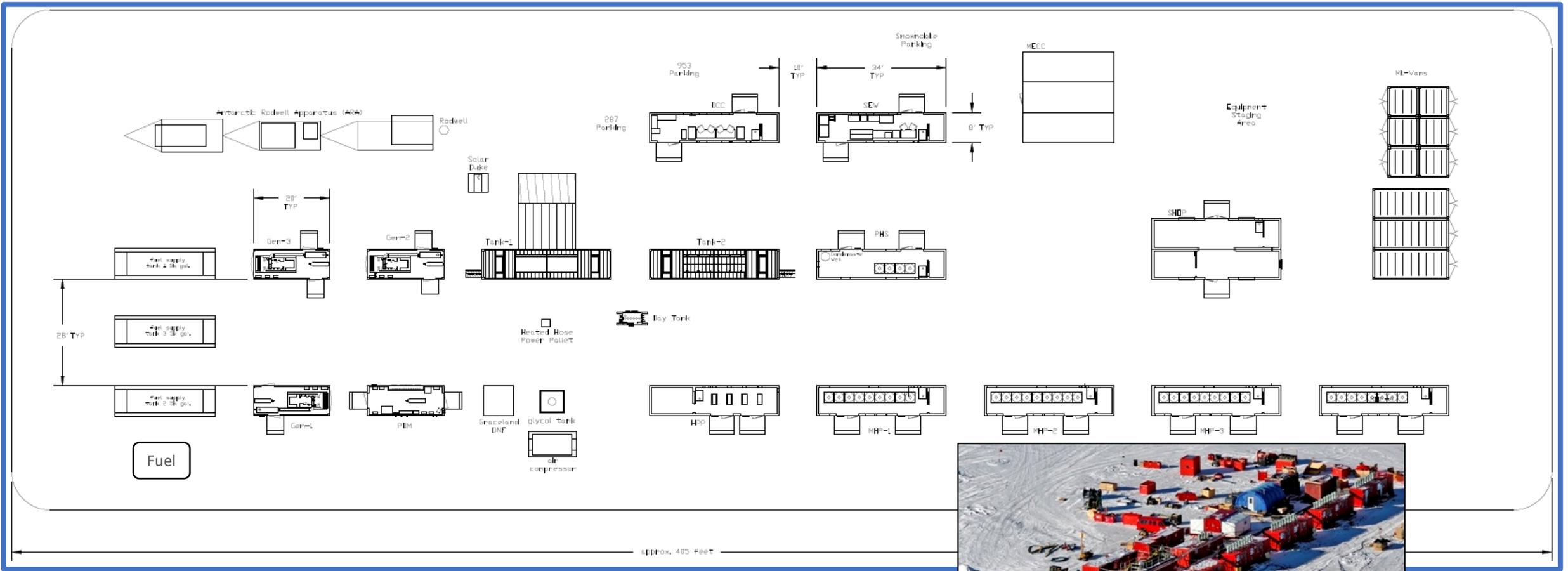
What's shipping?

- IFD sled
- IFD sheave
- IFD carrot
- IFD DNF



Other – What's Shipping

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Other – What's Shipping

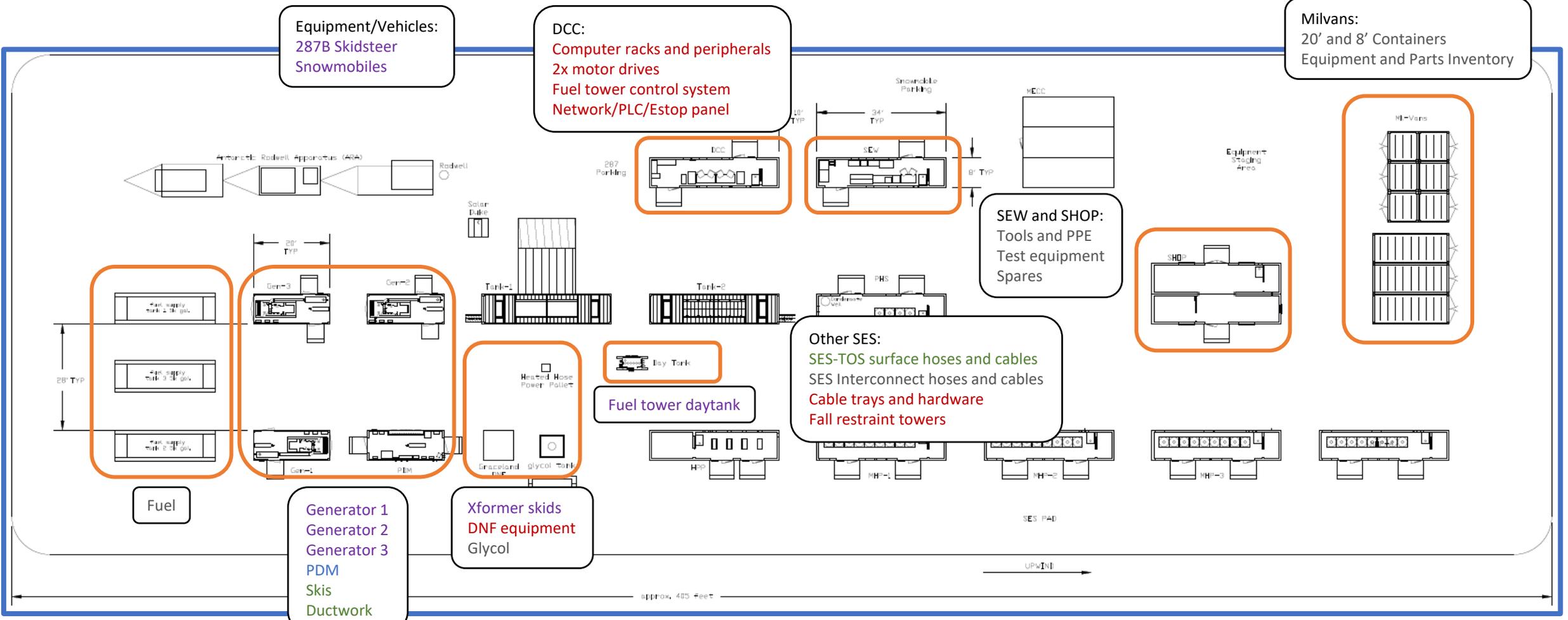
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Equipment/Vehicles:
287B Skidsteer
Snowmobiles

DCC:
Computer racks and peripherals
2x motor drives
Fuel tower control system
Network/PLC/Estop panel

Milvans:
20' and 8' Containers
Equipment and Parts Inventory



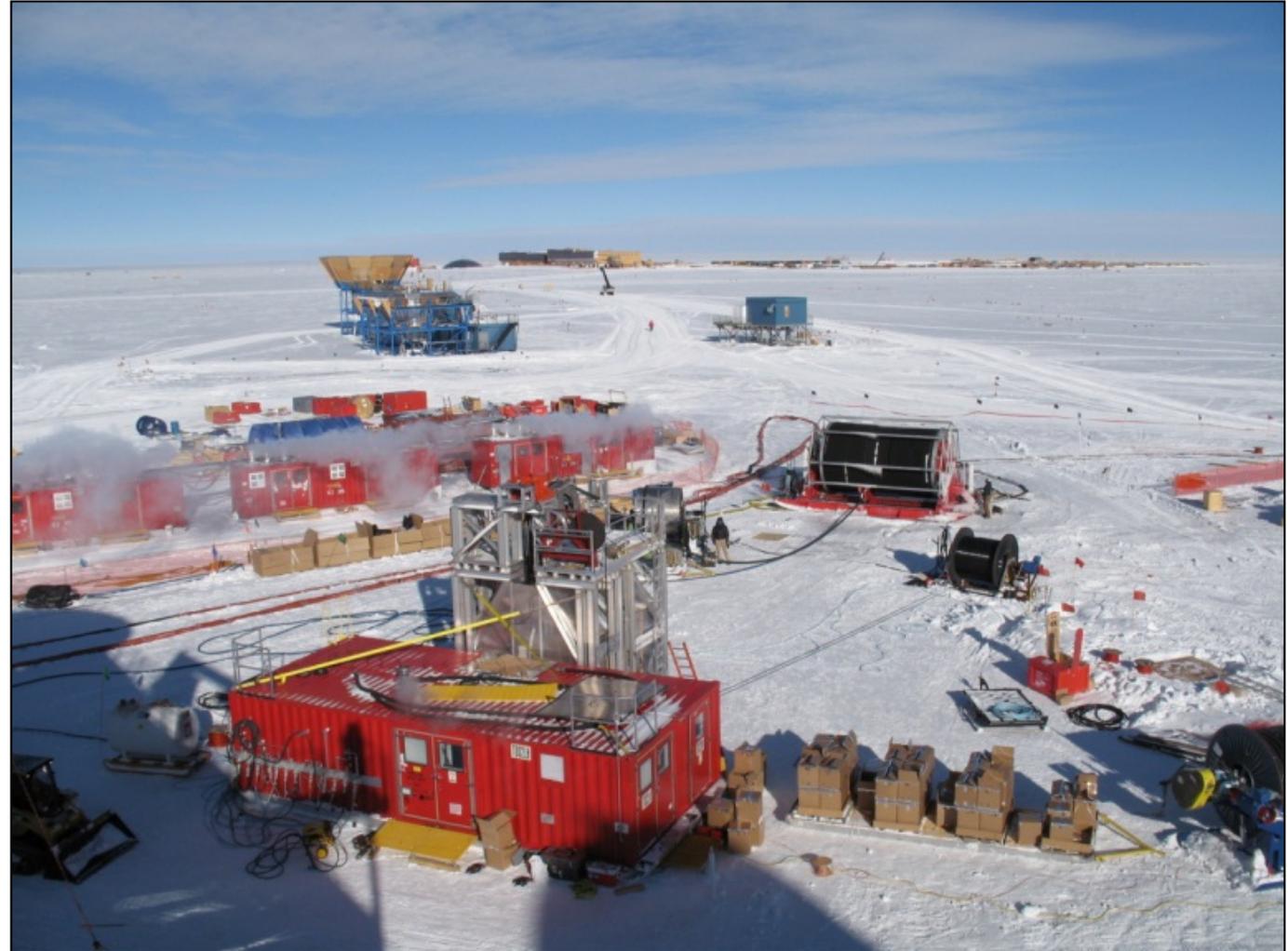
~400 ft

~120 ft



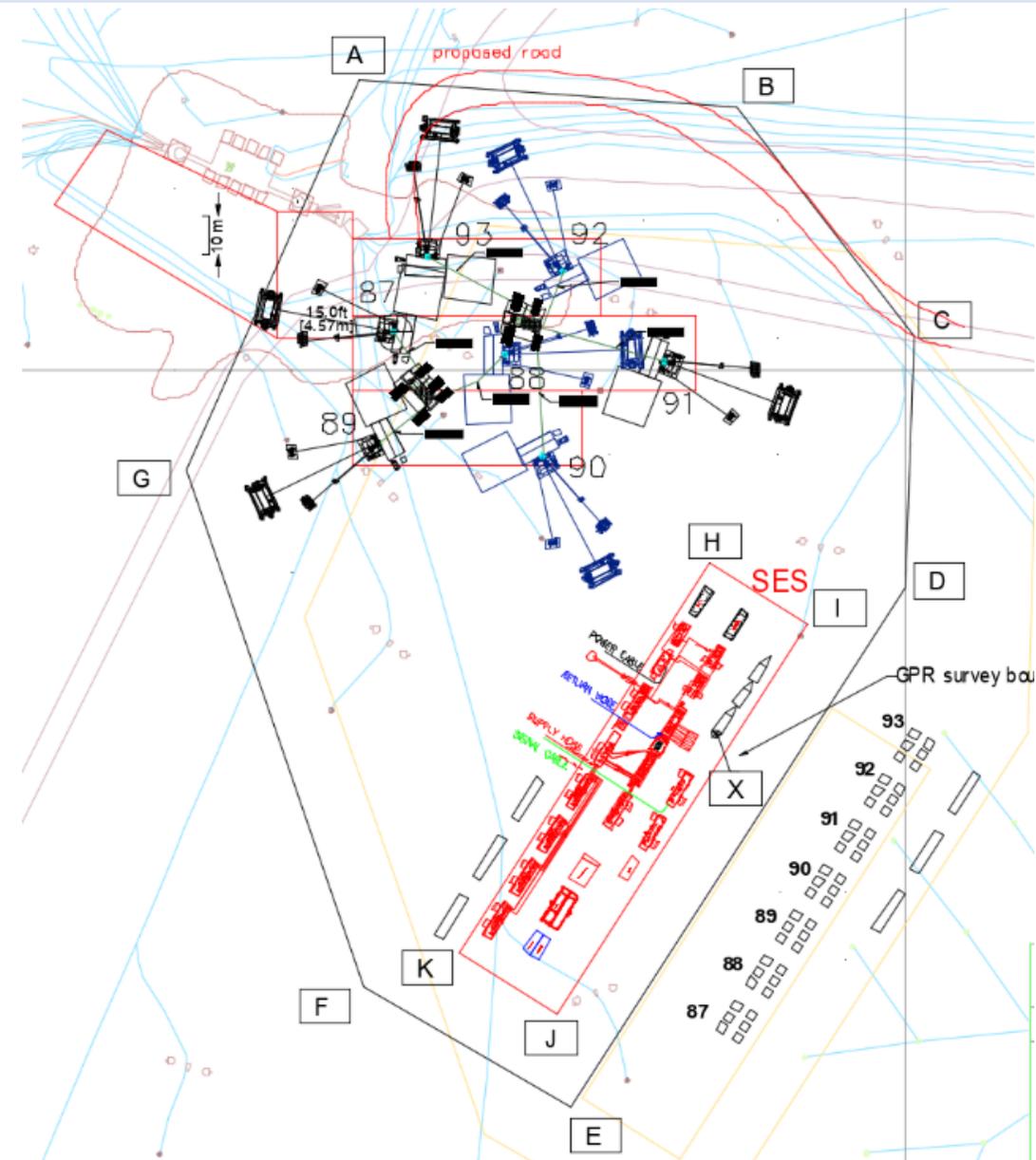
Hazards

- High voltage
- Hot water
- High pressure
- High tension
- Fire
- Noise
- Cold
- Freezing water lines
- Heavy equipment
- Lifting
- Trips, falls, cuts and scrapes



Operations

- Drill season operations
 - See Dar's talk
- Hole life cycle
 - Firm Drill
 - Deep Drill + Ream
 - Turn over to Deployment Team
 - Move reels to other TOS
 - Repeat
- Deep Drill and Ream
 - SES team ensures a reliable and steady flow of hot water is supplied to TOS
 - TOS team drives drill and maintains safe/smooth operation of reels
 - Driving drill involves constant monitoring of system parameters and referencing drilling strategy speed charts
- Other Operations
 - Instrument installation
 - Hole moves
 - Maintenance and repair



Drill Crew Makeup

24/7 Operation

3 Shifts

9 Drillers/Shift + Drill Manager

28 People

SKILLSETS

- Drill Manager
- Each Shift
 - Shift Lead
 - Deputy Shift Lead, Shift Safety Officer
 - DCC (SES) Operator
 - TOS Operator
 - Heater Expert
 - Electrical/Controls Expert
 - Mechanical Expert
 - Installation Experts
 - Equipment Operator
- Cross-Shift Expertise Required On-Site
 - Drill Engineer
 - Software Expert
 - Generator Tech
 - Electrician

Some key operations – examples of why 9 drillers/shift are required

Smooth Drilling

- 2 SES (DCC operator + oversight)
- 2 TOS (TOS operator + taping/oversight)
- 2 Setup other TOS
- 2 Maintenance and repair
- 1 Person off

9 TOTAL

Meals

- 2 SES
- 2 TOS
- 4 Meal
- 1 Person off

9 TOTAL

Hole Move

- 1 Installation setup
- 1 SES
- 1 Hose reel move
- 2 Other reels move
- 2 Surface supply hose move
- 2 Surface return hose move

9 TOTAL

Installation

- 3 installation
- 3 prepare SES for drilling
- 3 prepare TOS for drilling

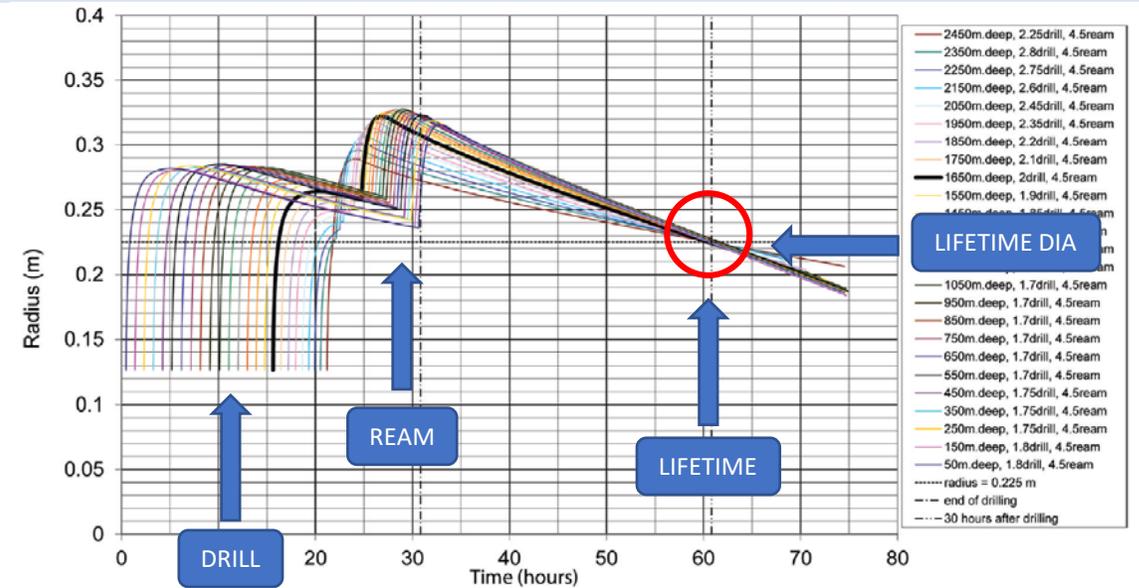
9 TOTAL



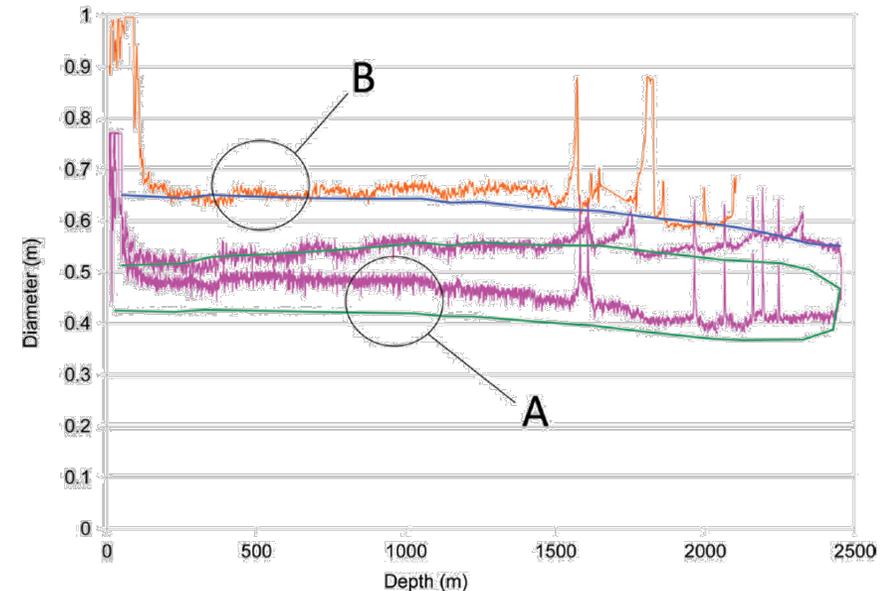
Thermal Drilling Model

- Model predicts hole profile during course of drilling/reaming
- Based on first-principals thermodynamics and heat transfer
- Includes heat loss through hose, ice temperature vs. depth, and freezeback
- Provides drill speed strategy, ream speed charts, drill time, fuel usage
- Compared against actual freezeback during Gen1
- Gen1: 45 hr holes -> 24 hr holes
- [Modeling hole size, lifetime and fuel consumption in hot-water ice drilling](#), 2014, Greener et.al.

Drill speed is iterated for constant assumed ream speed such that all depths are at the lifetime diameter at the expiration of the hole lifetime



A comparison of predicted (smooth line) and measured (jagged line) hole sizes (diameter vs depth in hole 40): (A) during drilling; (B) 4 hours after drilling was completed.



- Big complicated system, largest HWD ever
- Reusing proven equipment, resurrecting the EHWD
- Replacing equipment where needed, performing repairs and key upgrades
- Even though critical mass is already at Pole, lots of activities in North and lots of equipment Southbound
- A highly-skilled, well-designed drill team is essential to success



Thank you



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White Gen Trailer, RWCR, Container-B



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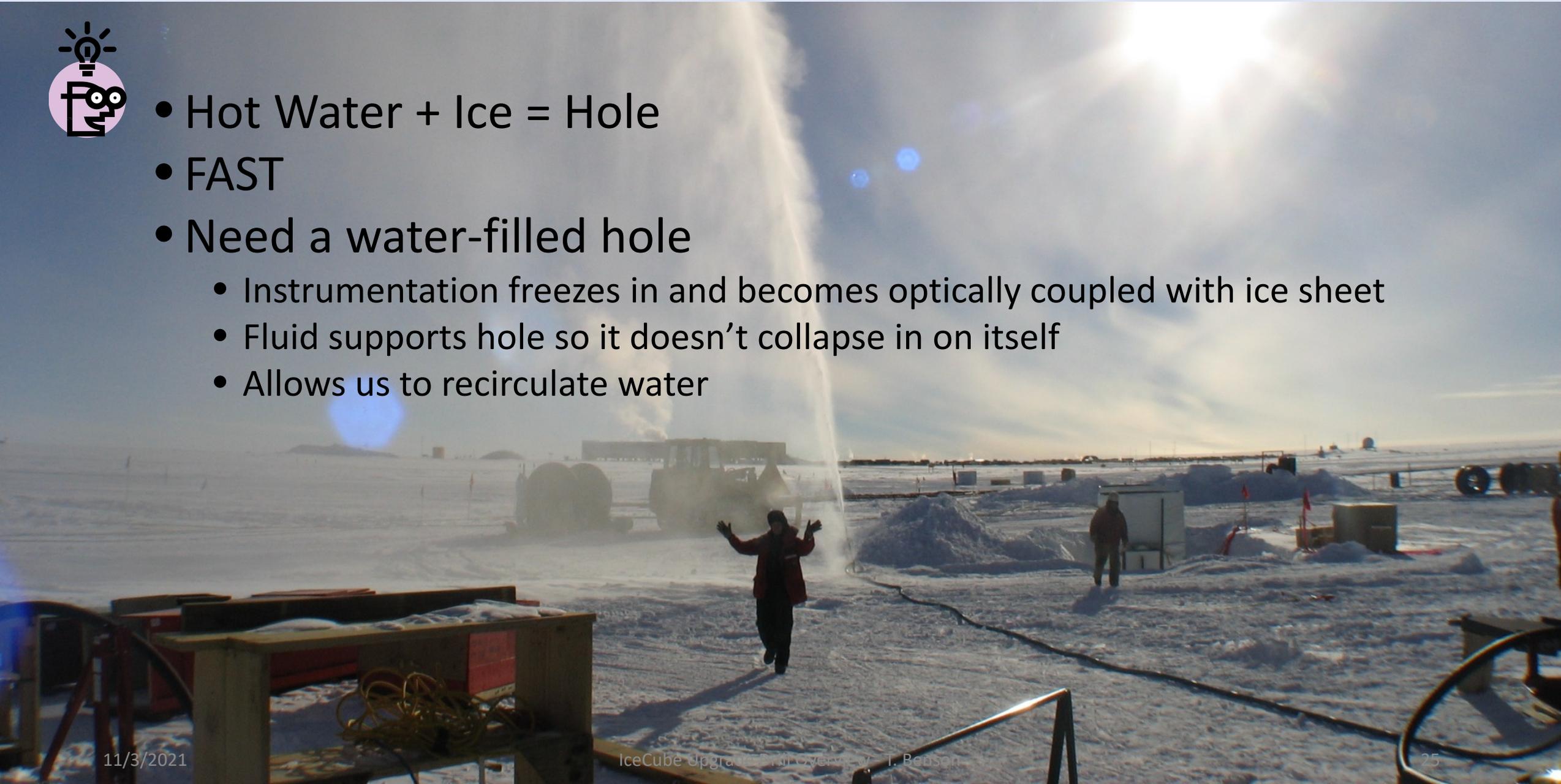


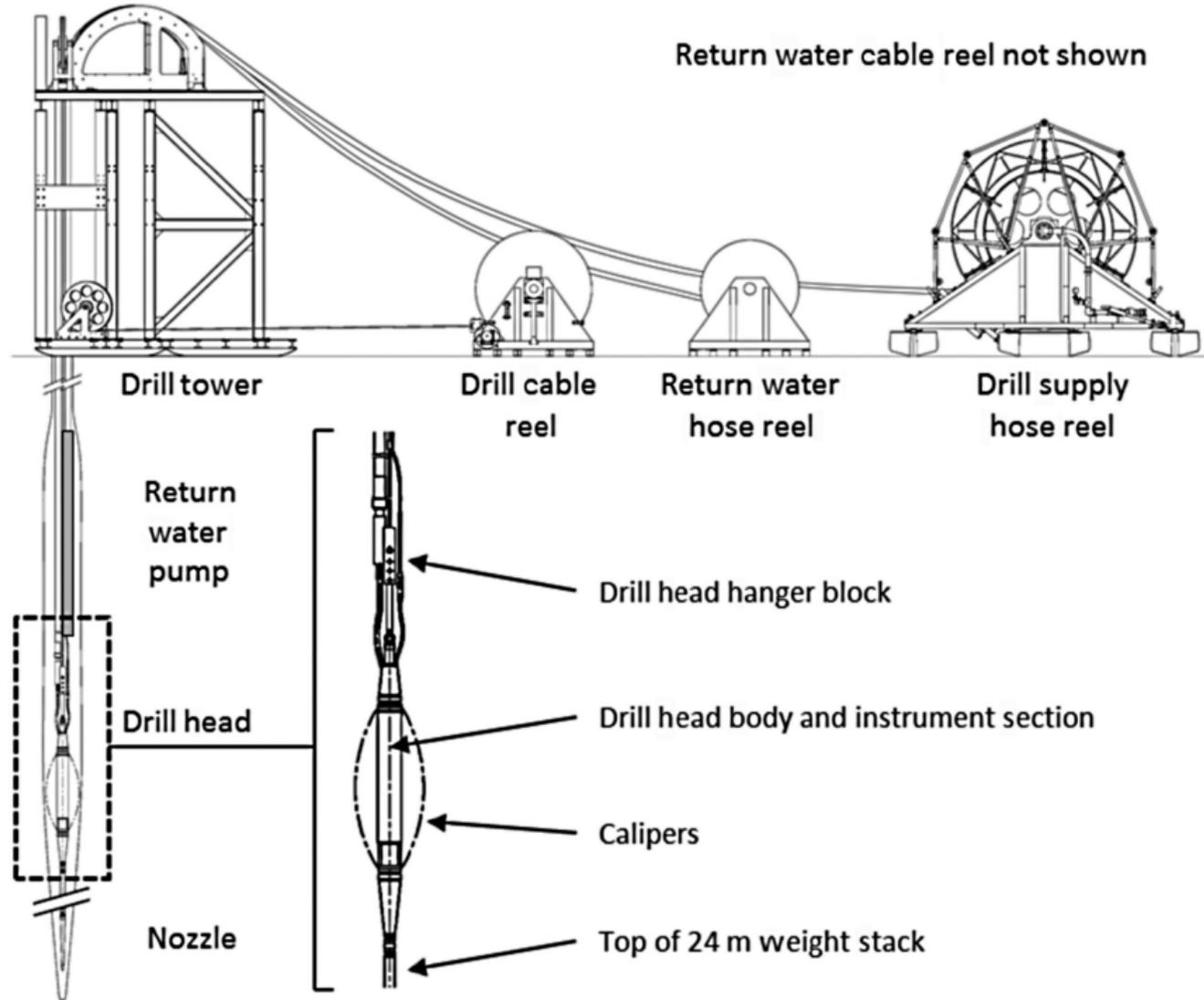
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Why a Hot Water Drill?



- Hot Water + Ice = Hole
- FAST
- Need a water-filled hole
 - Instrumentation freezes in and becomes optically coupled with ice sheet
 - Fluid supports hole so it doesn't collapse in on itself
 - Allows us to recirculate water





	18-19	19-20	20-21	21-22	Field Season 1	Field Season 2	Field Season 3	Total
						9 firn holes	7 deep holes	
Deep Drilling			X	X			53583	53583
Firn Drilling			X	X		3900		3900
Base Fuel	250 (A)	1000 (A)	X	X	3643	12346	17584	34823
Winter Heating						4305		4305
Total	250 (A)	1000 (A)			3643	20551	71167	96612

- High fuel efficiency is a basic drill system requirement
- Rigorous approach to logging fuel usage in real time
- Rich fuel-conscious culture
- See separate fuel talk

