IceCube Upgrade
Drilling & Installation

Terry Benson – Drill System Engineer
WBS 1.2 Implementation

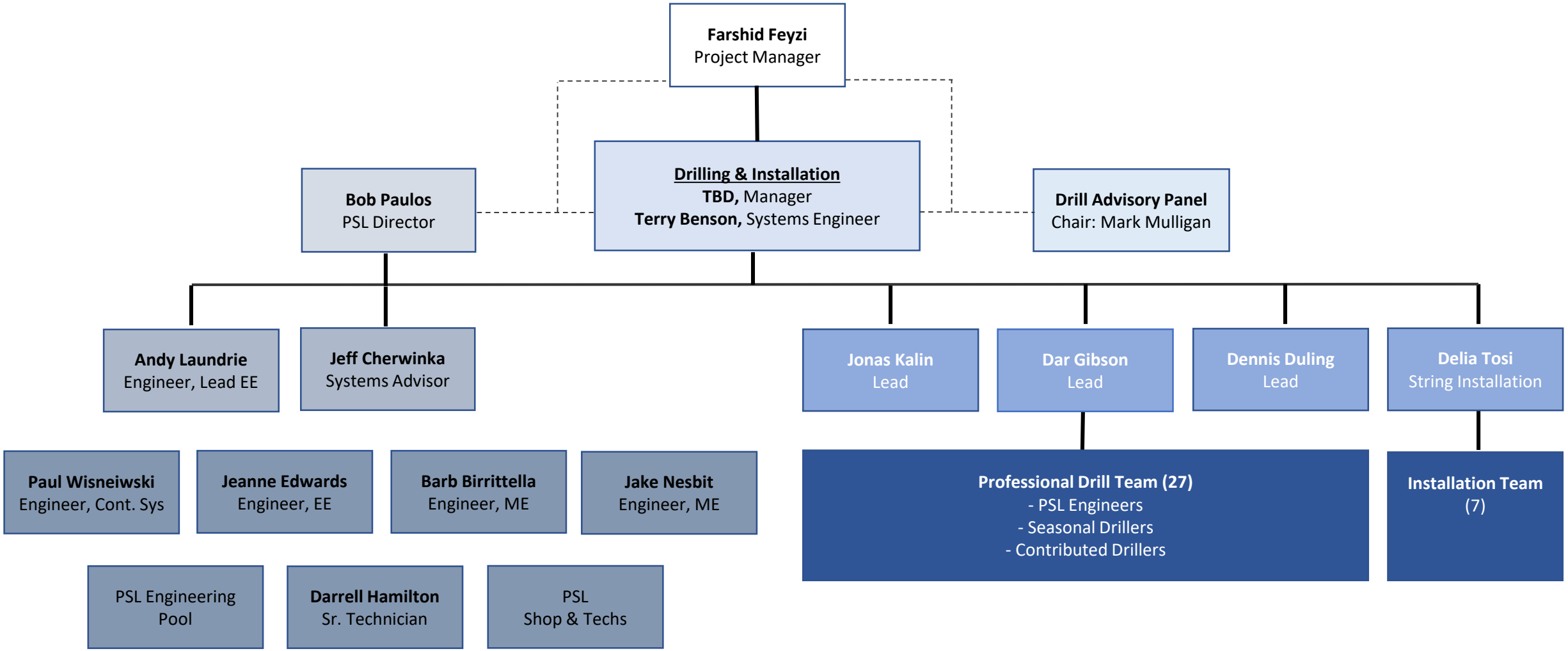
ICNO/Upgrade Project – NSF Site Visit Review
March 17, 2020

1.2 WBS Scope, Organization

WBS Description:

- Full development and operation of the hot water drill system in support of the IceCube Upgrade array installation. Includes resurrection of available Gen1 - Enhanced Hot Water Drill (EHWD) equipment; Design, procurement, and construction of new drill subsystems that, together with EHWD equipment, satisfies the project's drilling requirements; Integration, verification, and testing of the drill system and its subsystems; and field operation of the drill system to deliver required installation borehole specifications.

- **Summary: Rebuild the Gen1 EHWD; Safely drill 7 holes & install 7 strings in 22/23**
- L2 Lead: TBD / Terry Benson
- L3 Leads: Dar Gibson, Dennis Duling, Jonas Kalin, Delia Tosi (Installation)


Farshid Feyzi
Project Manager
Drilling & Installation
TBD, Manager
Terry Benson, Systems Engineer
Bob Paulos
PSL Director
Drill Advisory Panel
Chair: Mark Mulligan
Andy Laundrie
Engineer, Lead EE
Jeff Cherwinka
Systems Advisor
Jonas Kalin
Lead
Dar Gibson
Lead
Dennis Duling
Lead
Delia Tosi
String Installation
Paul Wisneiwski
Engineer, Cont. Sys
Jeanne Edwards
Engineer, EE
Barb Birrittella
Engineer, ME
Jake Nesbit
Engineer, ME
Professional Drill Team (27)
- PSL Engineers
- Seasonal Drillers
- Contributed Drillers
Installation Team
(7)
PSL Engineering
Pool
Darrell Hamilton
Sr. Technician
PSL
Shop & Techs

1.2: Implementation Management Turnover Plan

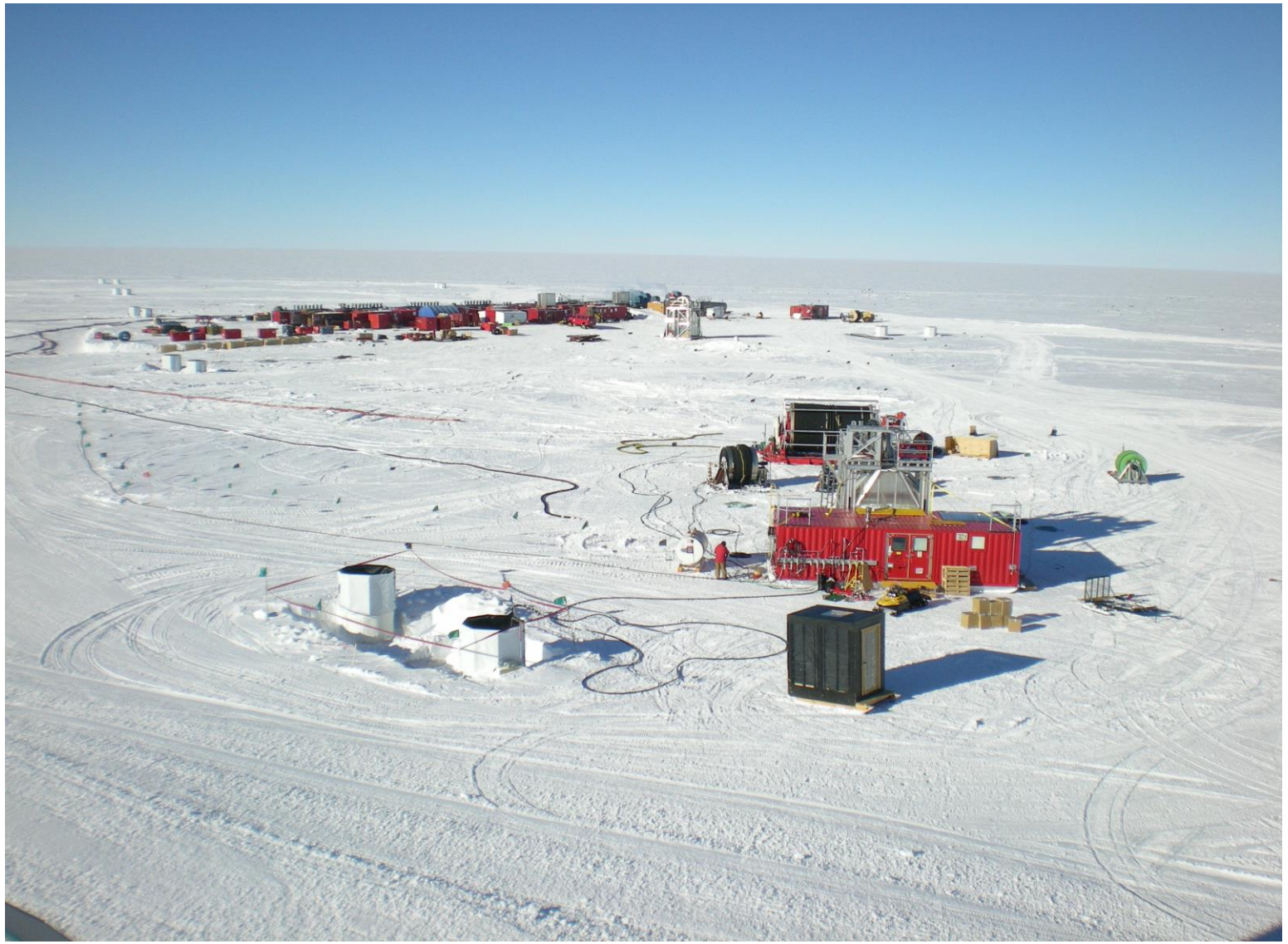
- L2 Drilling & Installation Manager: Tom Hutchings
  - Resigned Feb 21, 2020
- New L2 (Implementation Manager): TBD – To start April 1st
  - Maintain Drill Lead (L3): Dar Gibson
  - Maintain Installation Manager (L3): Delia Tosi

1.2: Staffing – FTE's

1.2 LABOR PROFILE	PY02	PY03	PY04	PY05
TOTAL HOURS	21,304	14,899	15,827	15,528
TOTAL FTE's	**11.8**	**8.3**	**8.8**	**8.6**
Personnel (FTE)				
L2 Implementation Manager (TBD)	1.0	1.0	1.0	0.75
L3 Drill Lead (Gibson)	1.0	1.0	1.0	0.75
L3 Installation Manager (Tosi)	0.3	0.3	0.5	0.5
Drillers, Full-Time	3.0	3.0	3.0	2.0
Drillers/Engineers (PSL, Seasonal, Subs, Etc)	6.5	3.0	3.3	4.6
ON ICE (Drill Personnel)	11	11	15	30
Contributed Drillers (included above)	(1)	(3)	(5)	(14)
ON ICE (Installation Personnel)	0	1	2	10
Contributed Installers (included above)	(0)	(0)	(1)	(6)

1.2: EHWD – Seasonal Equipment Site (SES)

1.2: EHWD – Tower Operations Site (TOS)



1.2: Deliverables

- Drilling:
  - 7 Holes in 1 drill season (2022/23)
  - 22m hole-to-hole spacing (+/- 3m) in center of IceCube array
  - 2600m depth, instrument physics region
  - Cleaner and reduced gas in physics region
  - 30 person drill team, 24 hr / 6 day operation
- Installation:
  - ~108 Instruments/hole

1.2: Overall Goals & Strategy

- Rebuild the EHWD: Drill & Instrument 7 holes in 2022/23
- Use Existing: Use as much of the existing EHWD equipment as possible
- Limit Replacement: Replace equipment only where obvious, for safety, or reliability
- Limit Upgrades: Upgrade only where necessary due to obsolescence, technology, safety
- Recruit Experience: Recruit experienced team of hot water drillers
- Improve Hole Ice Quality: Manage condensate and add filtration systems
- Value Engineering: Applied throughout design/rebuild
- Utilize Traverse: Use the USAP Traverse as much as possible

1.2: PY02 Planned v. Actual (Off-Ice)

Major Activity - Planned	Actual
Initiate Drill Hose Procurement	Initiated (in fabrication)
Initiate Drill Cable Procurement	Initiated
Evaluate Control System and Develop Conceptual Design	Completed (some activities lag)
Recruit Drill Leads	Completed
Overhaul Independent Firn Drill (IFD)	Completed & Shipped
Restart PSL Test-Bed, Begin Control System testing	Completed
Procure & Ship Skidsteer and Snowmobiles	Completed
Transfer EHWD Custodianship (ASC, UNL)	Complete (w/final documentation needed)
Overhaul Generator 1	Completed & Shipped
Drill Heads: Begin Testing/Inspection	On schedule
Form & Engage Drill Advisory Panel	Completed
Procure Heater, Preheat & EHWD Repair Parts	Behind schedule (compiling 19/20 findings)

1.2: PY02 Planned v. Actual (On-Ice)

Major Activity - Planned	Actual
Gen 2 & 3 Repairs, Tune, Prepare	Completed (some minor repairs remain)
Power Distribution Module, Repair & Synchronize	Completed & traversed to NPX
Secure and Organize UNL Equipment	Completed
EHWD Inspection, Evaluation, Inventory	Completed
Winches – Inspect & Test	Completed
Control System – Test/Integrate Prototype Motor Drives	Completed
ICL: Evaluate Cable Entry and Routing	Completed
Deploy Team of 8 to NPX	Deployed Team of 11 (+1 lead)
Retrograde of all damaged/suspect equipment	Completed, en route
Perform GPR Survey at Hole Locations	Completed (awaiting CRREL interpretation)
Fuel Tower Inspection	Completed (better than planned)

1.2: EHWD Initial Assessment

- EHWD in better condition than anticipated
  - No obvious/major obstacles (retro still to be tested, more discovery work)
- Generators & PDM will provide power and synchronize as needed
- Main Heaters preliminary tests complete, considered reliable
- Control System remains the critical path and is being addressed
  - Recruiting CS Engineer/Drill Lead
  - Finalizing requirements and focusing on this area
  - Motor drive replacement is well understood and field confirmed
- Rodwell Module replacement configuration design is a priority
- Drill Leads are proven

1.2: Support & Logistics Assessment

- ASC Support is reliable and responsive

- USAP Logistics reliability is a high risk
  - People and Cargo, Traverse vs. Plane
  - IceCube Upgrade / ASC engaged in regular meetings, started 3/5/2020
  - Ratcheting up communication and clarifying cargo details and priorities

1.2: 2020/2021 Goals

- Drilling:
  - Drill Hose: Complete procurement and ship to McMurdo
  - Drill Cable & Winch: Procure new cable, recondition winch
  - Control System:
    - Recruit CS Engineer (in progress)
    - Procure/Configure all Motor Drives (~32)
  - EHWD Repair Parts: Procure, assemble (as needed), ship
  - Generators (3): Traverse to NPX. Complete repairs to Gen2 and integrate Gen1
  - Rodwell subsystem: Complete replacement design/plan
  - Drill Heads: Complete navigation, sensor, and pressure testing
  - Drill Advisory Panel: Engage (complete, March 3)
  - Traverse: Gen2, Gen3, IFD, Fuel Tower, 20' milvan (empty), UNL Equipment
  - Fly to NPX: Skidsteer, Repair parts; Motor Drives; Gen1
- Installation:
  - Develop DOM installation procedures, staffing req's, coordination

ASC Support Requirements (20/21):

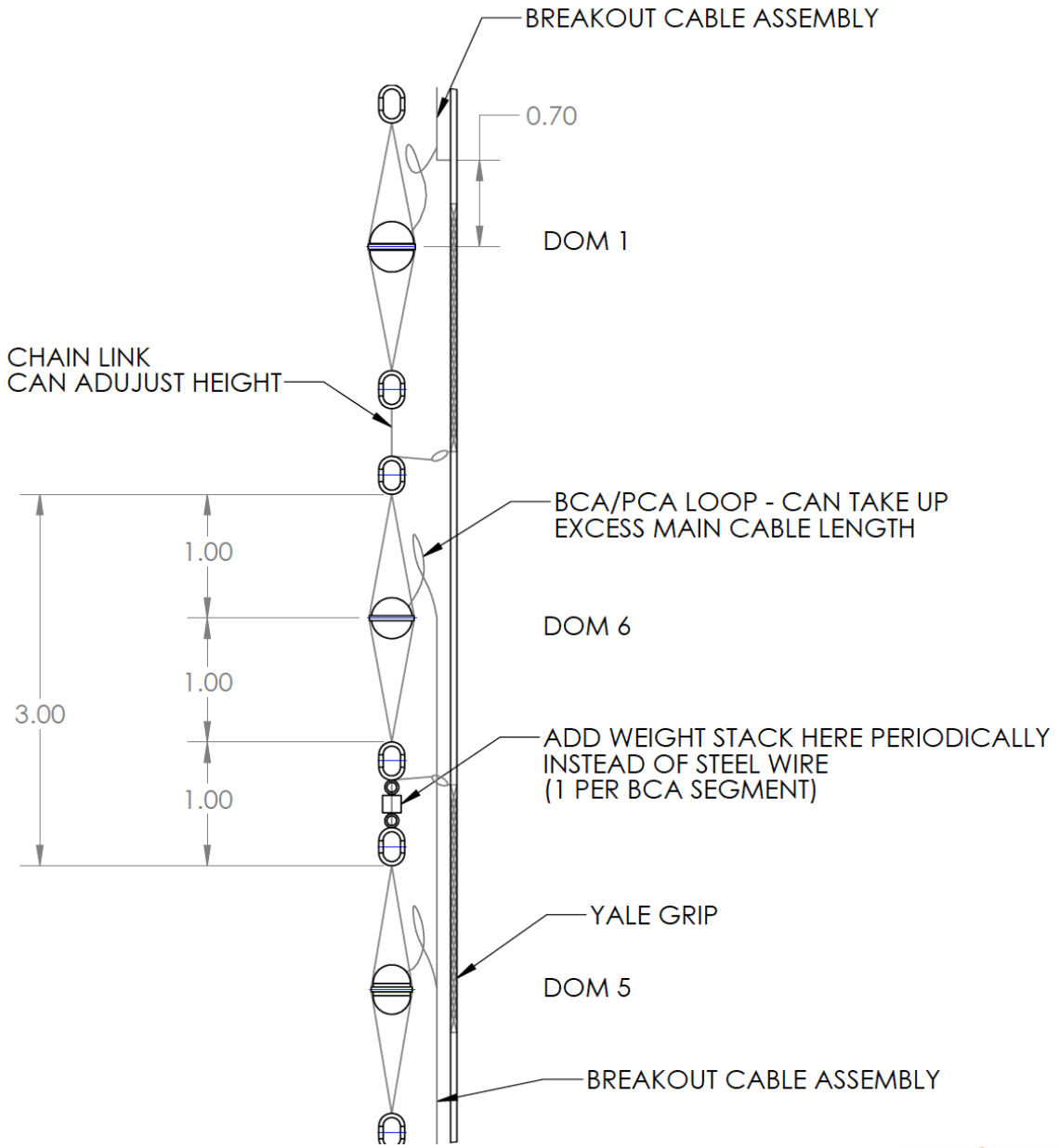
- Population:
  - South Pole: 12 beds (up to 20 deployments)
  - McMurdo: 1 in late Oct
- Cargo:
  - Vessel: 93,000 lbs (Drill hose, cable, winches, etc)
  - Traverse: 192,000 lbs (Gen2, Gen3, IFD, etc)
  - Fly: 43,000 lbs (Gen1, Control System, Skidsteer, Elec Panels)
- Fuel: ~1,000 gals (AN-8)
- Seed Water (2000 gals) for Heater Testing
- Equipment: Pooled van/truck, loader and skidsteer, snowmobiles
- Trades: Being defined with ASC throughout March
  - (Gen-tech, Electricians, welder, etc)
- Other: Develop ICL Tower Surface Cable Entry Plan

1.2 Installation

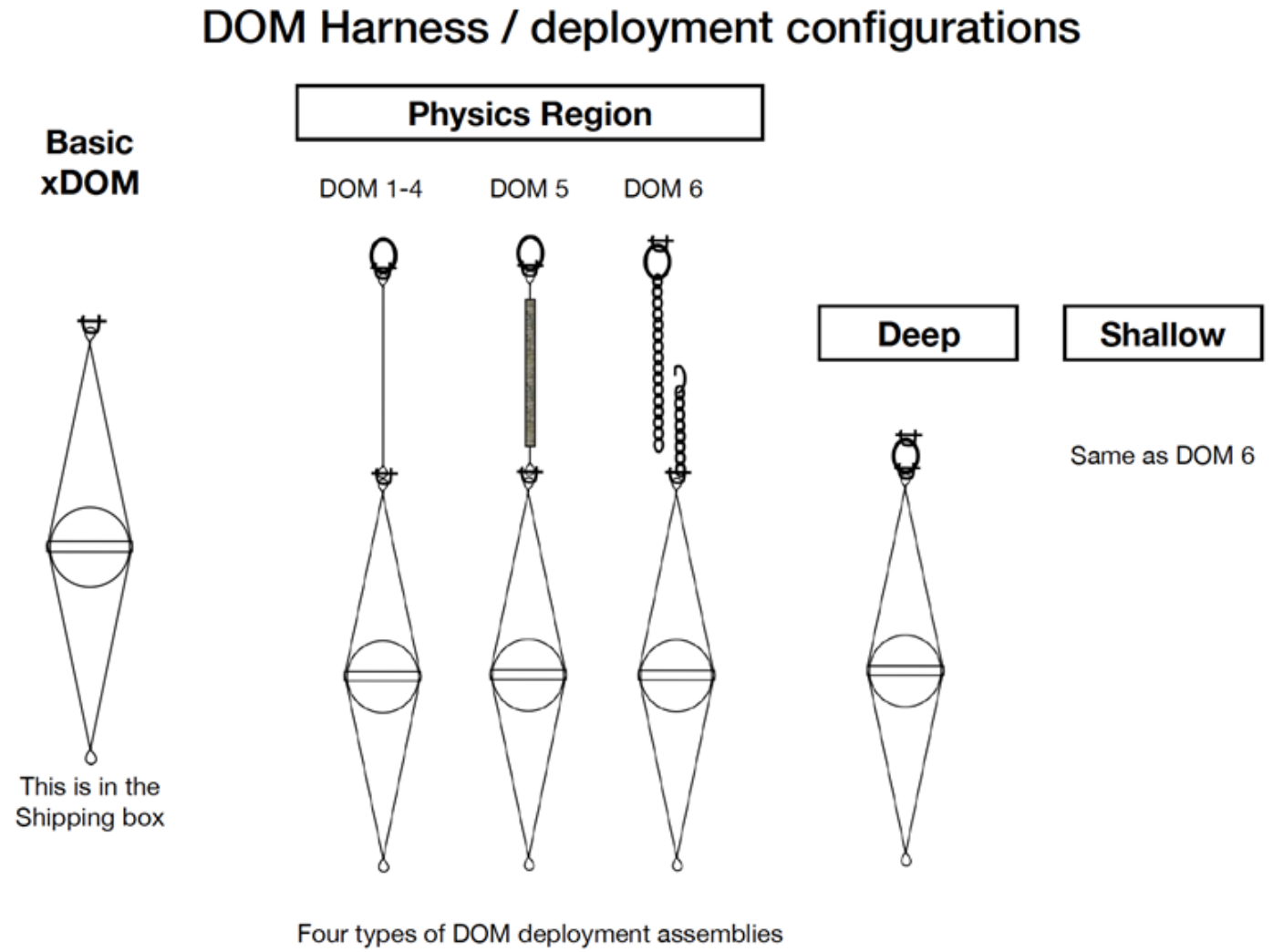
L3 Lead: Delia Tosi :

Installation: Gen 1 Comparison		
	Gen1	Upgrade
DOM/Device Qty	60	108 to 115
DOM Spacing	17m	3m to 175m
Depth	2450m	3 to 2450m, 4 to 2600m
Max Load on Cable	~2800 lbs	~2400 lbs
Max Load on Module	~1300 lbs	~1800 lb
Team	8	10
Deploy Time	12 hrs	20-24 hrs

Gen1 procedures are being adapted to take into account different sensors configuration, heavier DOMs, different DOM spacing



1.2 Installation



Extender: extends the length of the module to 3m in physics region

Weight: 16 kg/6 DOMs to counterbalance the buoyance

Chain: used to match up lengths between cable and DOM string in physics region, every 6 DOMs; as in Gen1 in shallow region

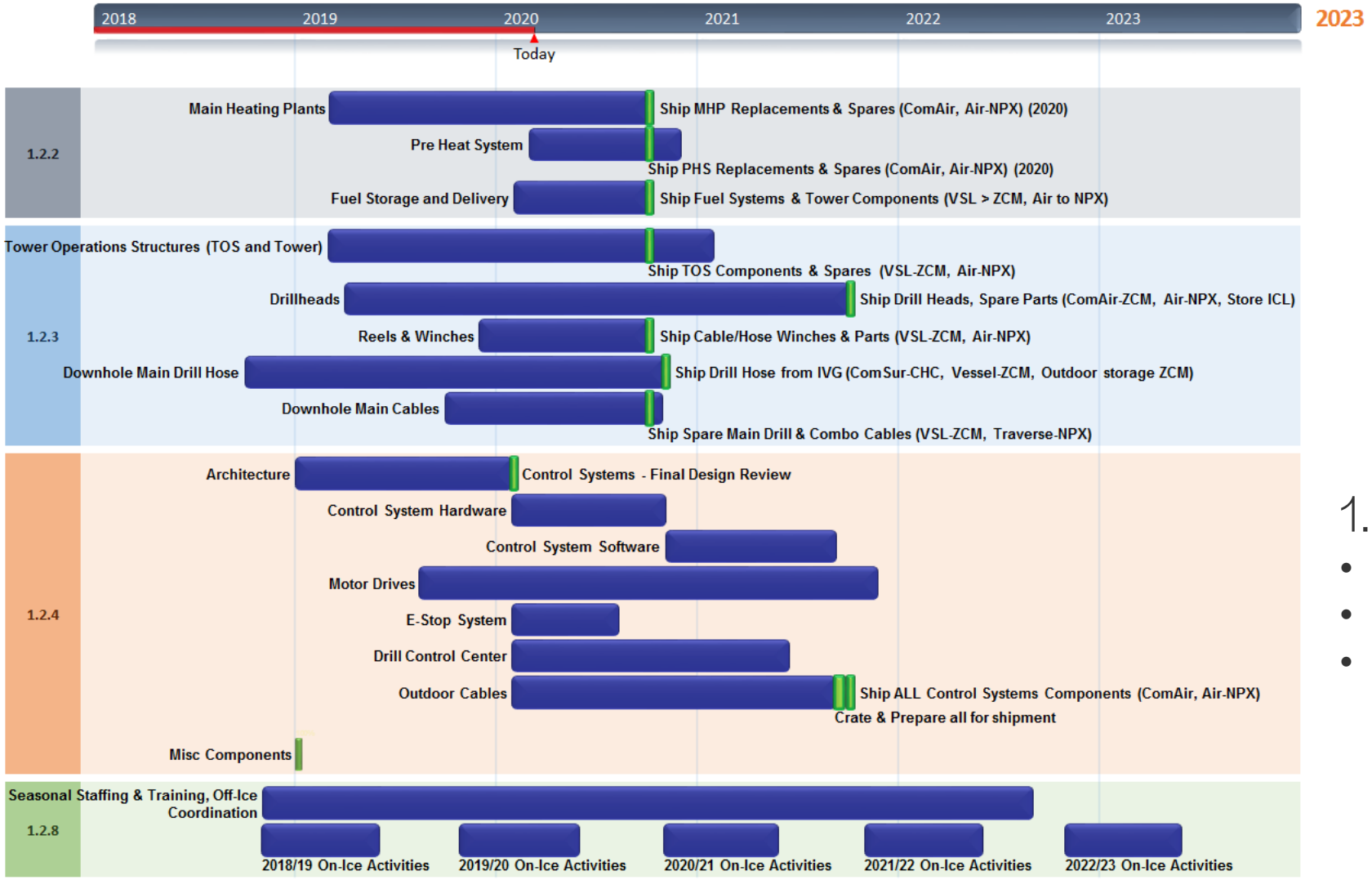
SAME MODULE FITS EVERYWHERE

1.2: Implementation Budget

1.2 Implementation	Project Year					
WBS L3	Year 1* Actuals	Year 2	Year 3	Year 4	Year 5	WBS Total
1.2.1 Drill Management and System Engineering	$343,754	$416,819	$356,402	$414,971	$298,897	$1,487,090
1.2.2 Thermal Plant	$12,602	$164,422	$0	$0	$0	$164,422
1.2.3 Tower Operations Site	$346,158	$1,497,854	$53,540	$0	$0	$1,551,393
1.2.4 Computing and Control Systems	$302,941	$650,062	$777,186	$196,650	$72,812	$1,696,710
1.2.5 Electric Generation and Distribution	$137,447	$95,199	$4,519	$0	$0	$99,718
1.2.6 Water Handling Systems	$21,996	$339,931	$6,722	$0	$0	$346,653
1.2.7 Support Equipment	$254,120	$198,670	$64,416	$69,255	$22,565	$354,906
1.2.8 Drill Field Seasons	$138,777	$729,676	$362,298	$840,534	$1,068,546	$3,001,054
1.2.9 String / Cable Installation	$15,989	$119,862	$50,736	$77,730	$66,487	$314,815
Annual Total	$1,573,783	$4,212,494	$1,675,819	$1,599,141	$1,529,307	$9,016,760

* - Year 1 is not included in totals

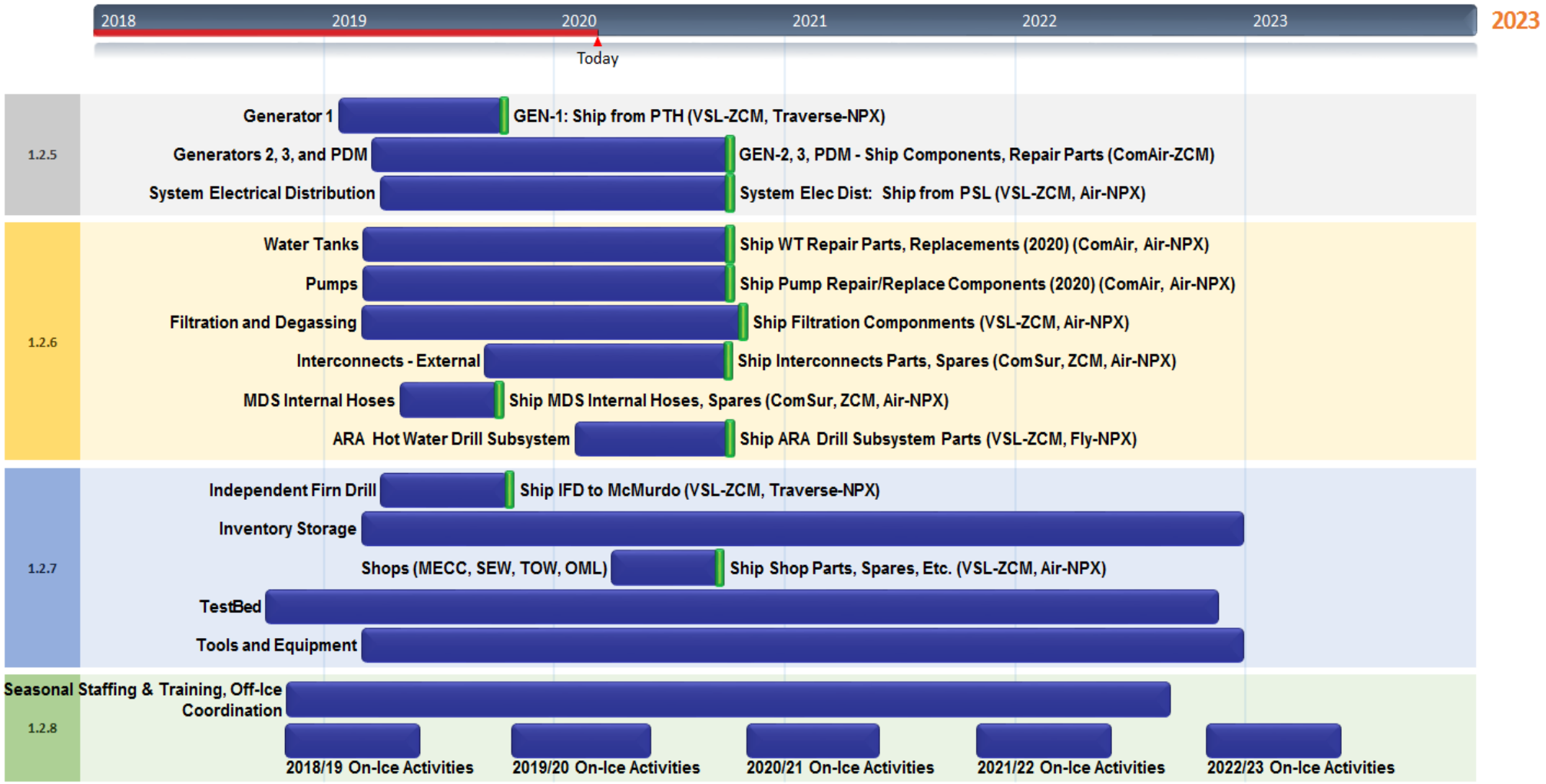
1.2: Implementation Schedule



1.2.4 – 1.2 Critical path

- Recruiting CS Lead (May 1)
- Focused attention
- Additional staffing

1.2: Implementation Schedule



1.2 Milestones and Key Activities

WBS	Milestone or Activity	Scheduled Finish Date	Actual
1.2.4.1.3	Control System - PDR	8/13/2019	12/6/2019 A
1.2.5.1.7	Gen1 - Ship	10/9/2019	10/20/2019 A
1.2.7.1.5	Ship IFD	10/18/2019	11/15/2019 A
1.2.3.4.4	Procure Drill Hose (place order)	11/25/2019	10/18/2019 A
1.2.4.1.5	Control System - FDR	1/28/2020	
1.2.2.3.5	Fuel Tower Final Design Review	5/22/2020	
1.2.2.1.5	Ship MHP Components	10/1/2020	
1.2.2.2.3	Ship PHS Components	10/1/2020	
1.2.2.3.9	Ship Fuel Tower Components	10/1/2020	
1.2.3.4.10	Ship Drill Hose	10/1/2020	
1.2.6...	Water Handling – Ship Components	10/1/2020	
1.2.7.5.3	Ship 287B and Snowmobiles	10/1/2020	
1.2.3.2.8	Ship Drillheads	10/1/2021	
1.2.4.9	Control System Ship	10/1/2021	
1.2.1.2.4.2	Drill Readiness Review	4/15/2022	

1.2 PY02/03 Key Activities

- Feb 18: Season Debrief / Strategic Planning - Completed
- Mar 3: Drill Advisory Panel Meeting - Completed
- Mar 5: ASC Support Planning Meeting - Completed
- April 1: Recruit Control System / Drill Lead (Kalin)
- April 30: PSL Test Bed Ready / Retro from Pole Arrives
- May 1: Recruit Control System / Drill Lead (Kalin)
- Sept 30: Ship all repaired equipment / procured parts to NPX
- Sept 30: Ship Main Hose from Italy & PSL to NPX
- Nov 15: Deploy Team (12)
- Nov-Feb: EHWD Repairs and Rebuild, CS Integration, Testing

1.2 Risks

1. Major Injury
2. Logistics & Support
3. Control System
4. Recruiting Experience
5. Mechanical Failure/Stuck Drill
6. EHWD Cold Soak and Aging (better understood)
7. Heater Reliability (better understood)
8. Generators (mostly understood)
9. Clean Water and Degassing (new requirements & drilling strategy)

1.2 Remaining Issues and Challenges

- Recruiting L2 manager
- Control System (focused attention)
- Recruiting & Retaining Experience
- USAP Cargo Support
- Budget Limitations

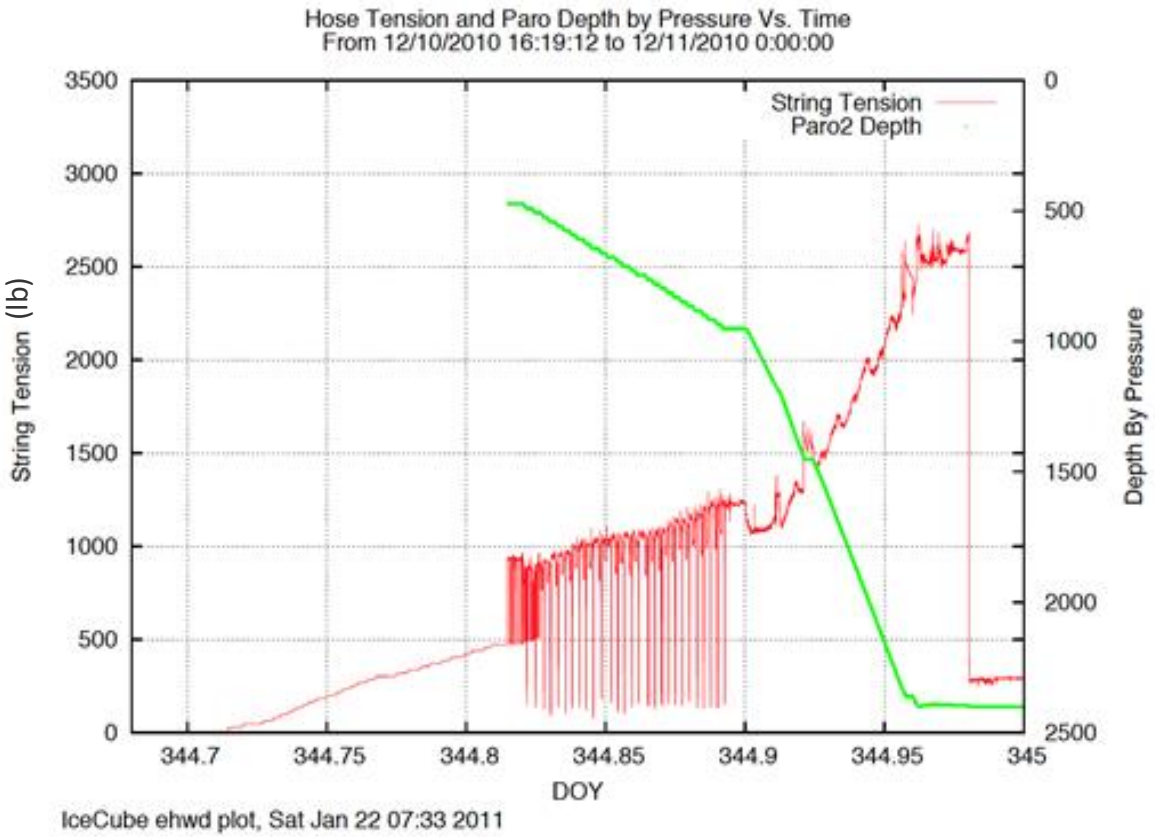
Thank you!

Backup

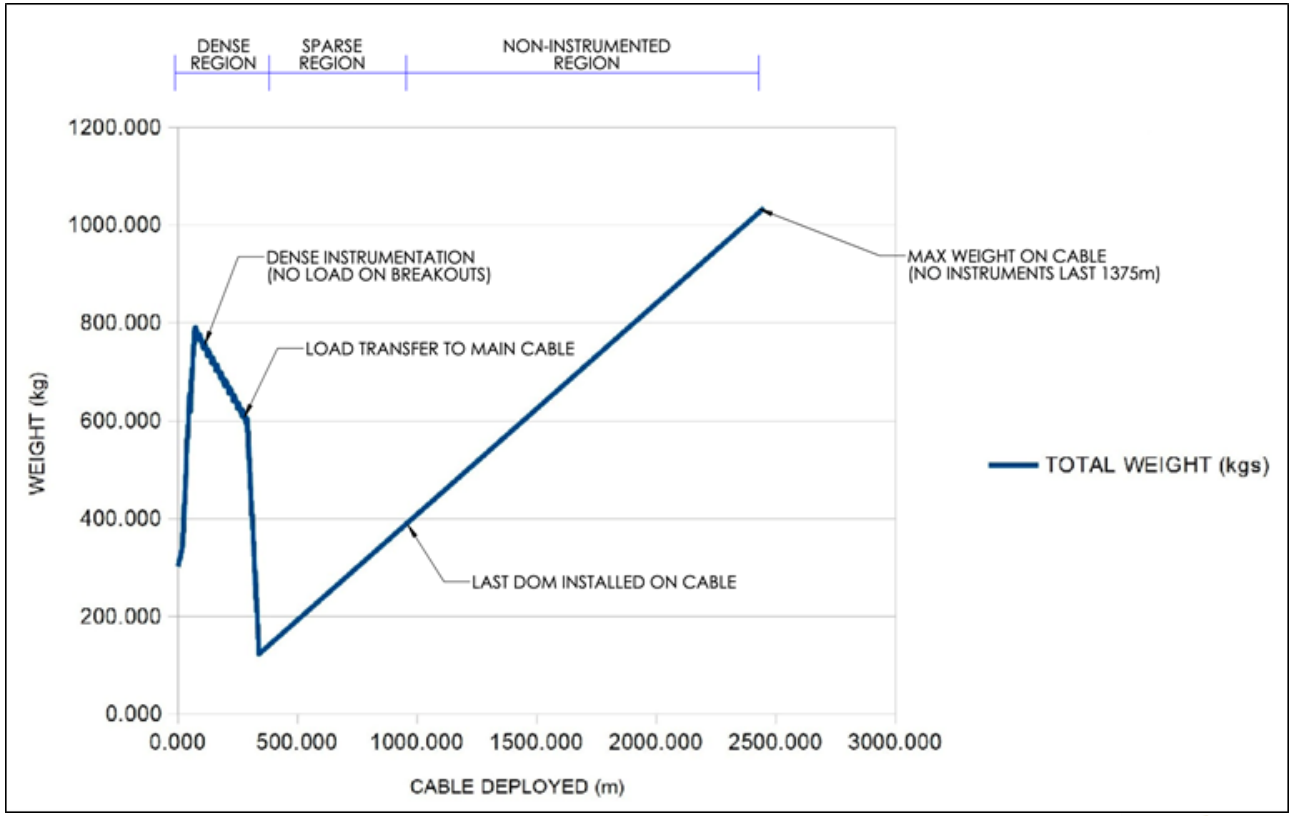
1.2 Installation - Loads

Installation: Gen 1 Comparison		
	Gen1	Upgrade
Max Load on Cable	~2800 lbs	~2400 lbs
Max Load on Module	~1300 lbs	~1800 lb

Gen 1



Upgrade



1.2: 2021/2022 Goals

- Drilling:
  - Stage & Commission EHWD
  - Wet-Test All Systems (possibly drill Rodwell)
  - Drill Hose: Deliver to NPX; Spool onto MSHR, Winter Store as DNDF
  - Drill Cable & Winch: Deliver to NPX: Load balance with MSHR
  - Control System: Complete system build; Stress Test
  - Generators: Finalize Synchronization and testing
  - Rodwell: Commission System
  - Independent Firn Drill: Commission and Drill 8 Firn Holes
- Installation:
  - Set-up MECC; Stress test systems and procedures
- Other:
  - ASC to Complete ICL/Tower Modifictions
  - Install SJB's, Trench & Run Surface Cables to ICL

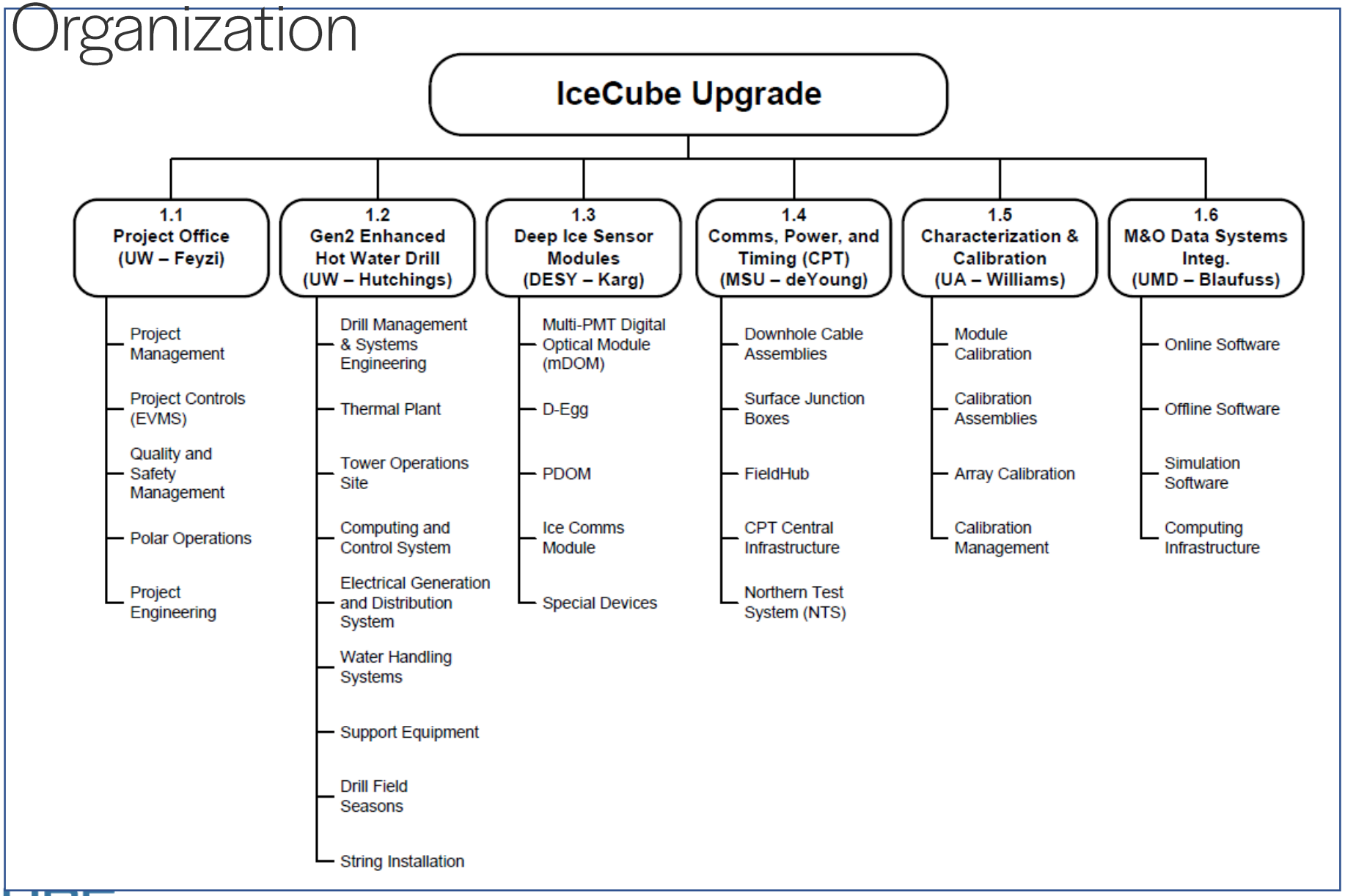
1.2: 2022/2023 Goals

- Drilling:
  - Start EHWD
  - Control System: Final safety tests
  - Rodwell: Re-establish
  - DRILL all 7 Holes

- Installation:
  - Establish DOM Handling Module (MECC)
  - Pre-Test DOM's as they arrive
  - INSTALL all 7 Strings

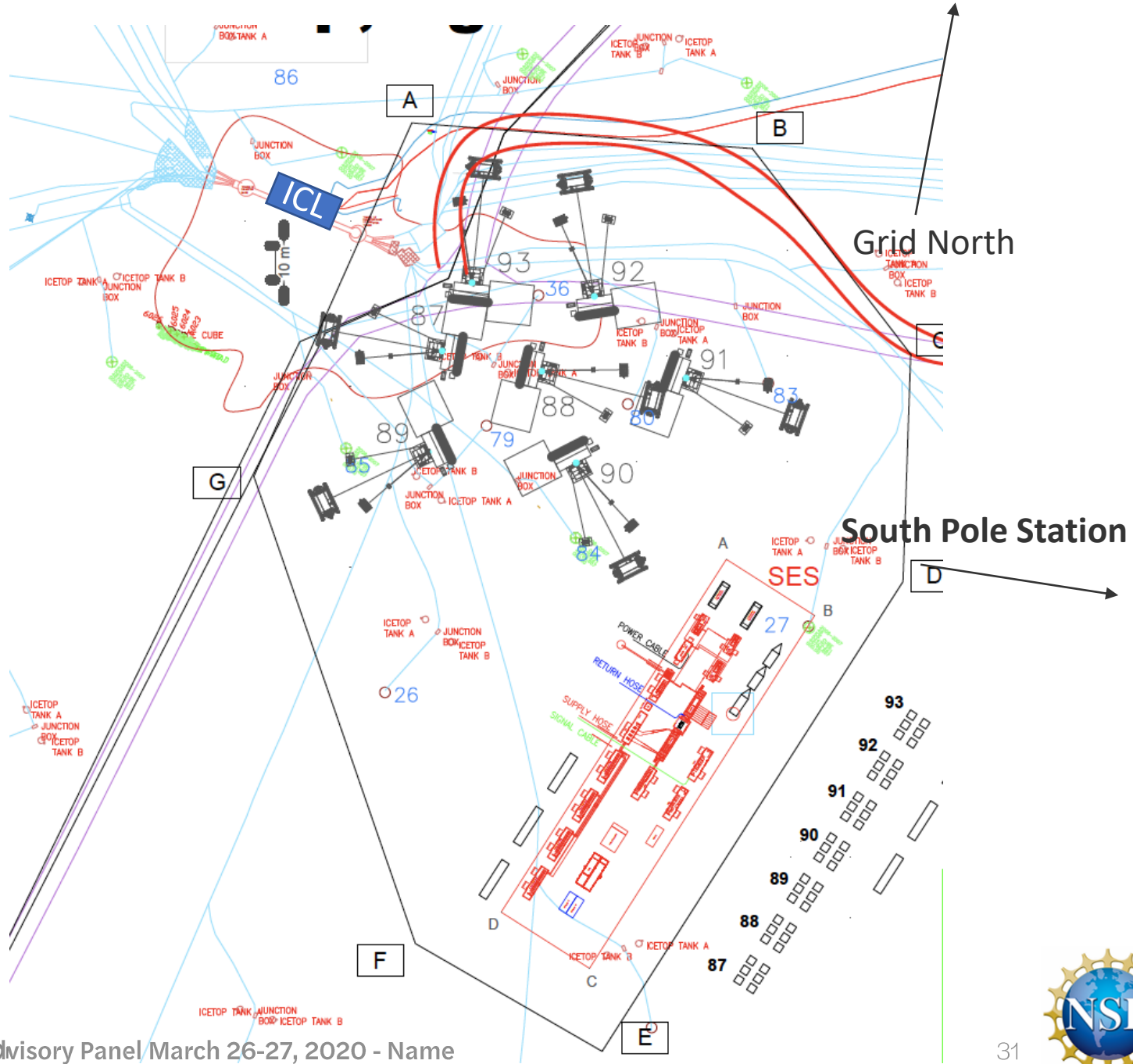
- Other:
  - Excavate SJB's; Trench & Cable Runs to Holes

Level 3 Organization

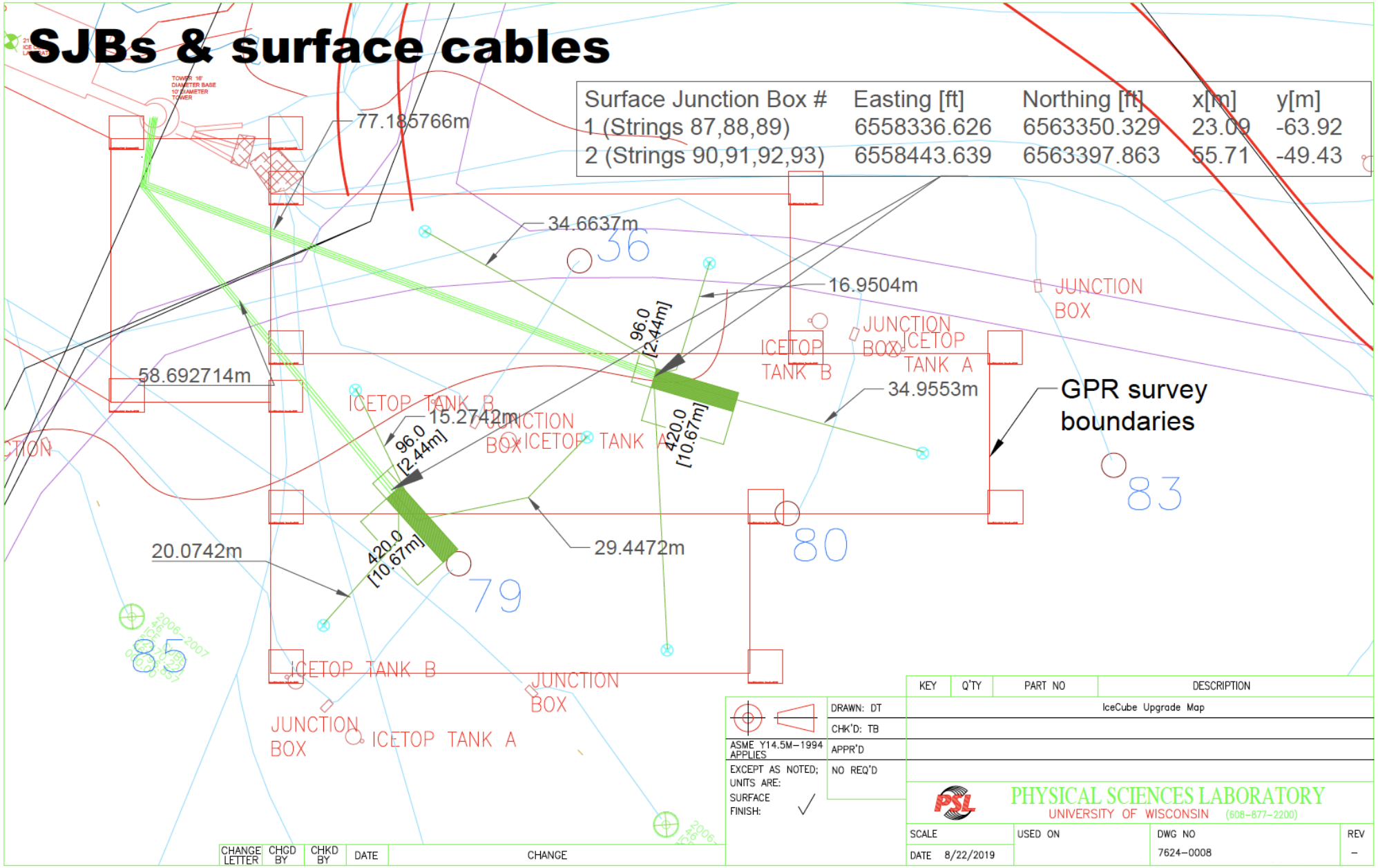


Surface Plan

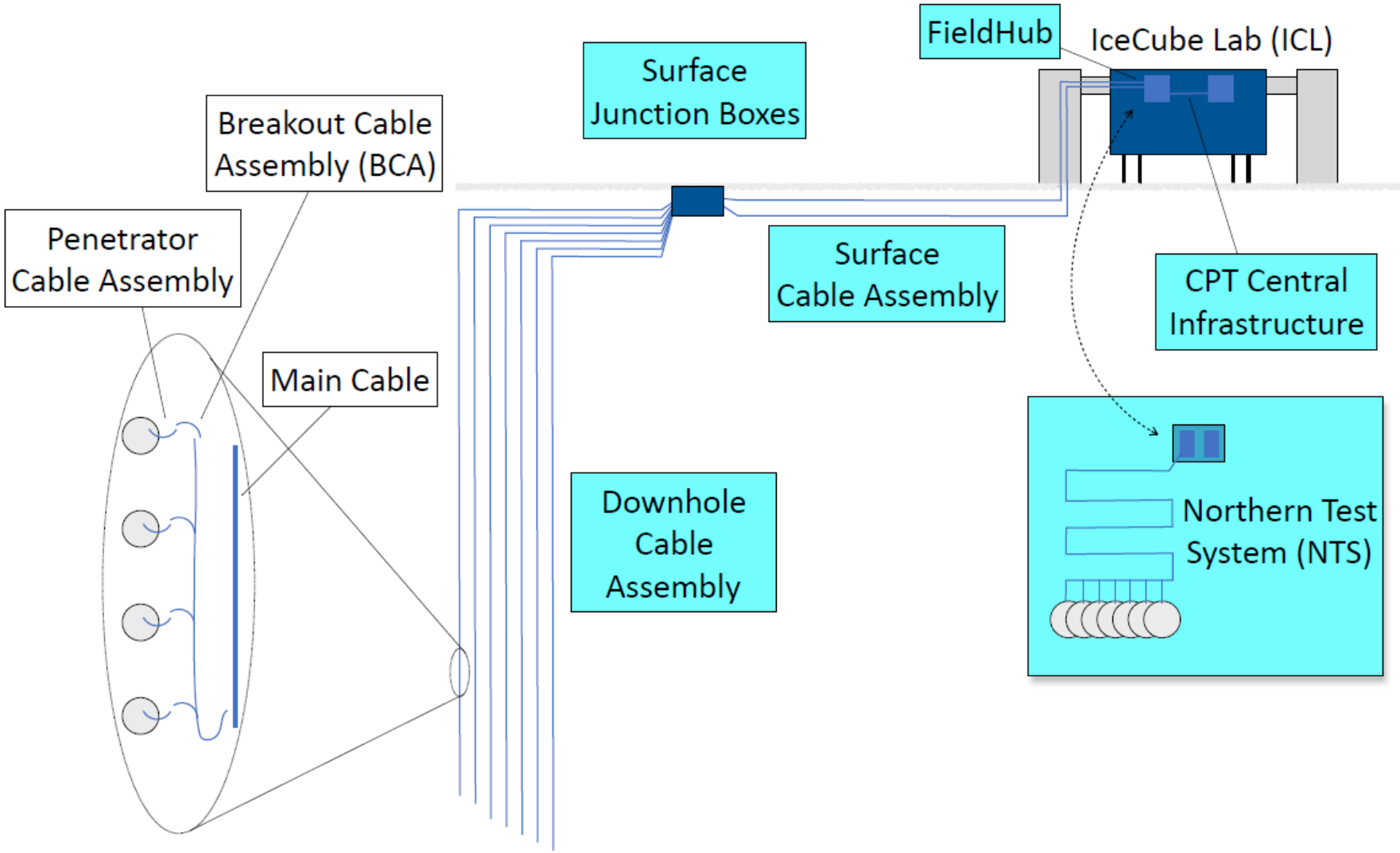
- Very close holes compared to IceCube Gen1
- Integration with IceCube holes and cables need close attention
- Logistics and cable management planning starting this year
- Integration with ICL, assess how we could do this. Is there a clear path



SJBs & surface cables



Configuration



Drill - Schematic