

IceCube Upgrade NSF Re-Baseline Review
April 26-28, 2022

Delia Tosi

1.2 Implementation – Installation



Speaker Bio

Background

- BS + MS + PE Electronic Engineering
- PhD Physics on acoustic neutrino detection (IceCube) + IceCube install team member
- Postdoc UC Berkeley & Stanford University

Scientist at UW Madison/WIPAC since 2013

- IceTop enhancement (scintillator panels & radio antennas)
- Borehole logging (SPICE, etc)
- IceCube Upgrade installation lead
- RNO-G drilling and installation
- Broad field experience

Polar experience

- 6 (+2) deployments to Antarctica
- 1 deployment to Greenland



IceCube Upgrade Installation

- **Install a string:** connect the sensors to pre-defined cable breakout and lower the string in the water-filled, freshly drilled hole to target depth.



IceCube Upgrade Installation (WBS 1.2.9 + 1.2.10)

- **Overall deliverable:** Successfully install 7 strings

Off-ice installation deliverables in 1.2.9:

Development of tools, equipment and procedures to ensure smooth and safe handling and testing of sensors at the South Pole and installation of 7 strings

1.2.9.1	Sensor Handling & Testing: Process & Equipment
1.2.9.2	Rigging for String Installation
1.2.9.3	Installation Monitor Equipment: Depth Monitor and Handheld Testers
1.2.9.4	Logging & Calibration Support
1.2.9.5	Develop Installation Training Package

Field specific installation activities in 1.2.10:

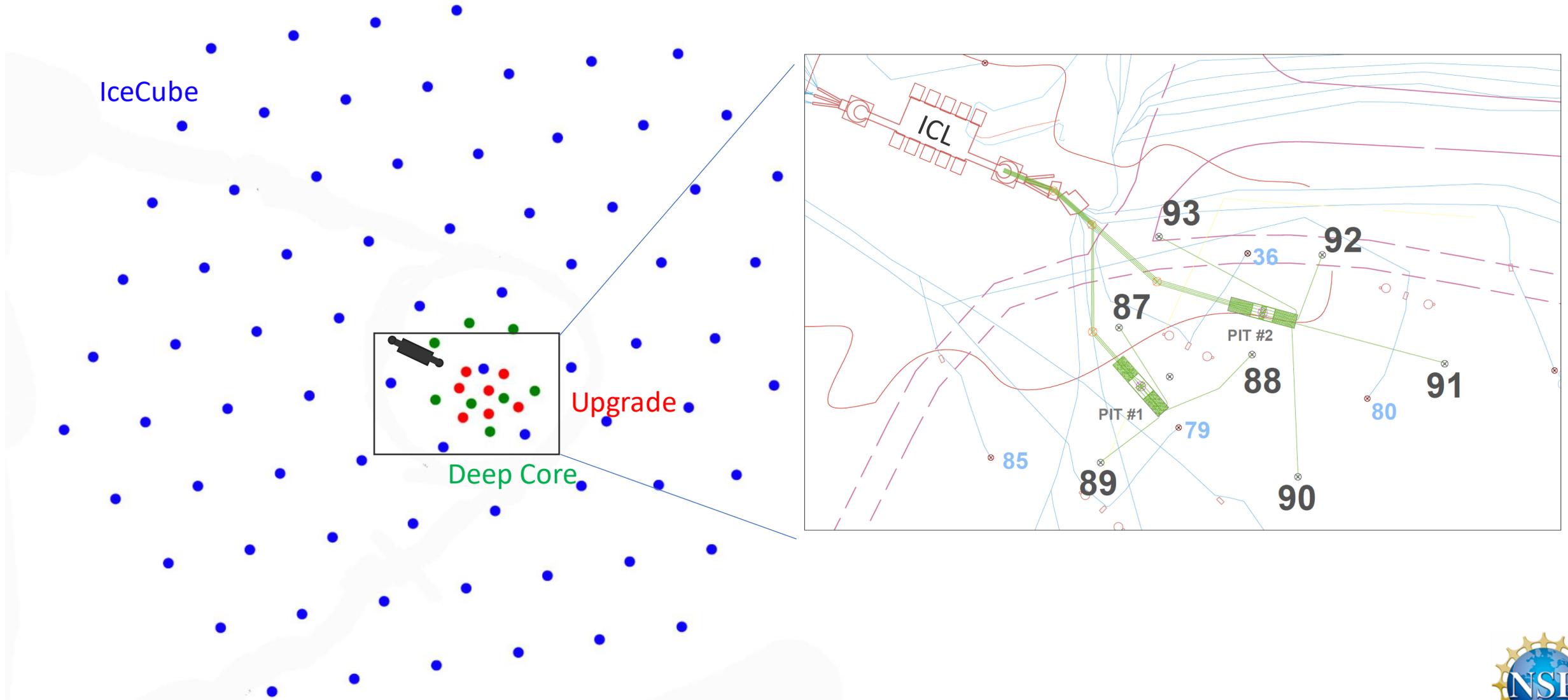
Detailed activities list and on-site management of polar field season work for installation; on-ice installation activities, including pre-installation activities and installation proper activities coordinated with deep drilling; [...]

1.2.10.1	Seasonal Staffing & Training, Off-Ice Coordination
1.2.10.2	Installation Field Season 0 (FY23)
1.2.10.3	Installation Field Season 1 (FY24)
1.2.10.4	Installation Field Season 2 (FY25)
1.2.10.5	Installation Field Season 3 (FY26)

Interfaces

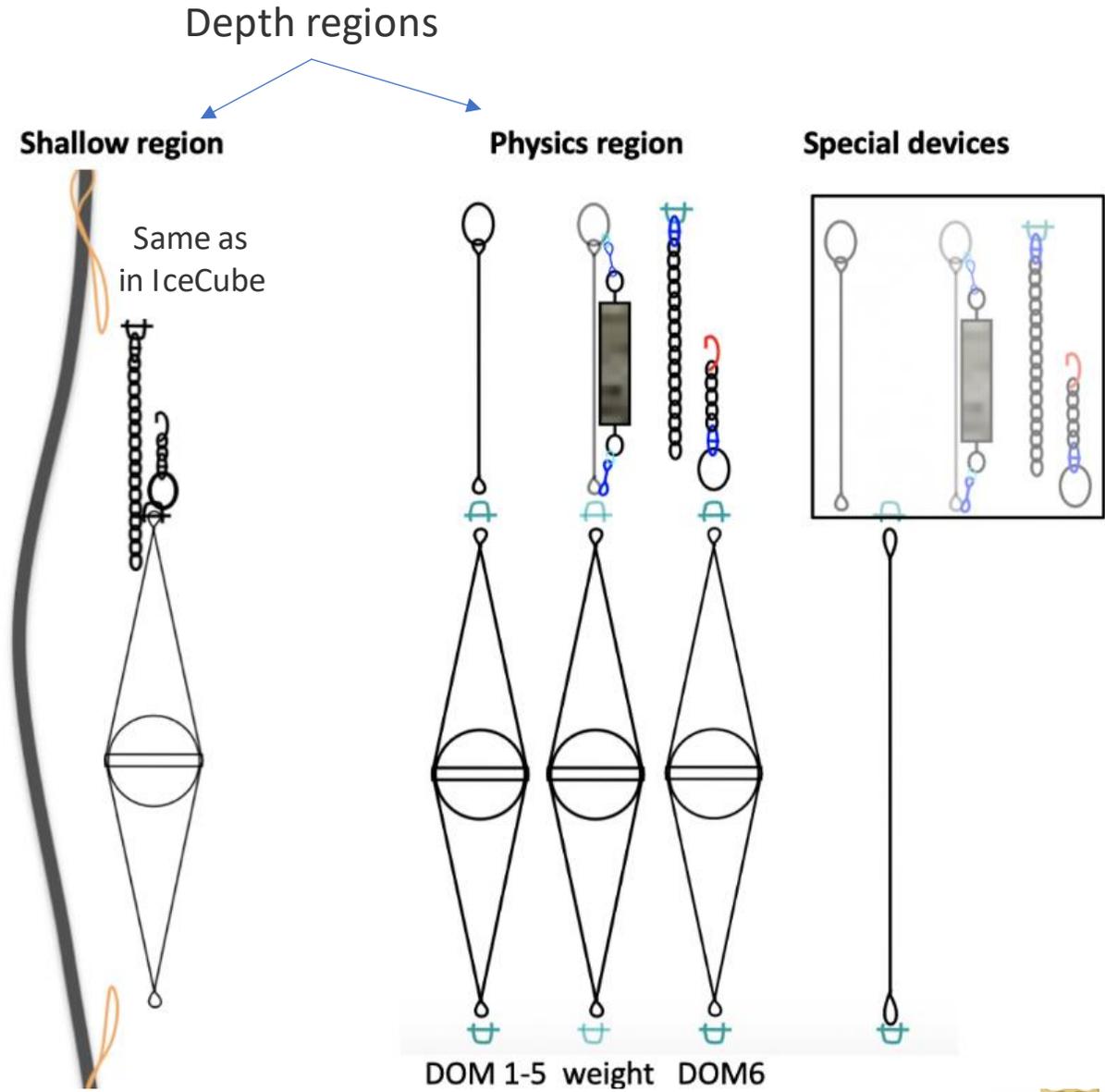
- Cables (1.4)
- Sensors (1.3)
- Calibration Devices (1.5)
- Hole (1.2): depth, type, lifetime diameter, driller support (personnel + equipment)
- Logistics and USAP Support
 - Cargo movement and timing
 - Population
 - On-Ice support and coordination

IceCube & Upgrade surface geometry

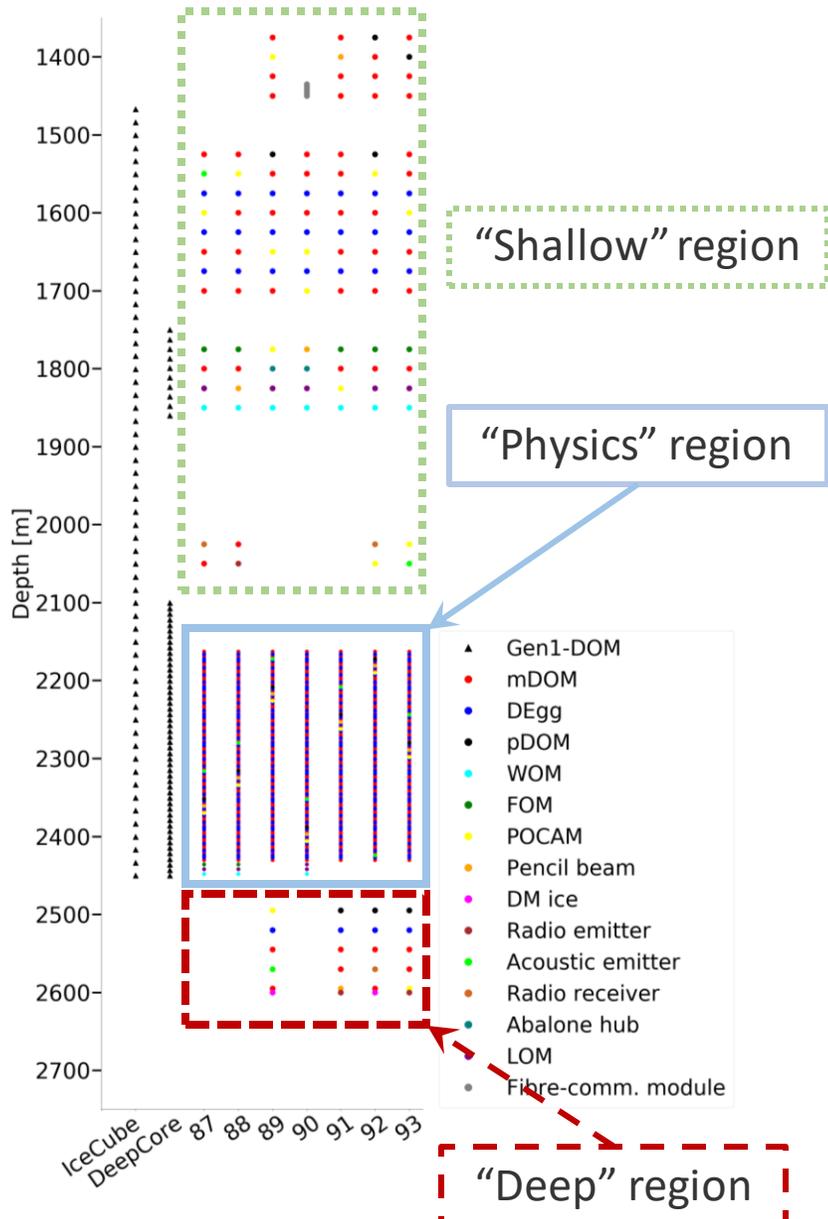


Upgrade String Design

- About 110 sensors/string
 - ≈ 60 mDOMs per string
 - ≈ 40 D-Eggs per string
 - 10-20 calibration and special devices
- Target bottom depth is 2450 or 2600
- Sensor spacing from 3m to 25m
- Attachment of sensors modular and standardized, independent on specific sensor type



IceCube & Upgrade vertical geometry



Type	String	87	88	89	90	91	92	93	Total
Optical modules 679	mDOM	59	57	57	53	60	58	58	402
	D-Egg	39	41	40	38	40	39	40	277
Calibration devices 61	pDOM	1	1	2	1	2	4	3	14
	POCAM	2	2	5	3	2	3	4	21
	Pencil Beam (PB)	1	2	1	2	3	1	1	11
	Acoustic Module (AM)	2	1	2	1	1	1	2	10
	Swedish Camera (SWE))	1	1	0	1	0	1	1	5
R&D devices 56	Long Optical Module (LOM)	0	1	2	1	3	3	2	12
	DM-ice	0	1	0	1	0	0	0	2
	Radio Pulsar (RP)	0	1	1	1	0	0	1	4
	Radio Receiver (RR)	1	0	0	0	0	2	0	3
	Abalone Hub (AH)	0	0	1	1	0	0	0	2
	Wavelength-shifting Optical Module (WOM)	4	4	0	4	0	1	1	14
	Fiber-optic Optical Module (FOM)	2	1	1	0	1	1	1	7
Fiber Test System (FTS)	0	0	0	6	6	0	0	12	
Pressure sensors	Paro (PS)	1	1	1	1	1	1	1	7
ALL	ALL	113	114	113	114	119	115	115	803

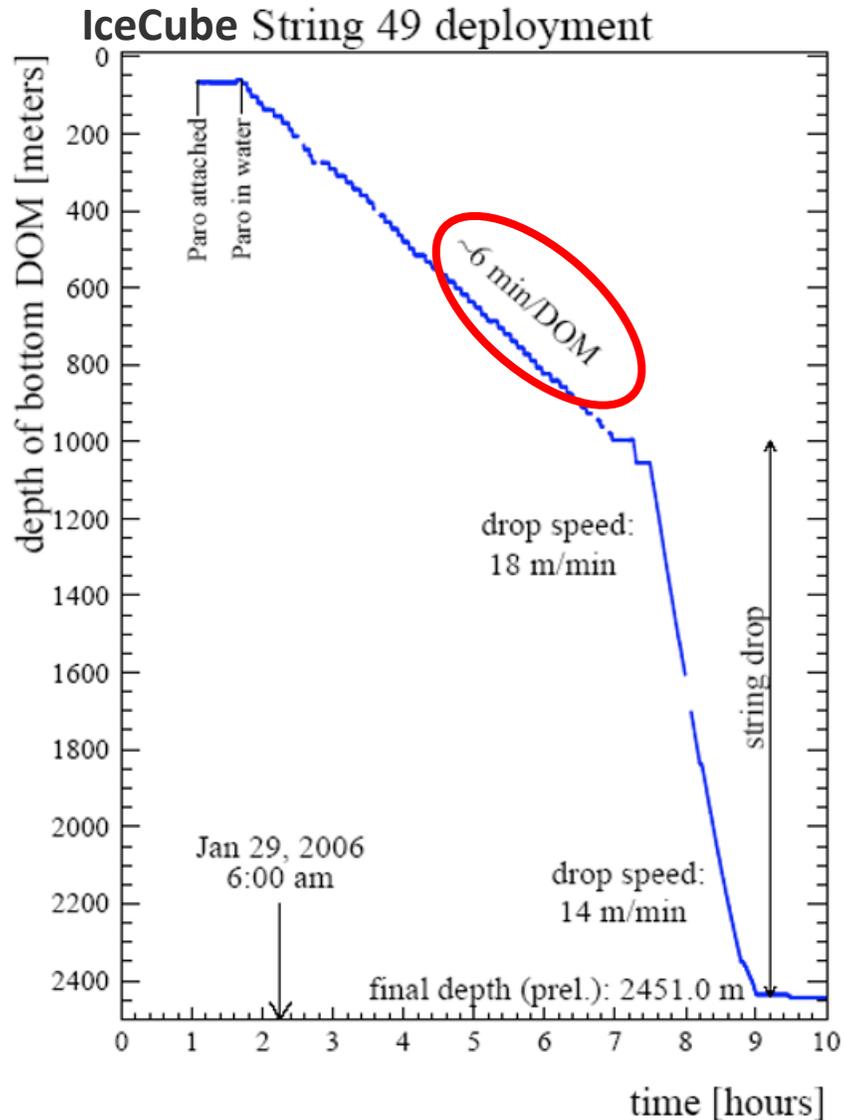
Minor revision undergoing for calibration/special devices placement in strings (very small changes)

Load on each string is calculated specifically on the properties of various sensors.

Max load on sensors: 850 kg

Max load on cables: 1460 kg

Installation Time Estimate



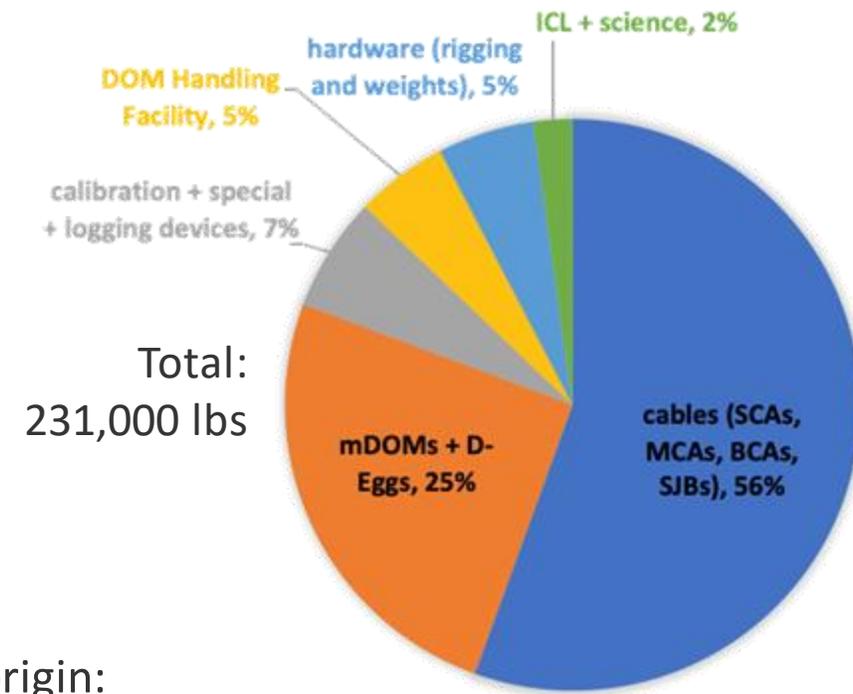
- String bottom depth by pressure sensor logged during IceCube Gen1 for each hole
- From this example, just scaling by number of sensors:
 $10 \text{ hours}/60 * 120 = 20 \text{ hours}$
- Assume 8 min/DOM to account for more complexity adds:
 $2 \text{ min} * 120 = 4 \text{ hours}$
- Total installation time: 24 hours → 2 shifts of 12 hours
- Similar results when performing bottoms-up analysis (step-by-step)



Installation Cargo

1.2.10 receives all the cargo that's not drill

- **Weight:** 30,000 lbs per string
 - Cable (SCA, MCA, SJB): 18,000 lbs
 - Sensors: 10,000 lbs
 - Hardware: 2,000 lbs
- **Packaging:** sensors packing optimized to maximize usable space for LC-130 transport (463L air force pallets) and considering points of origin:
 - mDOMs: 8x8 mDOMs (=64)
 - D-Eggs: 2 x 8 + 2 x 12 D-Eggs (=40)
 - Crates with special/calibr. devices and miscellaneous, breakout cables
- **Shipping:**
 - Cables and hardware all via USAP vessel + South Pole Overland Traverse (SPOT)
 - Sensors moved by Commercial Surface + USAP air lift (2 strings fit in one LC-130)



Population Supporting 1.2.10 Installation Activities

<u>FS2 main tasks</u>		FS2 Population	Personnel	Supporting WBS
Surface cable installation	CPT (electronics)		1	1.4
	CPT (cables)		1	1.4
Setup sensor testing chain & installation chain	SPAT SME		1	1.6
	Installation		1	1.2.10
Total (1.2.10 activities)			4	

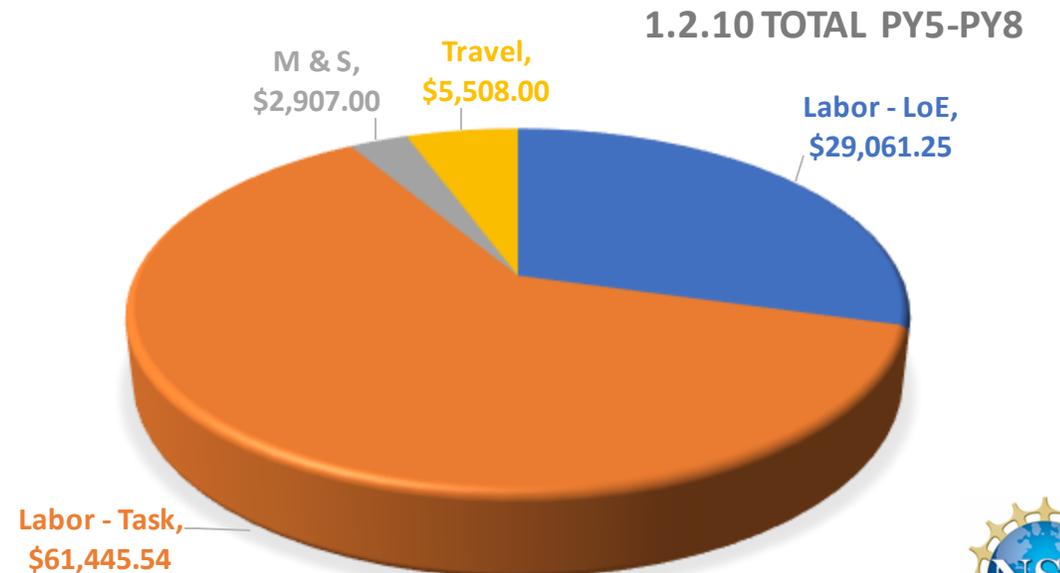
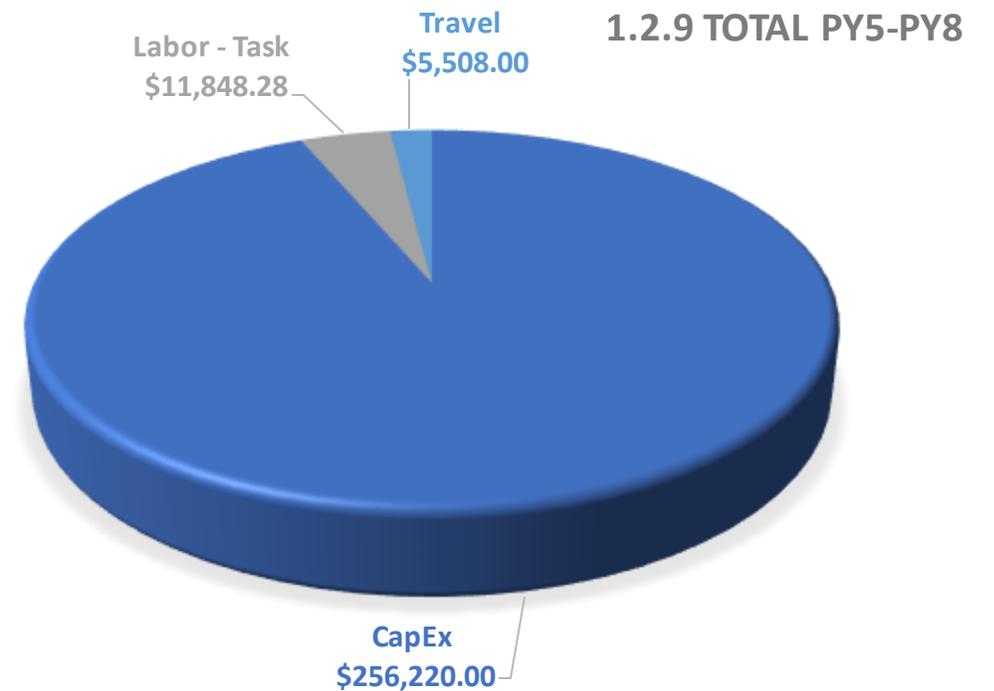
<u>FS3 main tasks</u>		FS3 Population	Personnel	Supporting WBS
ICL Comms/Power/Timing installation	CPT (electronics)		1	1.4
	CPT (cables) / Installation		1	1.4
	ICECUBE Integration		1	1.6
Sensor testing	SPAT SME		1	1.6
	SPAT Helper		1	In-kind
installation	Installation		9	1.2.10 (x1), in-kind (8)
Total (1.2.10 activities)			14	

Milestones 1.2.9 & 1.2.10

- 88 internal milestones
 - CapEx procurement
 - Systems Completion
 - Shipping
 - Personnel and cargo arrival
 - Systems ready at NPX
 - Surface cable installation complete
 - Readiness reviews
 - ...
- 9 L2 milestones:
 - Installation of each of 7 Strings, plus dust logging (12/19/2025 to 1/12/2026)
 - Lesson learned (1/14/2026)

Cost & Main Cost Drivers

- Cost and Main Cost Drivers
- 1.2.9 CapEx:
 - Pressure sensors (105k)
 - Rigging (108k)
- 1.2.10 Labor:
 - Drillers installation training (61k)
 - Installation Lead On-Ice labor (29k)



1.2.9 & 1.2.10 Risks

Installation related risks are captured in Risk Register and analyzed for schedule and cost exposure

TECH23	Sleds formerly from the 88 South Traverse project cannot be used
TECH24	Solar Garage cannot be used as testing tent

Assumption that IceCube Upgrade will be able to borrow USAP equipment (sleds & testing tent) that's already on-ice
 Conversation with ASC undergoing.

TECH25	Protect xDOM from ESD during staging and during installation. This includes sled transport, the DOM handling facility, and ESD protection while connecting the BCA to the PCA and BCA to Main Cable Assembly.
TECH26	Failure of a harness or rigging element that would result in undeploying partially the string and swapping instrumentation/BCAs.
TECH27	Failure of a harness or rigging element that would result in partial loss of string, unknown during deployment
TECH28	Failure of a harness or rigging element that would result in total loss of string (string is stuck during drop, or deployment cannot continue and undeployment cannot happen, instrumentation is abandoned)
TECH29	Dust Logger winch failure
TECH30	String Installation Winch Failure - The TU20 winch fails during installation operations. TU-20 needs to be swapped out

Response to Previous Reviews

ID	Recommendation	Responsible	Status	Estimated Date for closing	Notes	
LR3	Consider mechanization of cable pulling operations up the ICL towers to reduce labor and potential for injury.	John Kelley/Delia Tosi	open		John and Delia will work with ASC for this. Needs to be resolved in time for year before deep drilling. (in principle year 2 in a 3 FS project)	John and delia will work with ASC for this. Needs to be resolved in time for year before deep drilling. (in principle year 2 in a 3 FS project)
LR4	Research potential advantages of heating the cables in the area where they enter the ICL towers to make snaking them from the snow trench into ICL easier.	John Kelley	open		See above. Need a comprehensive plan for cable pulling with ASC.	See above. Need a comprehensive plan for cable pulling with ASC.
LR6	Extend tolerance or recommended alternate location for GPR scan of proposed nine firm holes and cable trenches to CRREL and define the level of fidelity needed.	Delia Tosi	open	11/1/22	Will provide plan to CRREL and survey crew by August 2022 That includes extended tolerance of hole placement and recommendations for alternate sites.	Will provide plan to CRREL and survey crew by August 2022 That includes extended tolerance of hole placement and recommendations for alternate sites.
NSFLR1	Improve documentation overall; and including documentation pertaining to (1) on-site personnel needs and (2) spares especially in the context of risk assessment	Vivian O'Dell/Farshid Feyzi/Ian McEwen/Delia Tosi	In progress			Document updated are in progress. Safety and quality plans and risk mitigation plans are being revised. New documents for project management have been developed.
NSFLR2	Consider risk mitigating scenarios within forthcoming logistical support guidance. Shallow drilling with the FS2 team, reducing the number of strings, or reducing the number of DOMs per string have been mentioned.	Mike DuVernois, Farshid Feyzi, Ian McEwen	closed	2/25/22	Have studied the effects of reducing the number of strings in a scoping document. Have also worked with AIL on the logistics needs and availability.	Have studied the effects of reducing the number of strings in a scoping document. Have also worked with AIL on the logistics needs and availability.

More details in breakout session

Summary

- Installation task similar to IceCube, with more complexity due to larger quantities of sensors (also heavier and multiple types)
- Installation schedule completely in Smartsheet
- Installation budget evaluated bottom-up
- Installation effort justified by activities in cost workbook as labor hours
- Installation cargo & population captured in master spreadsheet
- Field activities focused on FS2-FS3
- Personnel for FS2 identified; recruiting in-kind effort for FS3 by mid 2023

Back up slides

1.2.9 Installation off-ice

Development of tools, equipment and procedures to ensure smooth and safe handling and testing of sensors at the South Pole and installation of 7 strings

1.2.9.1	Sensor Handling & Testing: Process & Equipment Define and develop the handling process for sensors and special devices at the South Pole, including execution of the South Pole Acceptance Testing (SPAT). Coordinate with ASC to secure use of suitable support equipment at the South Pole.
1.2.9.2	Rigging for String Installation Determine & procure rigging hardware to be used during installation to connect safely the sensors to the Main Down Hole Cable.
1.2.9.3	Installation Monitor Equipment: Depth Monitor and Handheld Testers Development of tools to be used during and after installation to monitor the depth of the string and connectivity to the sensors through hand-held devices.
1.2.9.4	Logging & Calibration Support Support bore hole logging. Implementation of electronic logbook for geometry record.
1.2.9.5	Develop Installation Training Package Develop training and training tools for installation personnel

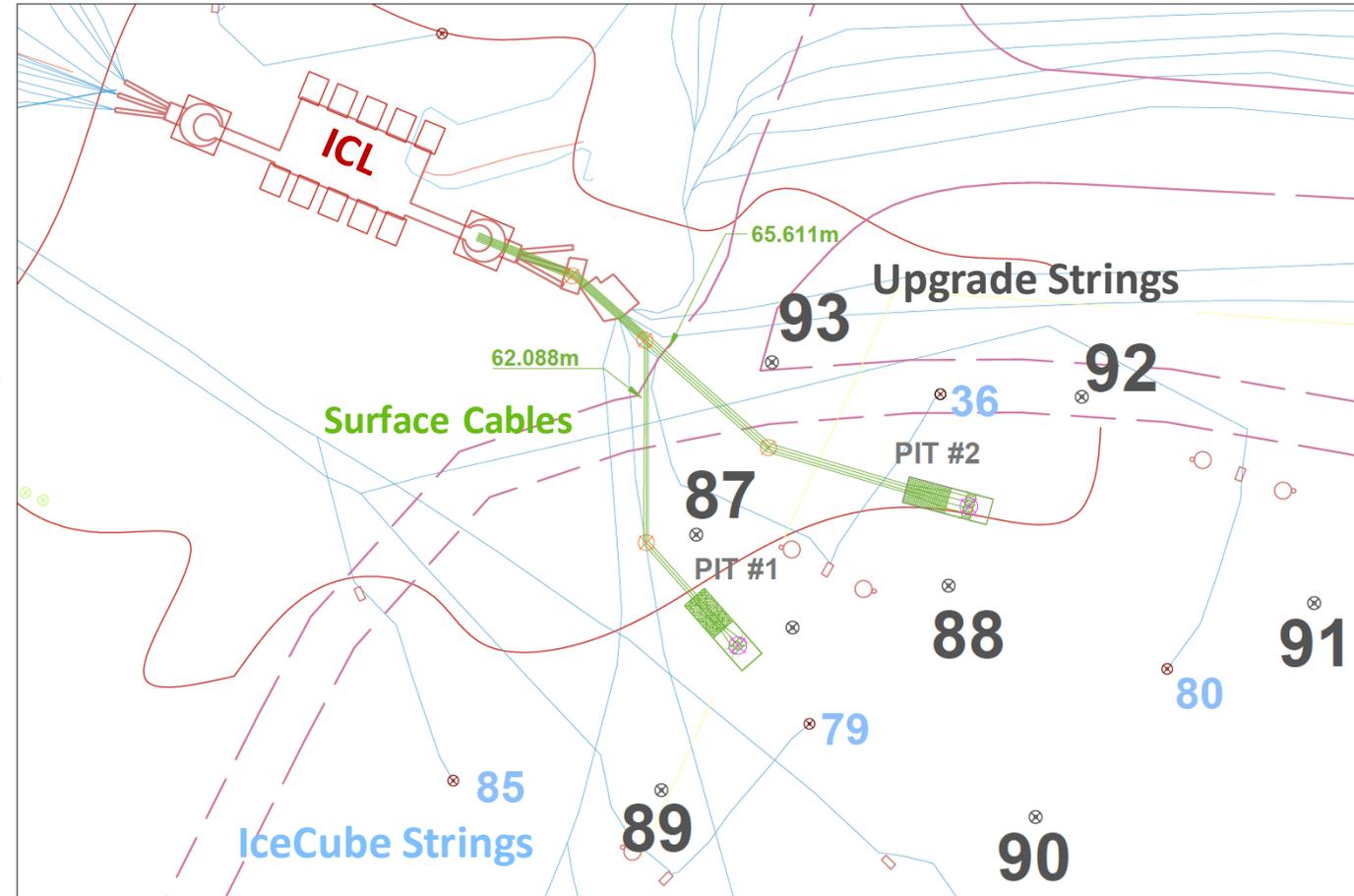
Level Of Effort (LOE) labor (Tosi) captured in 1.2.1, as well as Engineering Support to Installation. 1.2.9 captures specific task-oriented engineering

Milestones:

- Cap Ex Procurements
- Systems completion
- Technical readiness reviews
- Shipping

Field Season 2 activities (personnel)

- Install surface cables and surface junction boxes (1+1)
 - prepare west tower for cabling (*)
 - pull 7 surface cables into ICL (*)
 - install SJBs and connect surface cables to the SJBs
 - install SJB season covers and trench backfill (*)
 - install patch panels into ICL
 - install surface cable grounding clamps at ICL entry
 - install patch panels in the ICL and connect surface cables
 - test installed cables from ICL to SJB
 - install patch cables to FieldHub rack locations
- Install & commission Upgrade timing and power electronics into the ICL (1)
- Inventory of Installation tools
- Sensors Handling and Testing (1+1)
 - DOM Handling Facility Construction(*)
 - Setup testing setup
 - Receive and test two strings worth of sensors



FS2 Labor Effort - Installation

From Smartsheet

Primary	WBS	Start Date	End Date	Resource ID	Actual Rate	Labor Table Rate	Sheet Name	10-2024	11-2024	12-2024	01-2025	02-2025
Install FS2: IME Deployment and Integration	1.2.10.4.6.10	12/18/24	01/16/25	EN-EE	\$0	\$115	1.2 Rebaseline Cost Workbook PY4-PY8			18	18	
Install FS2: Install 7 Surface Cables into ICL Tower, Across Bridge, into ICL	1.2.10.4.7.7	12/17/24	12/26/24	EN-EE	\$0	\$72	1.2 Rebaseline Cost Workbook PY4-PY8			45		
Install FS2: Prep Cables & Attach to Grounding System in ICL	1.2.10.4.7.10	12/27/24	12/30/24	EN-EE	\$0	\$72	1.2 Rebaseline Cost Workbook PY4-PY8			23		
Install FS2: Unspool & Lay Surface Cables from Tower to SJB Pits	1.2.10.4.7.14	12/30/24	12/31/24	EN-EE	\$0	72	1.2 Rebaseline Cost Workbook PY4-PY8			18		
Install FS2: Install SJB's in Pits (2); Connect Cables	1.2.10.4.7.16	01/02/25	01/03/25	EN-EE	\$0	\$72	1.2 Rebaseline Cost Workbook PY4-PY8				9	
Install FS2: Surface Cable Continuity Test	1.2.10.4.7.19	01/07/25	01/08/25	EN-EE	\$0	\$72	1.2 Rebaseline Cost Workbook PY4-PY8				9	
Install FS2: Prep/Uncrate Cable Spools; Load onto 953 Loader	1.2.10.4.7.5	12/17/24	12/26/24	EN-ME	\$0	\$62	1.2 Rebaseline Cost Workbook PY4-PY8			32		
Install FS2: Install 7 Surface Cables into ICL Tower, Across Bridge, into ICL	1.2.10.4.7.7	12/17/24	12/26/24	EN-ME	\$0	62	1.2 Rebaseline Cost Workbook PY4-PY8			45		
Install FS2: Unspool & Lay Surface Cables from Tower to SJB Pits	1.2.10.4.7.14	12/30/24	12/31/24	EN-ME	\$0	62	1.2 Rebaseline Cost Workbook PY4-PY8			18		
Install FS2: Install SJB's in Pits (2); Connect Cables	1.2.10.4.7.16	01/02/25	01/03/25	EN-ME	\$0	\$62	1.2 Rebaseline Cost Workbook PY4-PY8				9	
Install FS2: Surface Cable Continuity Test	1.2.10.4.7.19	01/07/25	01/08/25	EN-ME	\$0	\$62	1.2 Rebaseline Cost Workbook PY4-PY8				9	
Install FS2: Field Hubs, timing system, patch panels and patch cables installation	1.2.10.4.8.1	01/08/25	02/03/25	GR	\$0	23	1.2 Rebaseline Cost Workbook PY4-PY8				117	18
Install FS2: Field Hubs, timing system, patch panels and patch cables installation	1.2.10.4.8.1	01/08/25	02/03/25	PO	\$0	31	1.2 Rebaseline Cost Workbook PY4-PY8				135	
Install FS2: Sensor Sleds Construction/Prep Oversight	1.2.10.4.4.1	12/01/24	12/05/24	SC	\$0	\$52	1.2 Rebaseline Cost Workbook PY4-PY8			9		
Install FS2: Sensor Testing Tent Prep Oversight	1.2.10.4.4.4	12/01/24	12/05/24	SC	\$0	\$52	1.2 Rebaseline Cost Workbook PY4-PY8			9		
Install FS2: Sensor Handling Facility Assembly Oversight	1.2.10.4.5.1	12/04/24	12/23/24	SC	\$0	\$52	1.2 Rebaseline Cost Workbook PY4-PY8			32		
Install FS2: Sensor Handling Dry Run	1.2.10.4.5.6	12/26/24	12/27/24	SC	\$0	\$52	1.2 Rebaseline Cost Workbook PY4-PY8			8		
Install FS2: Receive and Inspect Installation Kits & Weight Shipments	1.2.10.4.6.1	01/02/25	01/06/25	SC	\$0	\$52	1.2 Rebaseline Cost Workbook PY4-PY8				9	
Install FS2: Receive and Inspect String 87 & 88 Sensors, Calibration and Special Devices Shipments	1.2.10.4.6.2	12/15/24	12/16/24	SC	\$0	\$52	1.2 Rebaseline Cost Workbook PY4-PY8			6		
Load String 87 Sensors on Sleds 1,2 for testing prior	1.2.10.4.6.3	12/26/24	12/26/24	SC	\$0	52	1.2 Rebaseline Cost Workbook PY4-PY8			4		
Load String 88 Sensors on Sleds 3,4 for testing prior	1.2.10.4.6.5	12/27/24	12/27/24	SC	\$0	\$52	1.2 Rebaseline Cost Workbook PY4-PY8			4		
Install FS2: Conduct South Pole Acceptance Testing (SPAT) String 87 Sensors	1.2.10.4.6.7	12/26/24	01/02/25	SC	\$0	52	1.2 Rebaseline Cost Workbook PY4-PY8			18		
Install FS2: Conduct South Pole Acceptance Testing (SPAT) String 88 Sensors	1.2.10.4.6.8	01/03/25	01/10/25	SC	\$0	52	1.2 Rebaseline Cost Workbook PY4-PY8				30	
Install FS2: Conduct South Pole Acceptance Testing (SPAT) String 87-88 Special Devices	1.2.10.4.6.9	01/13/25	01/20/25	SC	\$0	52	1.2 Rebaseline Cost Workbook PY4-PY8				54	
Install FS2: IME Deployment and Integration	1.2.10.4.6.10	12/18/24	01/16/25	SC	\$0	\$52	1.2 Rebaseline Cost Workbook PY4-PY8			9	45	
Install FS2: Install 7 Surface Cables into ICL Tower, Across Bridge, into ICL	1.2.10.4.7.7	12/17/24	12/26/24	SC	\$0	52	1.2 Rebaseline Cost Workbook PY4-PY8			45		
Install FS2: Unspool & Lay Surface Cables from Tower to SJB Pits	1.2.10.4.7.14	12/30/24	12/31/24	SC	\$0	\$52	1.2 Rebaseline Cost Workbook PY4-PY8			18		
Install FS2: Store 87 & 88 Sensors in Cryo Helium Bay for Winter	1.2.10.4.9.3	01/16/25	01/20/25	SC	\$0	52	1.2 Rebaseline Cost Workbook PY4-PY8				18	
Install FS2: Store 87 & 88 Special Devices and BCAs in ICL for Winter	1.2.10.4.9.5	01/16/25	01/20/25	SC	\$0	52	1.2 Rebaseline Cost Workbook PY4-PY8				18	
Install FS2: Clean up Testing Tent & Store SPAT	1.2.10.4.9.6	01/21/25	01/23/25	SC	\$0	\$52	1.2 Rebaseline Cost Workbook PY4-PY8				18	
Install FS2: Setup SPAT	1.2.10.4.4.7	12/17/24	12/24/24	SE	\$0	\$55	1.2 Rebaseline Cost Workbook PY4-PY8			18		
Load String 87 Sensors on Sleds 1,2 for testing prior	1.2.10.4.6.3	12/26/24	12/26/24	SE	\$0	\$55	1.2 Rebaseline Cost Workbook PY4-PY8			4		
Load String 88 Sensors on Sleds 3,4 for testing prior	1.2.10.4.6.5	12/27/24	12/27/24	SE	\$0	55	1.2 Rebaseline Cost Workbook PY4-PY8			4		
Install FS2: Conduct South Pole Acceptance Testing (SPAT) String 87 Sensors	1.2.10.4.6.7	12/26/24	01/02/25	SE	\$0	\$55	1.2 Rebaseline Cost Workbook PY4-PY8			54		
Install FS2: Conduct South Pole Acceptance Testing (SPAT) String 88 Sensors	1.2.10.4.6.8	01/03/25	01/10/25	SE	\$0	55	1.2 Rebaseline Cost Workbook PY4-PY8				54	
Install FS2: Conduct South Pole Acceptance Testing (SPAT) String 87-88 Special Devices	1.2.10.4.6.9	01/13/25	01/20/25	SE	\$0	\$55	1.2 Rebaseline Cost Workbook PY4-PY8				54	
Install FS2: Install 7 Surface Cables into ICL Tower, Across Bridge, into ICL	1.2.10.4.7.7	12/17/24	12/26/24	SE	\$0	55	1.2 Rebaseline Cost Workbook PY4-PY8			36		
Install FS2: Store 87 & 88 Sensors in Cryo Helium Bay for Winter	1.2.10.4.9.3	01/16/25	01/20/25	SE	\$0	55	1.2 Rebaseline Cost Workbook PY4-PY8				18	
Install FS2: Store 87 & 88 Special Devices and BCAs in ICL for Winter	1.2.10.4.9.5	01/16/25	01/20/25	SE	\$0	\$55	1.2 Rebaseline Cost Workbook PY4-PY8				18	
Install FS2: Clean up Testing Tent & Store SPAT	1.2.10.4.9.6	01/21/25	01/23/25	SE	\$0	55	1.2 Rebaseline Cost Workbook PY4-PY8				18	
Install FS2: Position Sensor Handling Facility near Tower	1.2.10.4.5.5	12/24/24	12/24/24	TE	\$0	\$29	1.2 Rebaseline Cost Workbook PY4-PY8			4		



1.2.10 Installation Field Seasons

Detailed activities list and on-site management of polar field season work for installation; on-ice installation activities, including pre-installation activities and installation proper activities coordinated with deep drilling; labor, travel, M&S for installation lead; all the remaining labor is provided by in-kind personnel and personnel from other WBSes (1.6 and 1.4)

1.2.10.1	Seasonal Staffing & Training, Off-Ice Coordination Off ice training (installation team, drillers and management is trained for installation activities at the South Pole)
1.2.10.2	Installation Field Season 0 (FY23) Activities and cargo movement related to installation in FS0 (FY23)
1.2.10.3	Installation Field Season 1 (FY24) Activities and USAP cargo movement related to installation in FS1 (FY24)
1.2.10.4	Installation Field Season 2 (FY25) USAP cargo movement related to installation in FS2 (FY25). Installation of Field Hubs, patch panels and patch cables. Surface Cables Assemblies are installed into the into the ICL through the ICL west tower and connected to the Field Hubs. Surface Junction Boxes are installed for all the 7 Strings. The Sensor Testing Setup, sleds and tent are prepared. Two strings worth of sensors are fully tested.
1.2.10.5	Installation Field Season 3 (FY26) Activities and USAP cargo movement related to installation in FS3 (FY26). Test of 7 strings of sensors. Installation of 7 strings. Coordination with Drill Activities.

Milestones:

- Personnel and cargo arrival
- South Pole Acceptance Test (SPAT) ready
- Surface cable installation complete
- Readiness review
- Installation of each string

Field Season 3 activities (personnel)

String prep (1x):

- Test 800 sensors
- Stage instrumentation prior to installation

Installation proper list of tasks (per shift):

- Shift lead (1x)
- DOM suppliers (2x): sort sensors according to string deployment order in sensor handling facility
- DOM supplier TOS side (1x): preps the next sensor
- DOM installers (2x) : attach sensors to cable at the hole
- Winch operator (1x): operate TU-20 and hoist
- Logger (1x): Logs instrumentation, measures inter-sensor distance

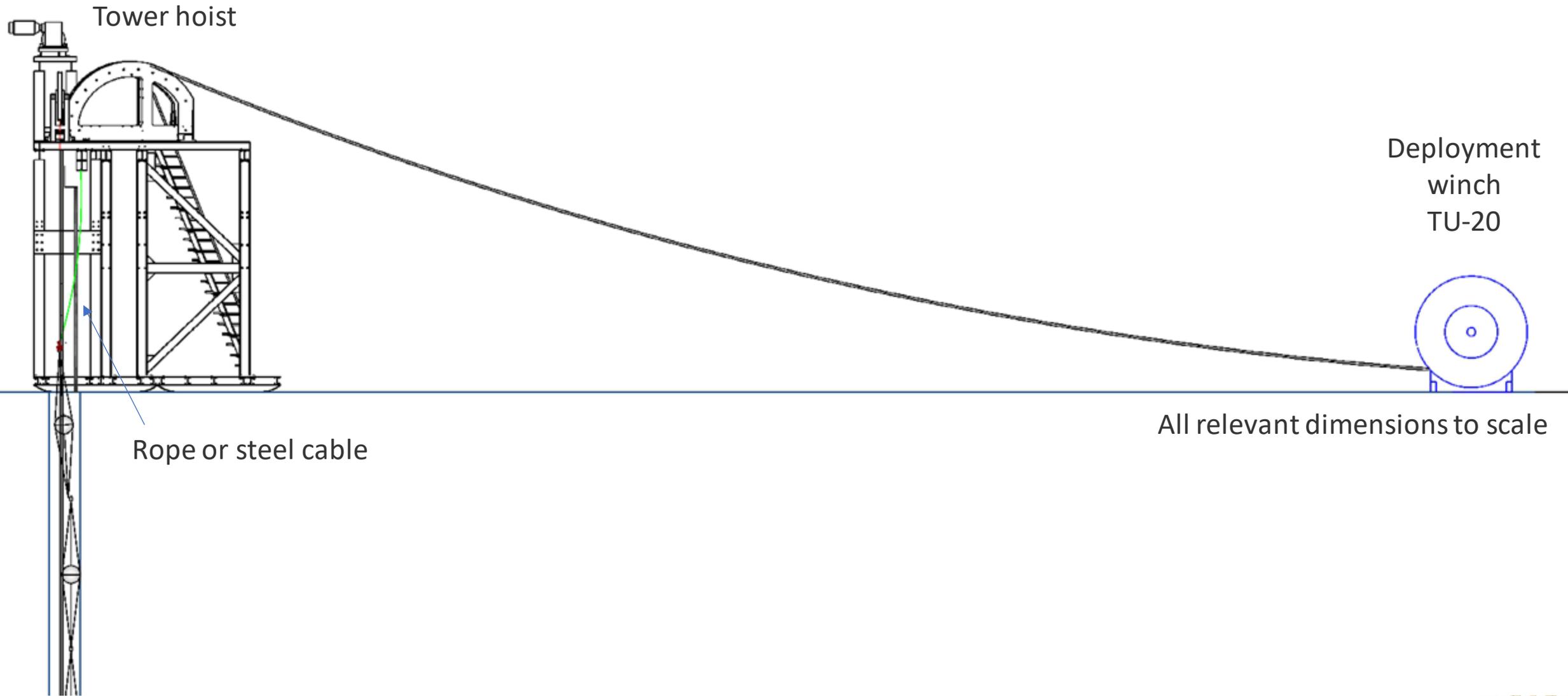
Cables specific tasks (2x)

- Oversee main cable assembly (MCA) spool loading on TU-20 prior to each hole
- Assist with breakout cable assembly (BCA) installation and DOM connectivity test during deployment
- Cable drag and cable connection to SJB after installation
- Perform connectivity test from ICL to in-ice devices. Isolate any problematic wire pairs and debug any connectivity issues.
- Connect ICL patch cables to FieldHubs
- Support DOM and special device commissioning and any in-water calibration operations
- Excavate Pit1-Pit2, backfill after installation is completed (*).

SmartSheet Labor Report - Installation

Primary	WBS	Start Date	End Date	Resource ID	Actual Rate	Labor Table Rate	Sheet Name	10-2025	11-2025	12-2025	01-2026	02-2026
Install FS3 Receiver and Inspect ICDs & lead members	12.0.5.4.5	12/01/25	12/03/25	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			27		
Install FS3 Receiver and Inspect BODs and String 99-93 Sensors	12.0.5.4.6	11/25/25	11/26/25	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8		27			
Install FS3 Oracle Training and Installation Preparation	12.0.5.4.16	12/08/25	12/12/25	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			45		
Install FS3 Oracle Readiness Review for 1st Hole Drill/Deployment	12.0.5.4.17	12/15/25	12/15/25	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			9		
Install FS3 Install String 87	12.0.5.4.3	12/11/25	12/19/25	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			12		
Install FS3 Connect Ince Cable to SUB 87 in PI#1	12.0.5.5.1.10	12/20/25	12/21/25	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			4		
Install FS3 Install String 88	12.0.5.5.3	12/23/25	12/24/25	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			12		
Install FS3 Trench Hole 88 to PI#1	12.0.5.5.2.9	12/26/25	12/26/25	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			4		
Install FS3 Connect Ince Cable to SUB 88 in PI#1	12.0.5.5.2.11	12/26/25	12/26/25	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			4		
Install FS3 Backfill Hole 88 to PI#1	12.0.5.5.2.12	12/26/25	12/26/25	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			4		
Install FS3 Install String 89	12.0.5.5.3	12/26/25	12/27/25	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			12		
Install FS3 Trench Hole 89 to PI#1	12.0.5.5.2.8	12/26/25	12/26/25	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			4		
Install FS3 Connect Ince cable to SUB 89 in PI#1	12.0.5.5.2.10	12/26/25	12/26/25	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			4		
Install FS3 Backfill Hole 89 to PI#1	12.0.5.5.3.11	12/26/25	12/26/25	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			4		
Install FS3 Install String 90	12.0.5.5.4.3	12/31/25	01/01/26	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			12		
Install FS3 Trench Hole 90 to PI#1	12.0.5.5.4.8	01/02/26	01/02/26	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			4		
Install FS3 Connect Ince cable to SUB 90 in PI#1	12.0.5.5.4.10	01/02/26	01/02/26	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			4		
Install FS3 Backfill Hole 90 to PI#1	12.0.5.5.4.11	01/02/26	01/03/26	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			4		
Install FS3 Excavation PI#2 (Assist)	12.0.5.5.5.1	01/03/26	01/03/26	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			18		
Install FS3 Install String 91	12.0.5.5.5.5	01/03/26	01/04/26	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			12		
Install FS3 Trench Hole 91 to PI#2	12.0.5.5.5.10	01/05/26	01/05/26	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			4		
Install FS3 Connect Ince Cable to SUB 91 in PI#2	12.0.5.5.5.12	01/05/26	01/05/26	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			4		
Install FS3 Backfill Hole 91 to PI#2	12.0.5.5.5.14	01/05/26	01/05/26	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			4		
Install FS3 Install String 92	12.0.5.5.6	01/08/26	01/09/26	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			12		
Install FS3 Trench Hole 92 to PI#2	12.0.5.5.6.11	01/10/26	01/10/26	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			4		
Install FS3 Connect Ince Cable to SUB 92 in PI#2	12.0.5.5.6.13	01/10/26	01/11/26	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			4		
Install FS3 Backfill Hole 92 to PI#2	12.0.5.5.6.14	01/11/26	01/11/26	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			4		
Install FS3 Install String 93	12.0.5.5.7.3	01/11/26	01/12/26	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			12		
Install FS3 Trench Hole 93 to PI#2	12.0.5.5.7.8	01/13/26	01/13/26	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			4		
Install FS3 Connect Ince Cable to SUB 93 in PI#2	12.0.5.5.7.10	01/13/26	01/13/26	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			4		
Install FS3 Backfill Hole 93 to PI#2	12.0.5.5.7.11	01/13/26	01/13/26	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			4		
Install FS3 Backfill Remove Temp Vent Flag and Survey PI#2	12.0.5.5.7.13	01/13/26	01/13/26	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			4		
Install FS3 Operational Detail- String 8 Cable Installation	12.0.5.7.1	01/13/26	01/14/26	EWME	\$0	\$92.12	Releasee Cost Workbook P14PV8			8		
Install FS3 Oracle sensor Handling Training	12.0.5.4.4	12/10/25	12/10/25	IK	\$0	\$0	12 Releasee Cost Workbook P14PV8			36		
Install FS3 Oracle sensor Handling Training	12.0.5.4.4	12/10/25	12/10/25	IK	\$0	\$0	12 Releasee Cost Workbook P14PV8			36		
Install FS3 SPT String 88	12.0.5.4.12	12/15/25	12/12/25	IK	\$0	\$0	12 Releasee Cost Workbook P14PV8			27		
Install FS3 Excavation PI#1	12.0.5.4.13	12/11/25	12/15/25	IK	\$0	\$0	12 Releasee Cost Workbook P14PV8			18		
Install FS3 Oracle Training and Installation Preparation	12.0.5.4.16	12/08/25	12/12/25	IK	\$0	\$0	12 Releasee Cost Workbook P14PV8			180		
Install FS3 Oracle Training and Installation Preparation	12.0.5.4.16	12/08/25	12/12/25	IK	\$0	\$0	12 Releasee Cost Workbook P14PV8			180		
Install FS3 Oracle Readiness Review for 1st Hole Drill/Deployment	12.0.5.4.17	12/15/25	12/15/25	IK	\$0	\$0	12 Releasee Cost Workbook P14PV8			36		
Install FS3 Oracle Readiness Review for 1st Hole Drill/Deployment	12.0.5.4.17	12/15/25	12/15/25	IK	\$0	\$0	12 Releasee Cost Workbook P14PV8			36		

String Installation Step-by-Step



Training at PSL

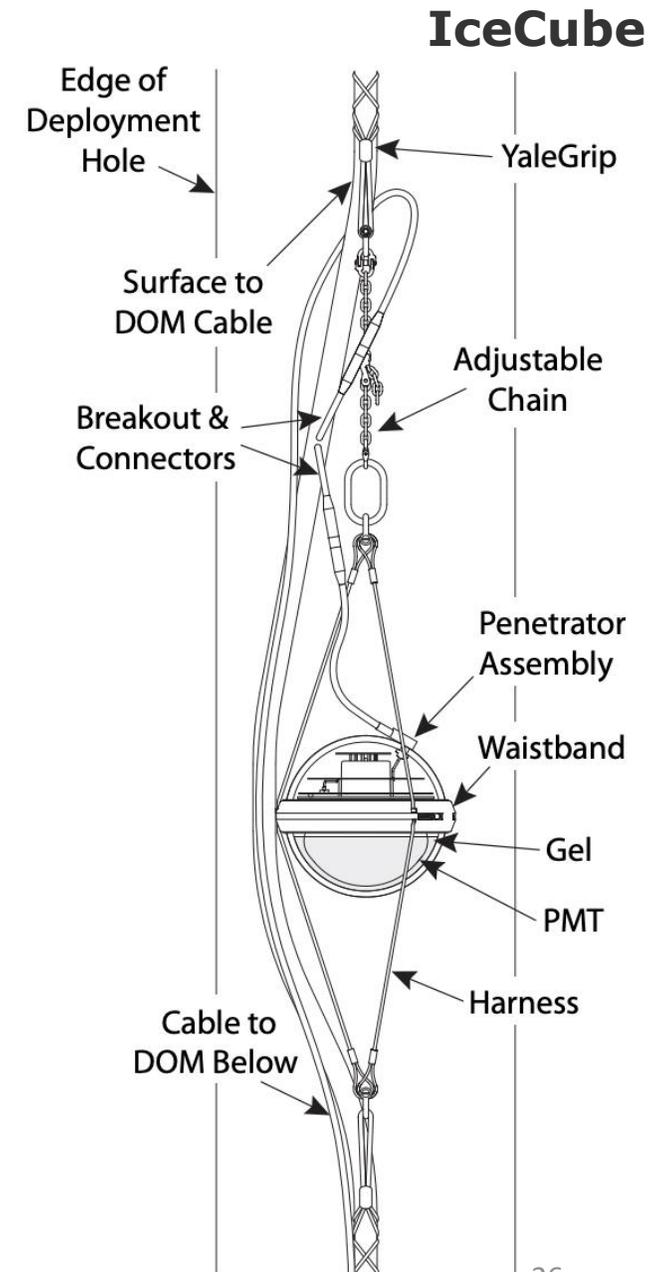
A deployment tower exists at PSL, in connection with a deep cased well (18" diameter to 50', then 10" diameter to 250')

- It was used for deployment training every year during IC construction
- Will be used to practice procedures in as much as detail as possible.



IceCube String Installation

- 60 DOMs/string, spaced 17 m (7 m in DeepCore)
- The in-ice cable was secured to the DOM by top and bottom load bearing YaleGrips.
- Installation by load transfer between main cable and DOM
- Max force on cable during deployment: 8 kN
- Max load on harness < 450 kg
- Cable and harness designed with a minimum safety factor of 4
- 8 - 13 hours /string

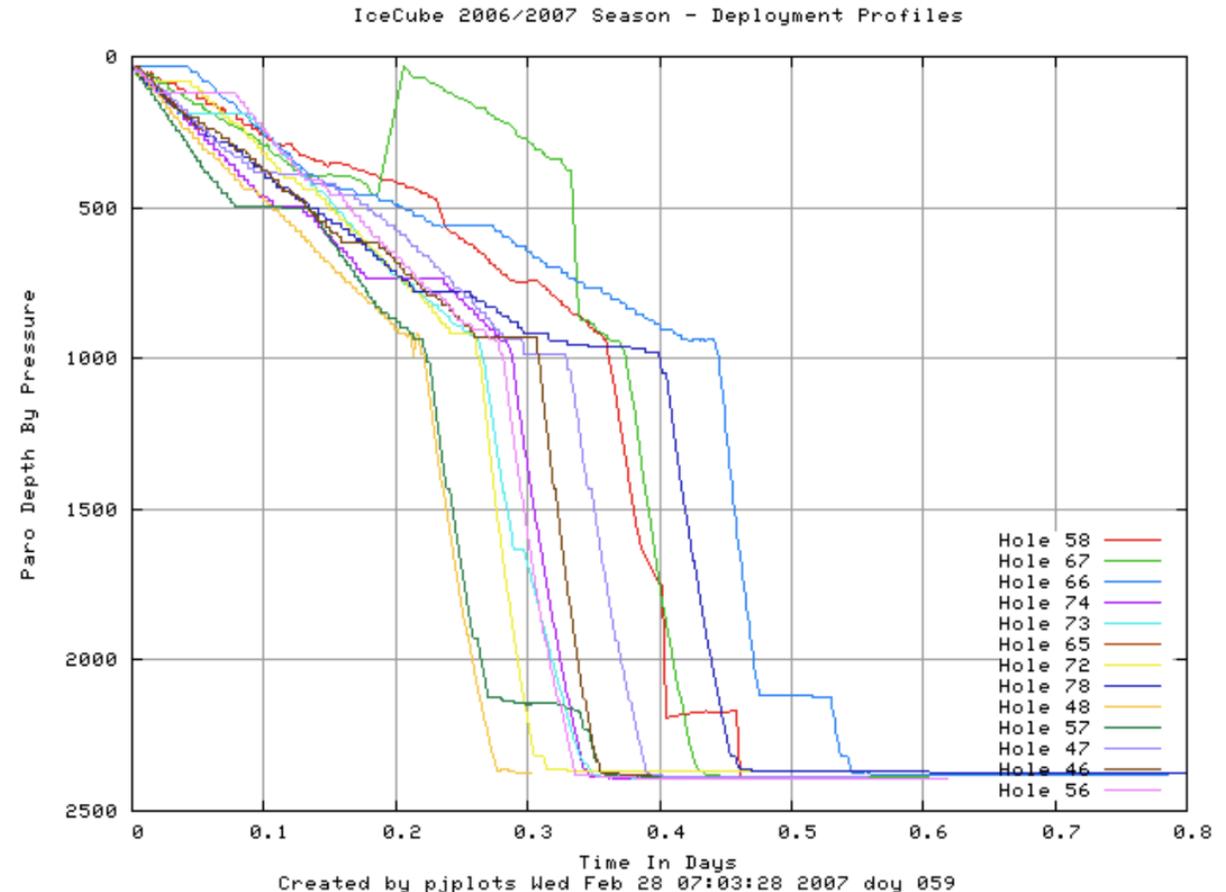


Deployment time

How long to deploy a string?

- IceCube from 2007/2008 indicate more like 7-8 min average / DOMs
- For 110 devices/string, 10 minutes/device → 18.3 hours.
- Extrapolated from first IceCube season: $110/60 \times 12$ hours → 22 hours
- ~110 devices / string
- → Aim at 20 hours, get ready for 24.

Gen1 deployment data 06/07: 8 to 14 hours



String Static Load Calculation

