IceCube Upgrade Installation

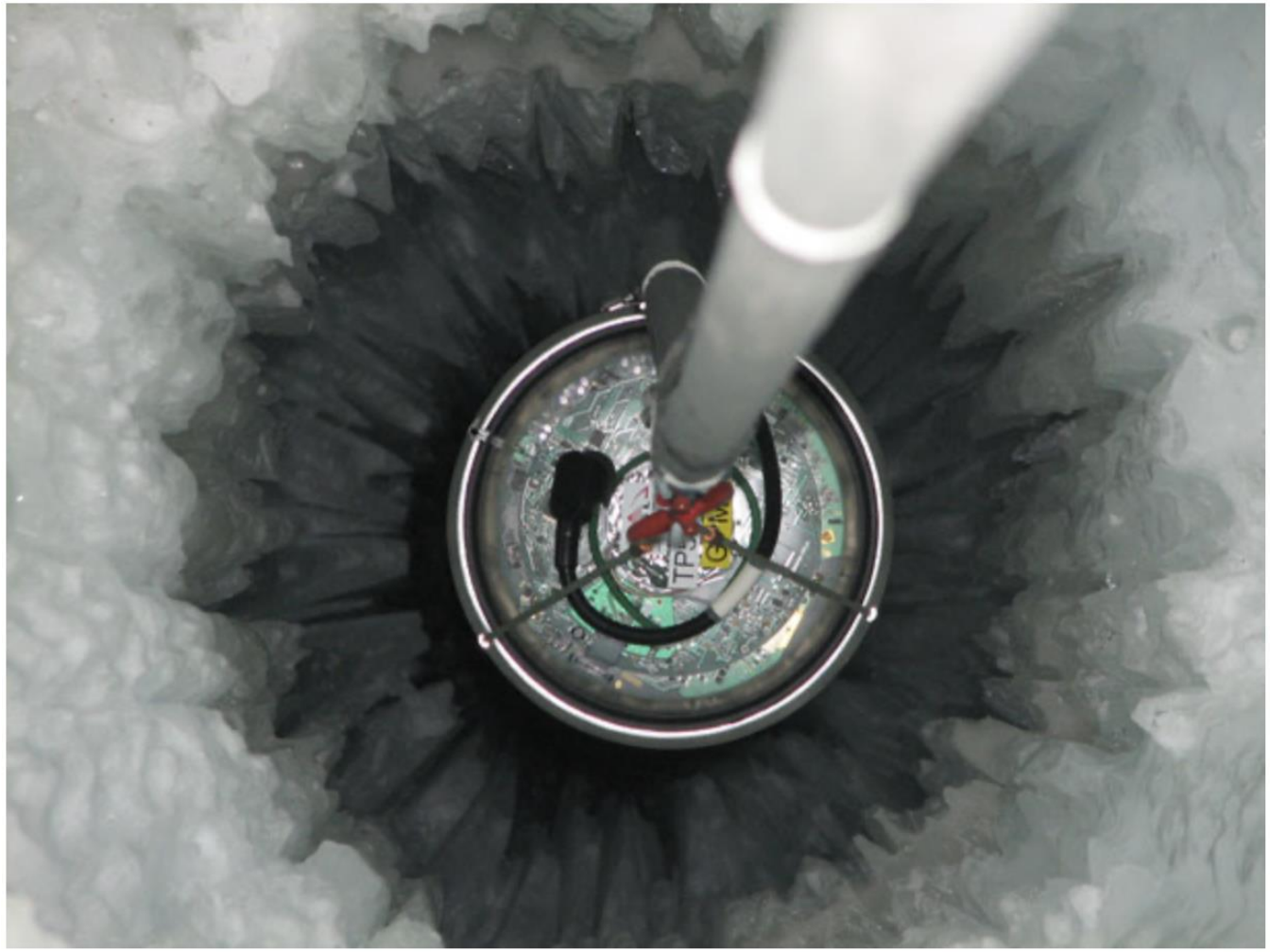
Breakout Session

IceCube Upgrade - Rebaseline Review
April 26-28, 2022

Delia Tosi – Installation Lead

Installation

- WBSs of interest:
  - 1.2.1: Implementation Management & Systems Engineering
  - 1.2.9: Installation Off-Ice
  - 1.2.10: Installation Field Seasons
- Technical progress
- Population & Cargo
- Main Cost Drivers



1.2.1 Installation L4s

1.2.1 Implementation Management & Systems Engineering
1.2.1.1 Implementation Management and Controls
1.2.1.2 Drill Management & Systems Engineering
1.2.1.3 Installation Management & Systems Engineering
- 1.2.1.3.1 2021-22 Management & Systems Engineering
- 1.2.1.3.2 2022-23 Management & Systems Engineering
- 1.2.1.3.3 2023-24 Management & Systems Engineering
- 1.2.1.3.4 2024-25 Management & Systems Engineering
- 1.2.1.3.5 2025-26 Management & Systems Engineering

1.2.1.4 Implementation Quality and Safety
1.2.1.5 Implementation Travel
1.2.1.6 Transportation and Logistics
- 1.2.1.6.1 Shipment Milestones
- 1.2.1.6.2 Drill Shipment Prep
- 1.2.1.6.3 Drill Shipping
- 1.2.1.6.4 Installation Shipment Prep
- 1.2.1.6.5 Installation Shipping

Installation Lead Labor + Engineering Support (Labor)
Total: $227k

FTE	PY5	PY6	PY7	PY8
Installation Management	15%	10%	5%	5%
Installation System Engineering	25%	30%	25%	20%

Vendor domestic trips (Travel)
Used key assumptions

Crating & Shipping (Labor+M&S):
total: $18k

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

Milestones:

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

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:

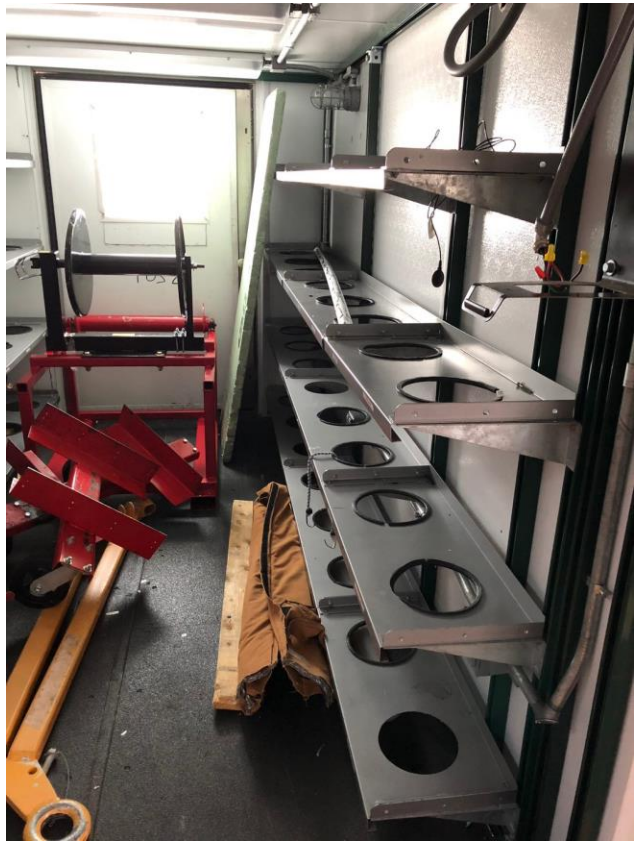
- Personnel and cargo arrival
- South Pole Acceptance Test (SPAT) ready
- Surface cable installation complete
- Readiness review
- Installation of each string

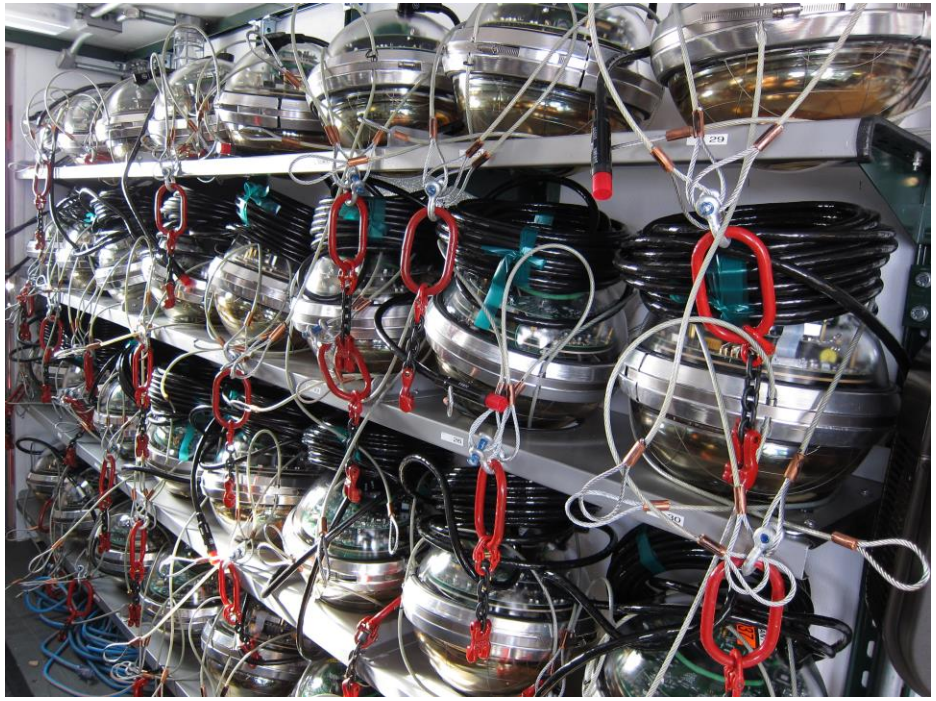
1.2.9 Installation Off-Ice

Technical Status & To-do

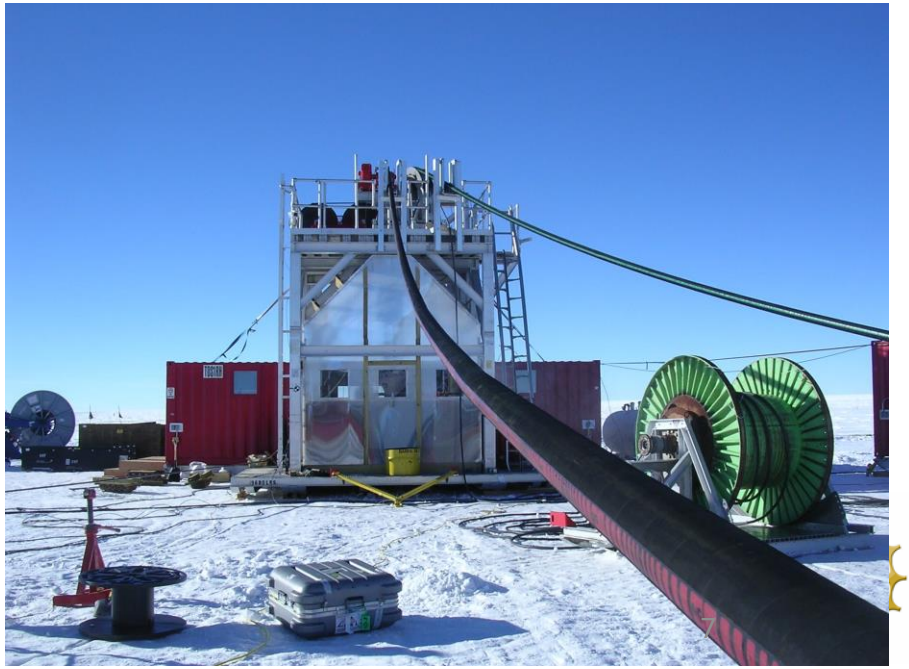
Sensor Handling & Testing in Gen1

- String sensors were placed on sleds and tested in a tent



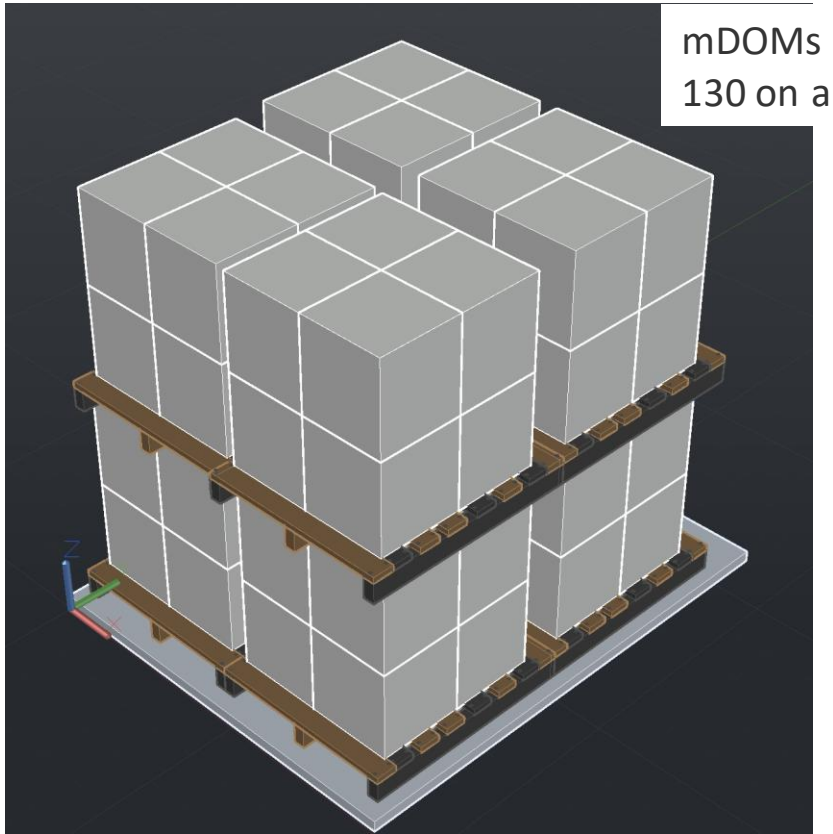


- Then unboxed and place on TOS shelves while drilling ongoing



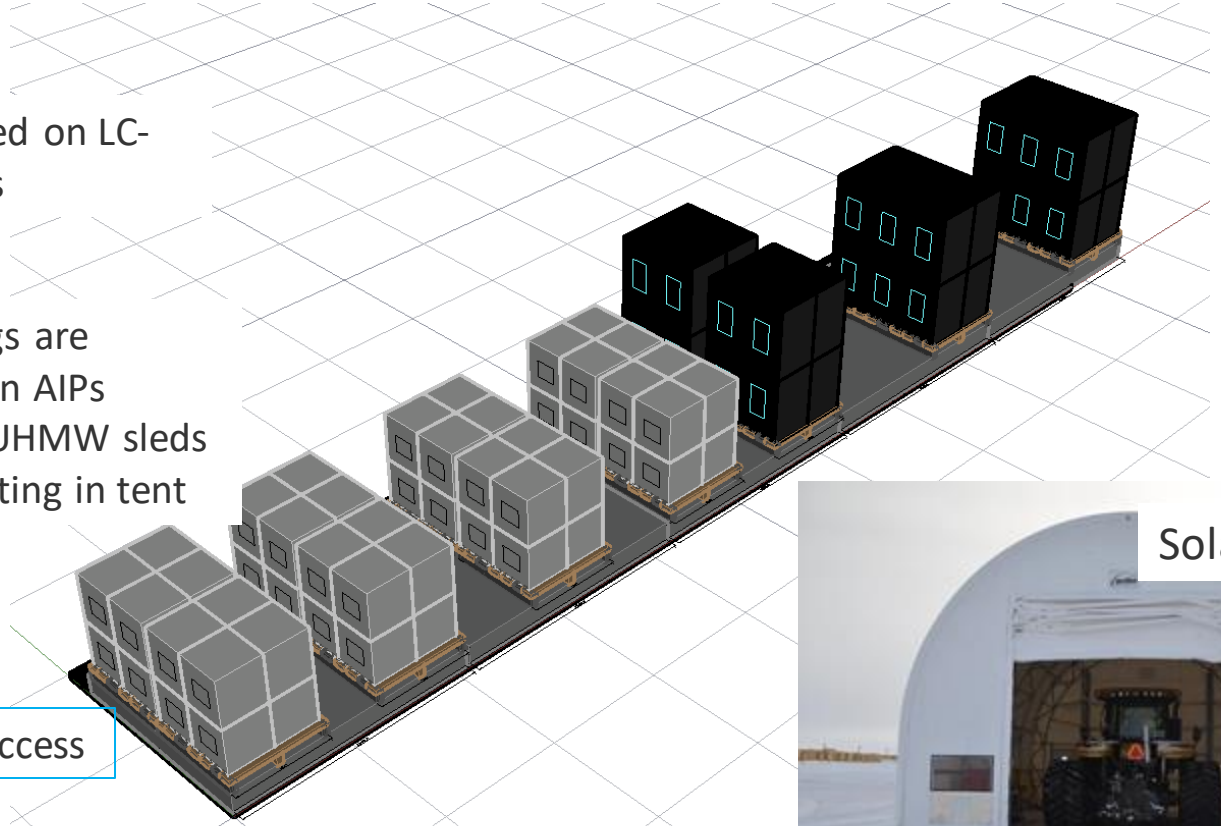
1.2.9.1 Sensor Handling in Upgrade

- Sensor Handling: details are intertwined with point of origin constraints, sensor dimensions, Antarctic logistics, and how sensors are moved at the South Pole and tested prior to deployment.
- Sensor packing fully developed, discussion undergoing with ASC to use on-ice sleds/AIPs/tent for sensor testing



mDOMs are transported on LC-130 on air force pallets

mDOMs/DEggs are transported on AIPs mounted on UHMW sleds at NPX for testing in tent



Penetrator access

Solar Garage

1.2.9.1 Sensor Handling Facility

To be completed in PY4

-Mobile building, on skis
-No power

hole

TOS from above
not on scale

old shelves

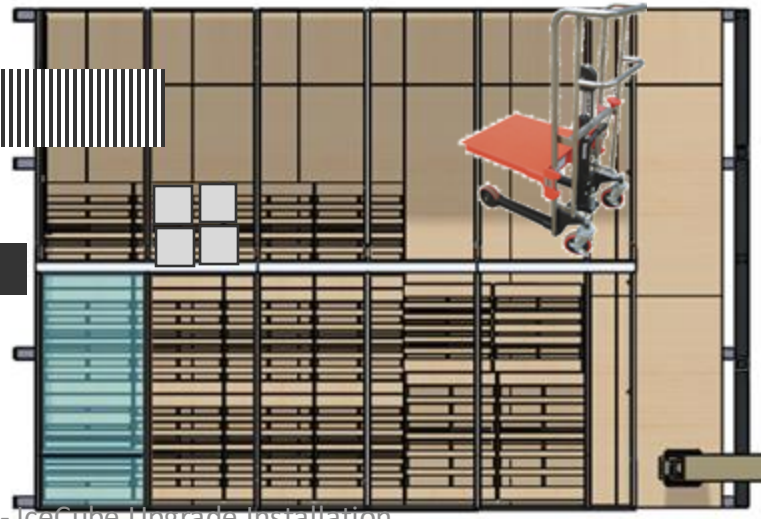
Area reserved to
storage of special
devices

Lift table

358”

Lift’n buddy

231”



Sensor sled

Deck mounted truck crane
equipped with pallet forks

1.2.9.2 Rigging & Installation Operations

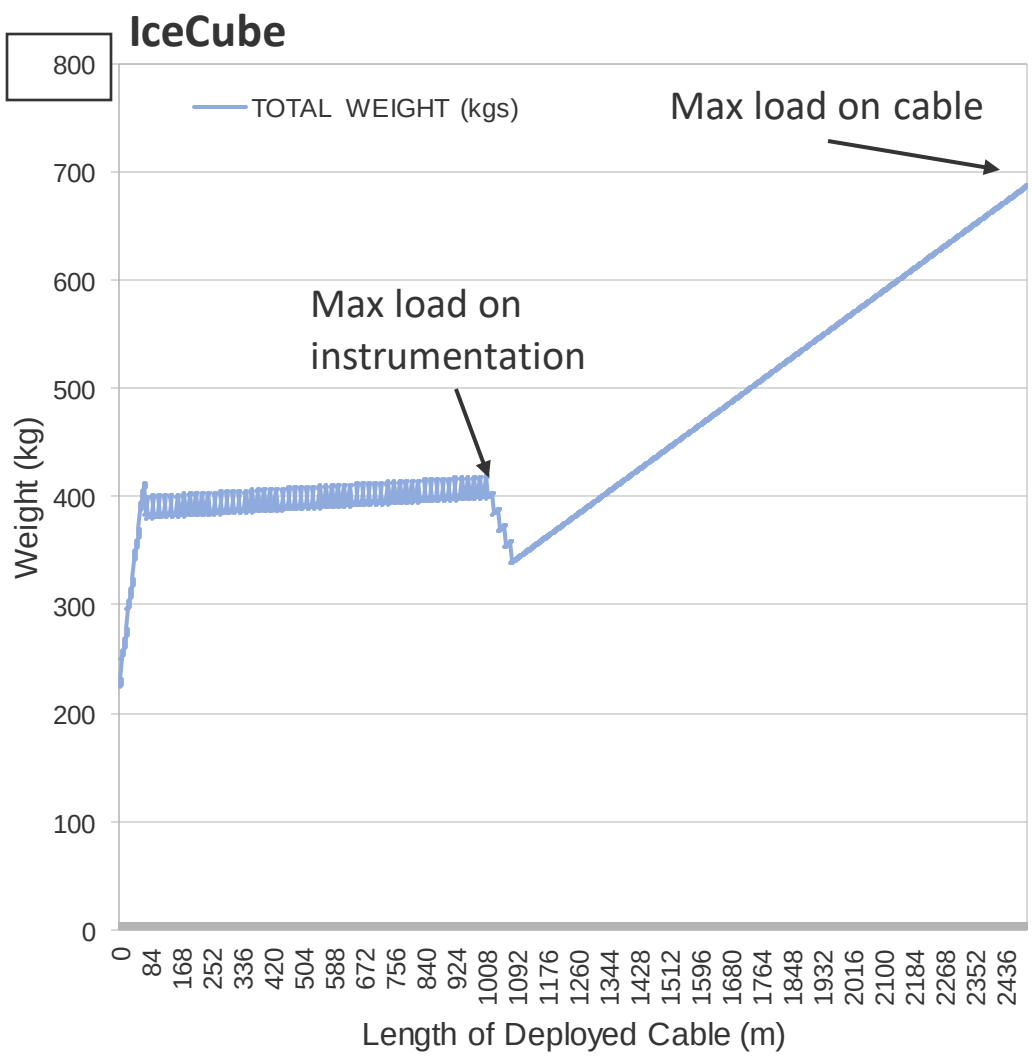
Rigging hardware and installation operations are closely linked to:

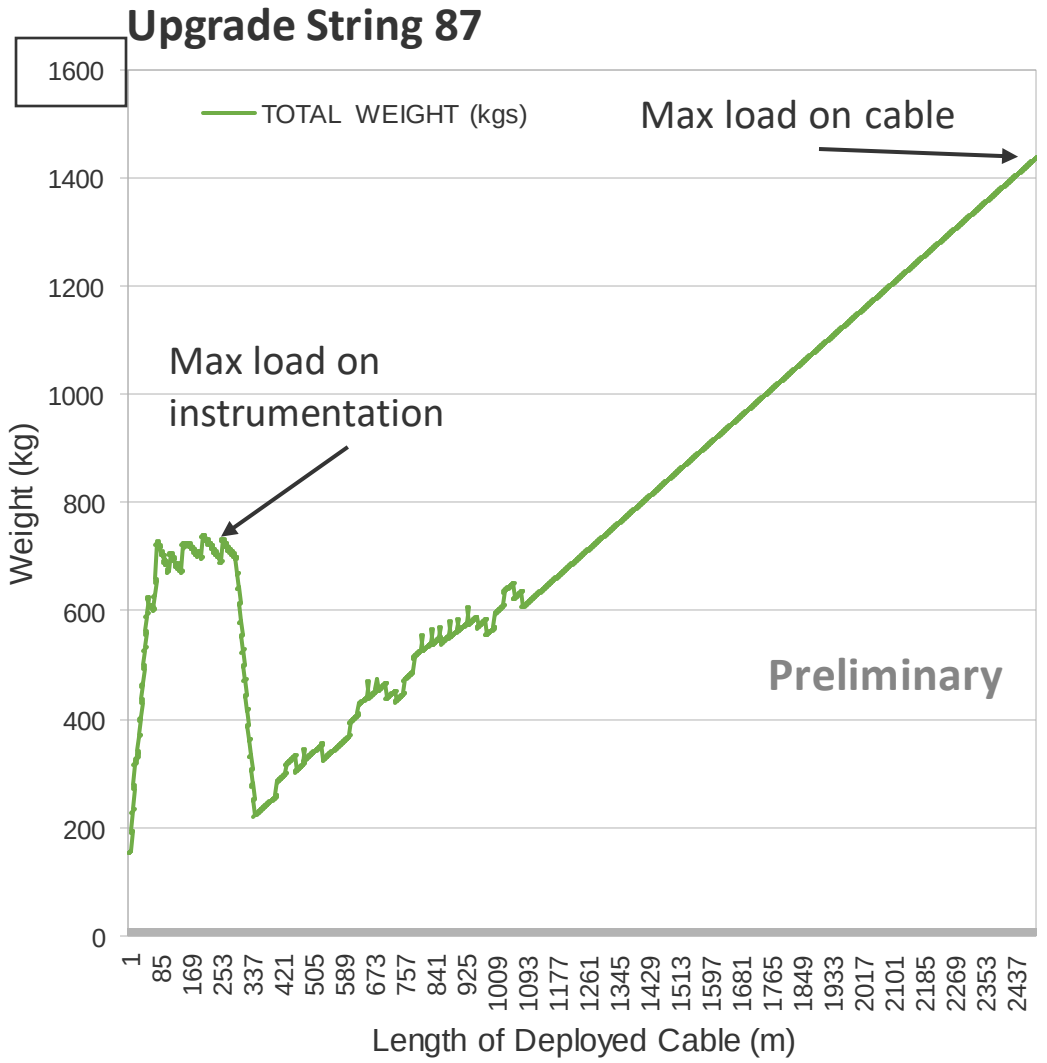
- each other
- sensor spacing
- sensor specs
- cable specs

} Max load on main cable assembly, breakouts and sensor

hardware and procedure to connect sensors to the cable

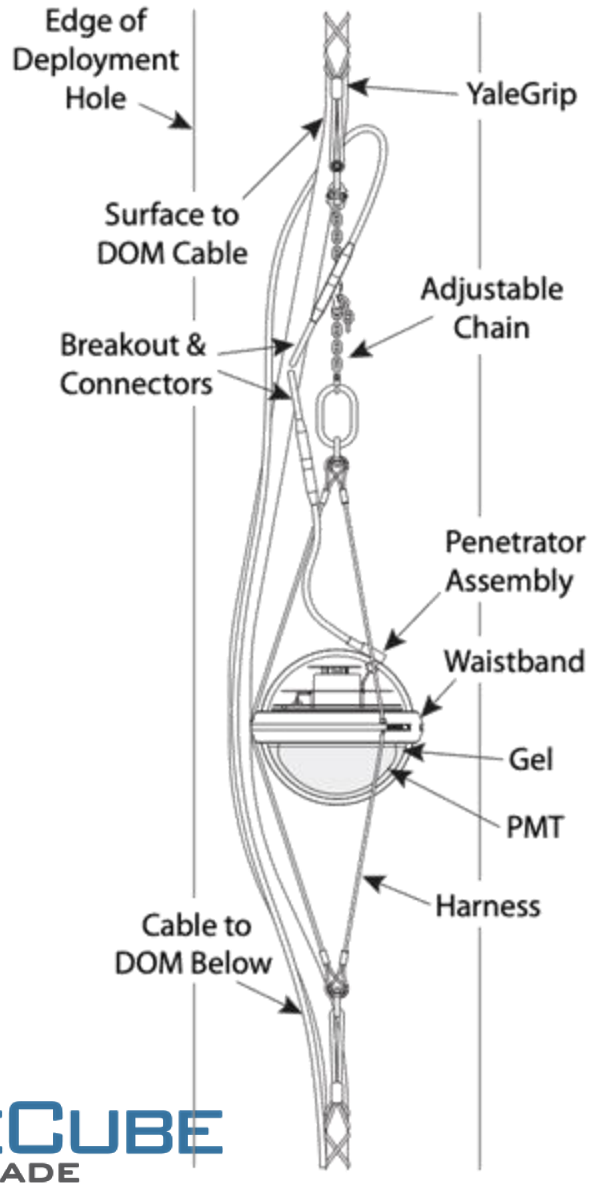
String Static Load Calculation (1.4-1.2)



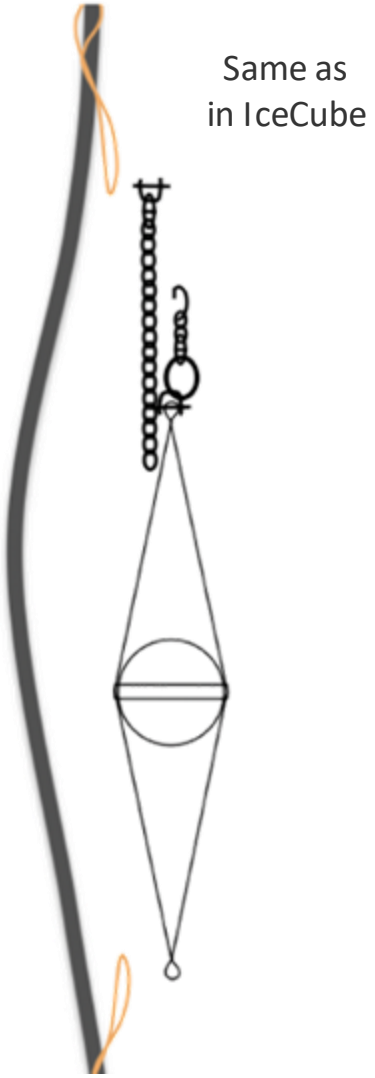


Installation video from IceCube Gen1
https://youtu.be/Lclhveinvmw

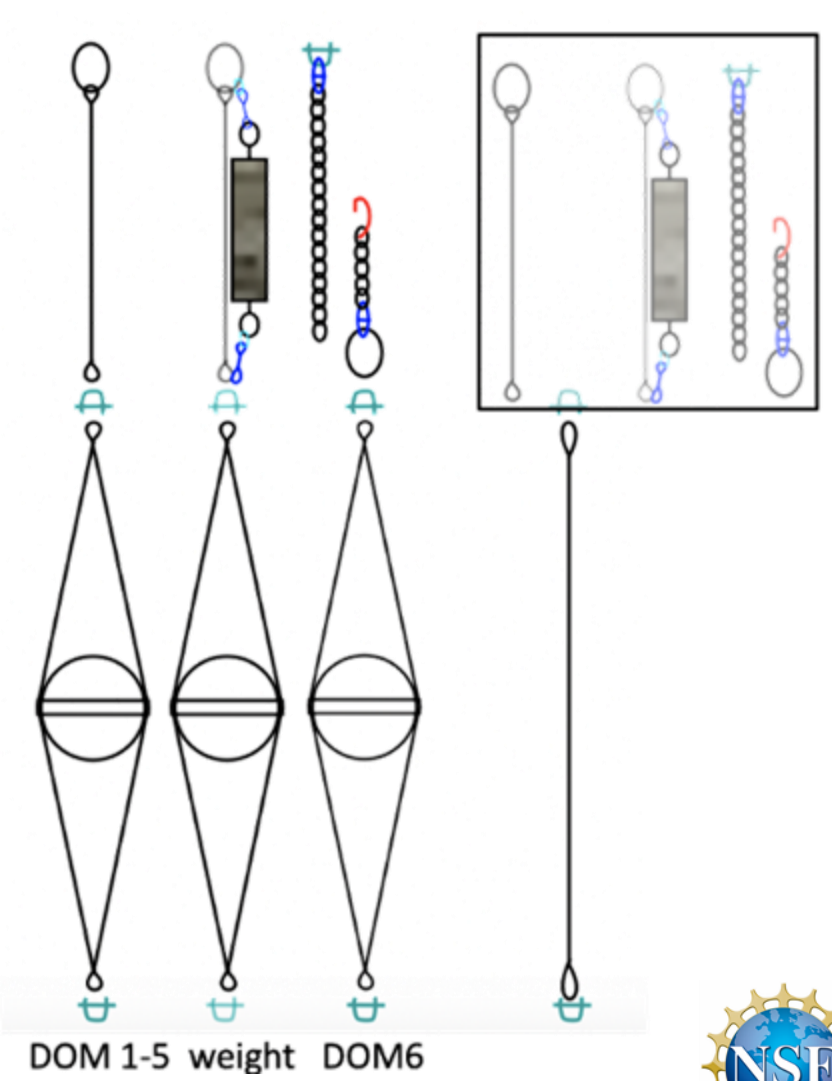
IceCube



IceCube Upgrade

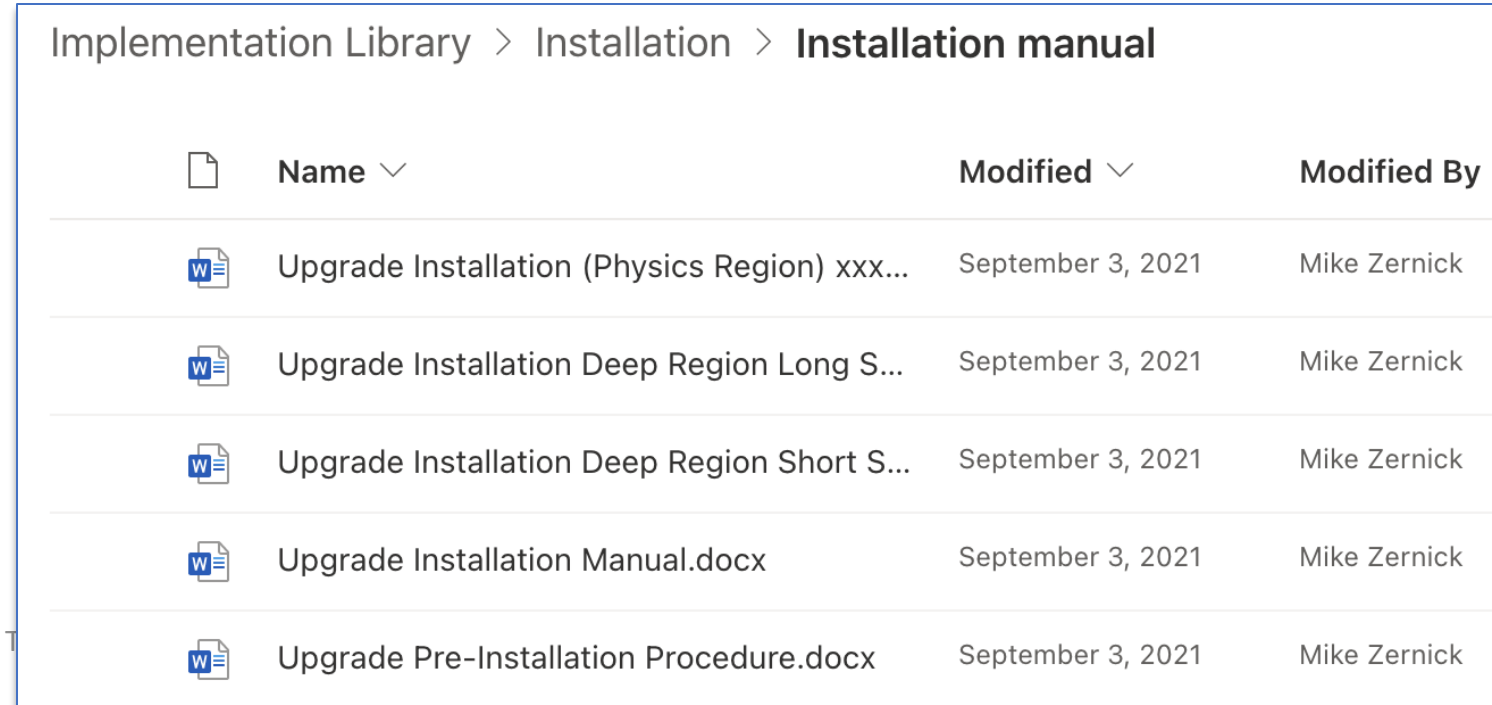


Same as in IceCube



1.2.9.2 Rigging for String Installation: Summary

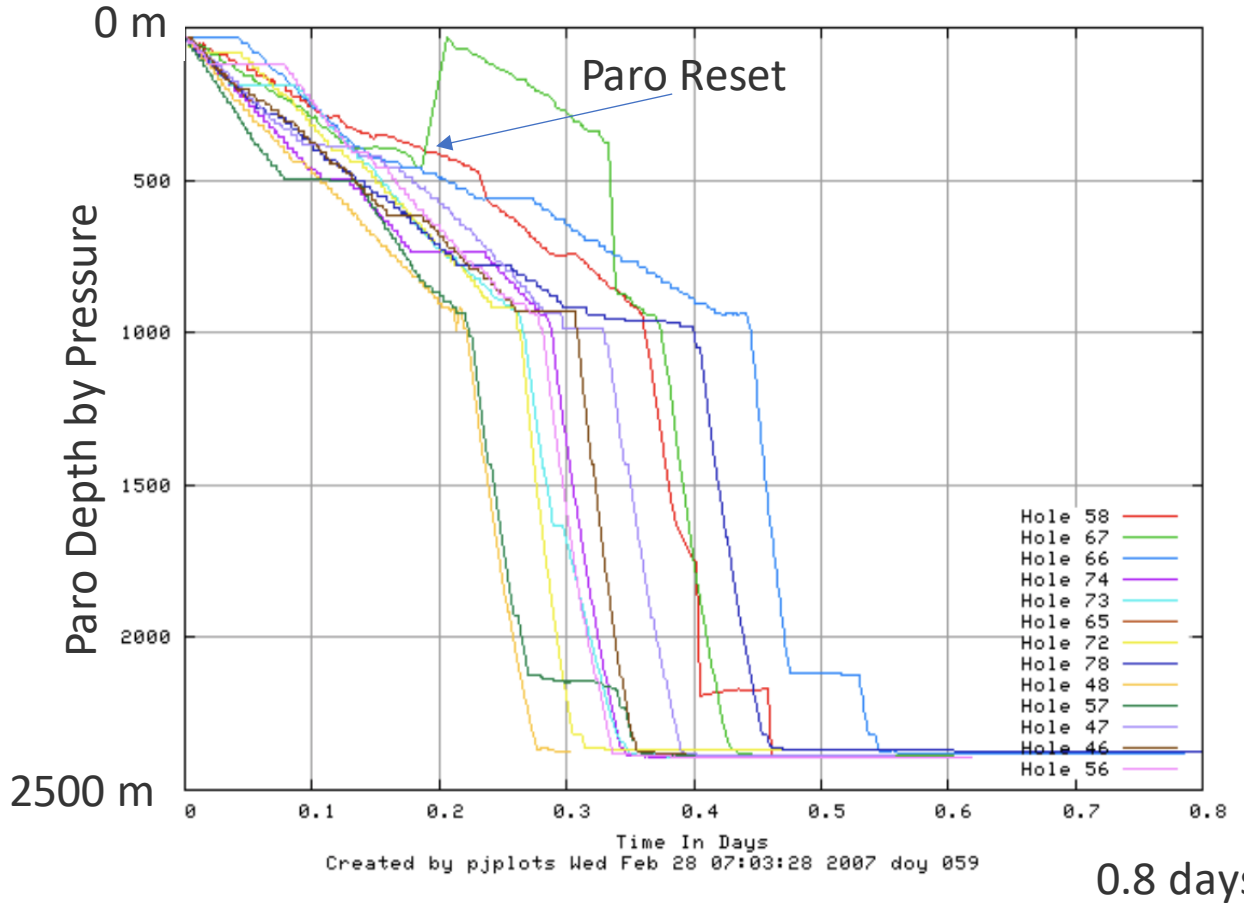
- Installation SOP drafts for each depth region
- Baseline rigging similar to what used in IceCube installation, cheaper &/or lighter alternatives being evaluated
- Procurement in PY5, shipping October 2023
- Time allocated should be plenty for procurement, could also split among vendors



1.2.9.3 Installation Monitoring Equipment

- Suite of tools to be used in installation to test connectivity and monitor depth
- Similar concept to Gen1 but different implementation
- 3 separate devices [PY4 to PY6]:
  a) Continuous depth monitoring via dedicated display in Drill Control System
  b) Hand-held connectivity tester in TOS to verify continuity of quad and breakout cable assembly
  c) Hand-held connectivity tester in ICL after installation is complete

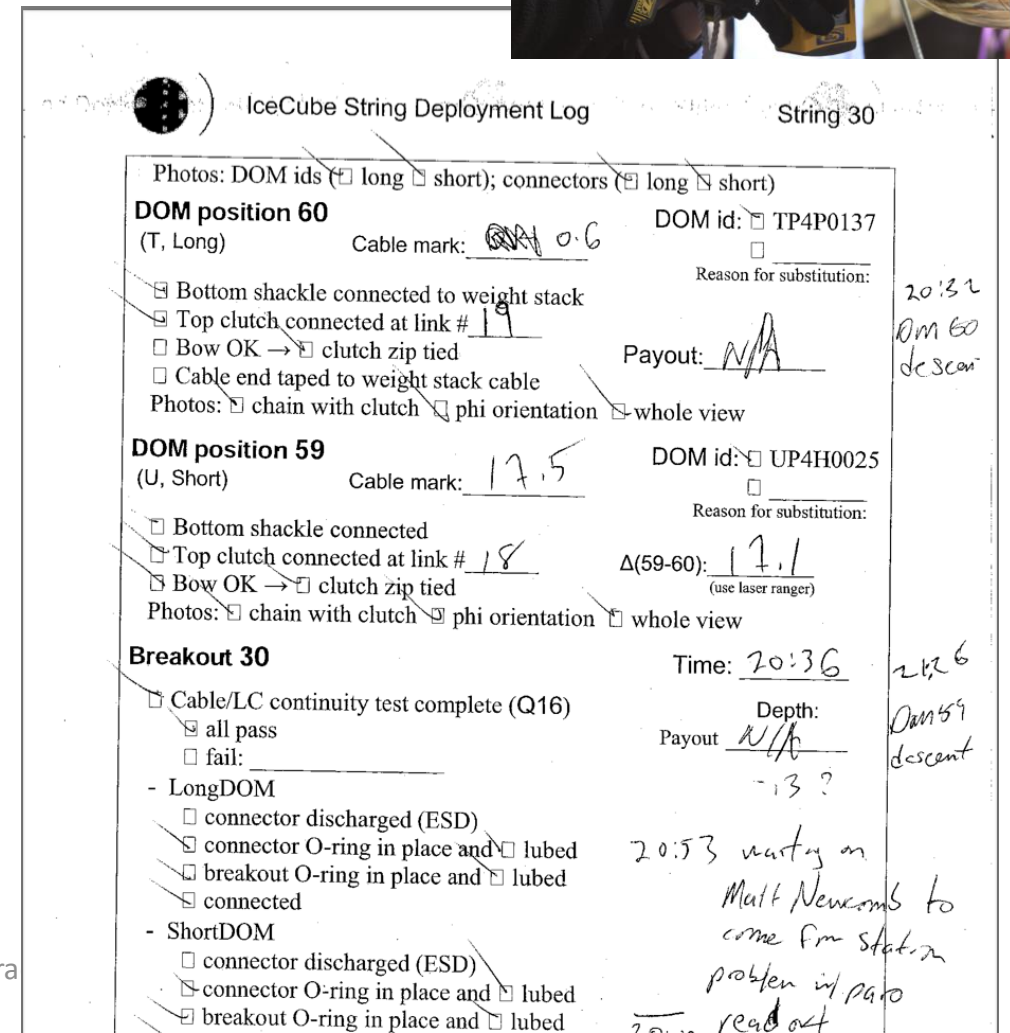
IceCube Gen1 deployment data 06/07:



0.8 days

1.2.9.4 Logging & Calibration Support

- Installation team in IceCube logged sensors position, serial number and distance from previous sensor on a paper logbook
  → the information collected + surveyor date provided Stage 1 geometry
- Plan for Upgrade is to have logging tablets programmed to make collection of geometry information more efficient (keep paper as back up)



IceCube String Deployment Log String 30

Photos: DOM ids (☐ long ☐ short); connectors (☐ long ☐ short)

DOM position 60
(T, Long) Cable mark: 0.6 DOM id: ☐ TP4P0137
☐ _____ Reason for substitution:
☒ Bottom shackle connected to weight stack
☒ Top clutch connected at link # 19
☐ Bow OK → ☐ clutch zip tied
☐ Cable end taped to weight stack cable
Payout: N/A
Photos: ☐ chain with clutch ☐ phi orientation ☒ whole view
20:32 DOM 60 descent

DOM position 59
(U, Short) Cable mark: 17.5 DOM id: ☐ UP4H0025
☐ _____ Reason for substitution:
☐ Bottom shackle connected
☐ Top clutch connected at link # 18
☐ Bow OK → ☐ clutch zip tied
Δ(59-60): 17.1 (use laser ranger)
Photos: ☐ chain with clutch ☒ phi orientation ☐ whole view

Breakout 30
Time: 20:36
☐ Cable/LC continuity test complete (Q16)
☒ all pass
☐ fail: _____
Depth:
Payout N/A
-13 ?
- LongDOM
☐ connector discharged (ESD)
☒ connector O-ring in place and ☐ lubed
☐ breakout O-ring in place and ☐ lubed
☒ connected
20:53 waiting on Matt Newcomb to come fm station pole in pato
- ShortDOM
☐ connector discharged (ESD)
☒ connector O-ring in place and ☐ lubed
☒ breakout O-ring in place and ☐ lubed
read out
2126 DOM 59 descent

1.2.9.5 / 1 2.10.1 Installation Training

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.

1.2.10 Installation Field Activities

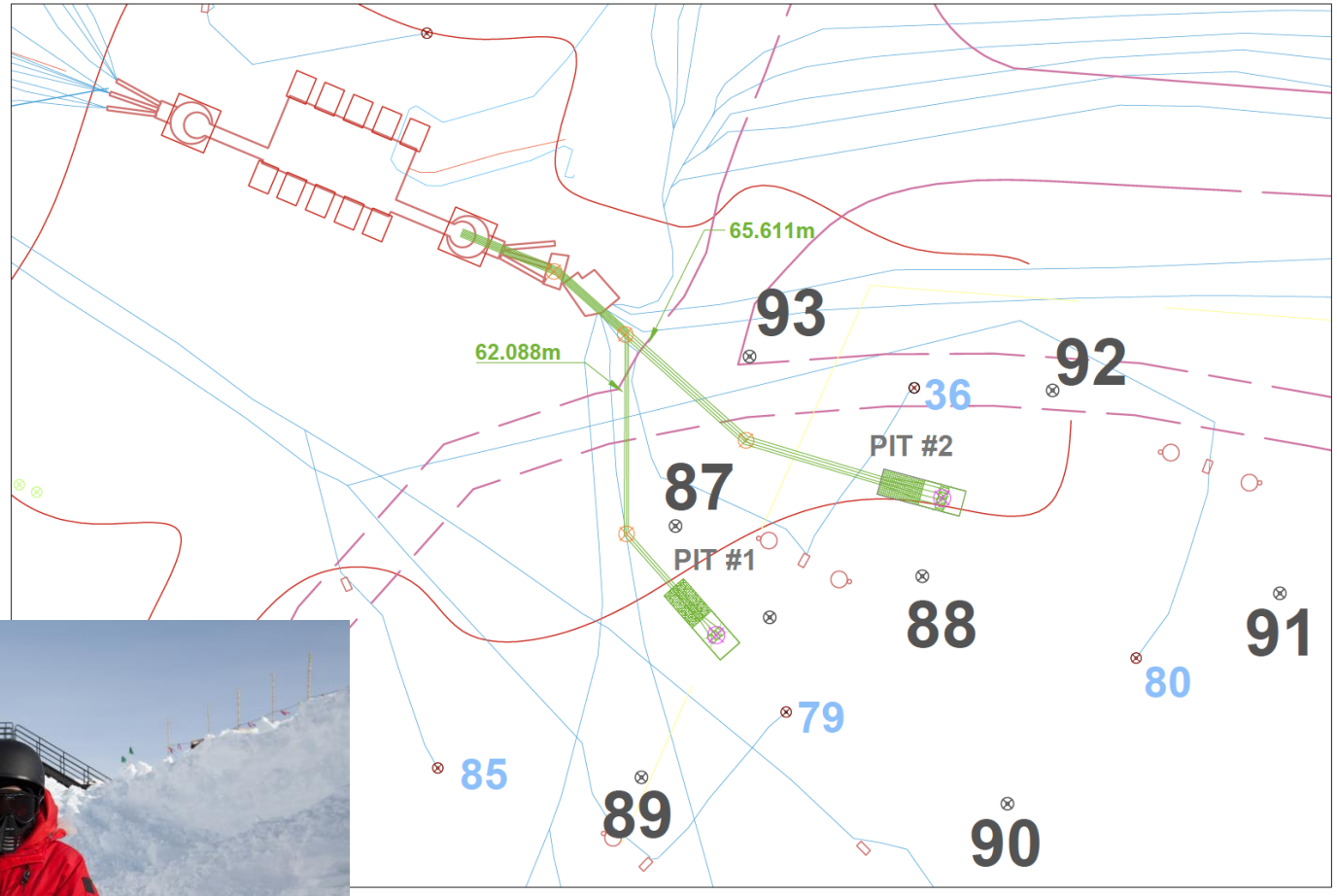
Tasks & Population

IceCube Upgrade

NSF

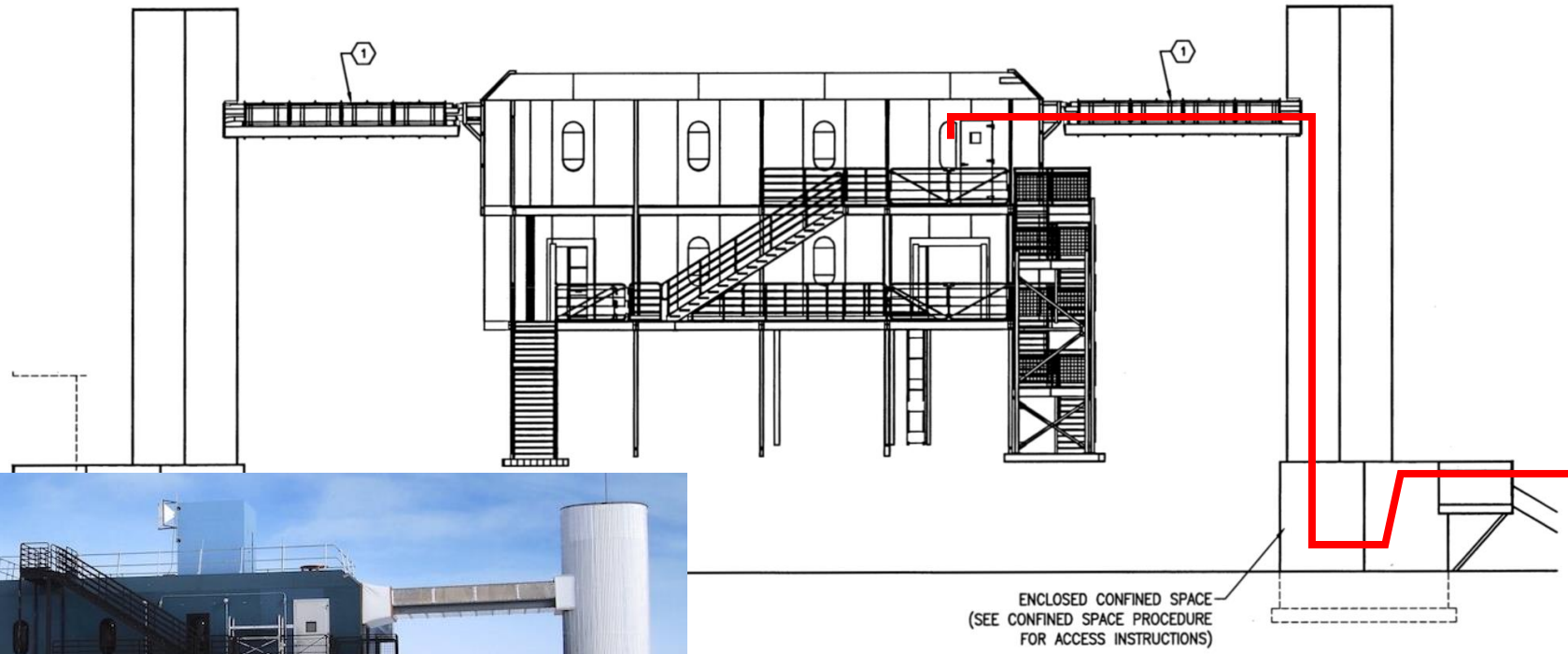
Field Season 2 Installation tasks & personnel

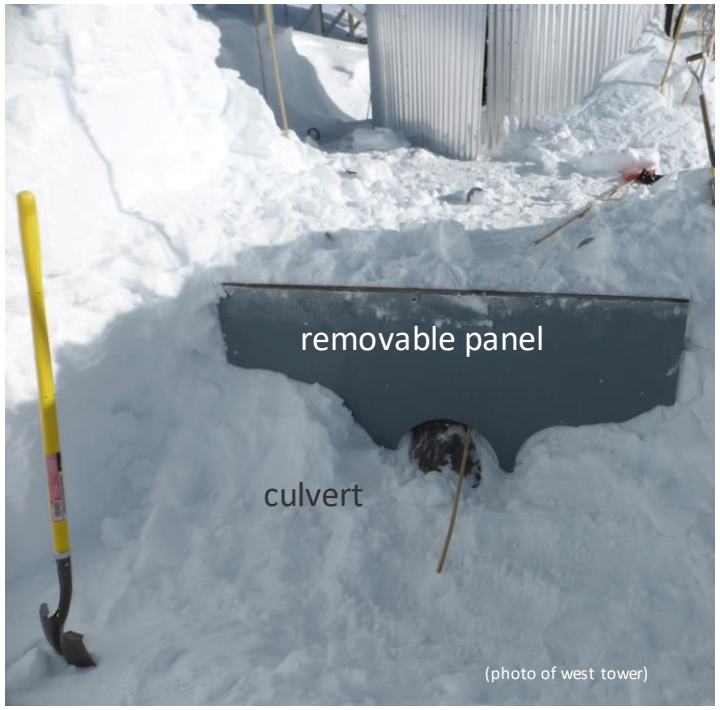
- Install surface cables and surface junction boxes
- Install & commission Upgrade timing and power electronics into the ICL
- Inventory of Installation tools
- Setup Sensors Handling and Testing
- Team size of 4



Surface Cable Assembly Entry in East Tower

A couple options investigated jointly with ASC in 2019-20, plan developed shortly before COVID in spring 2020 with ASC meeting

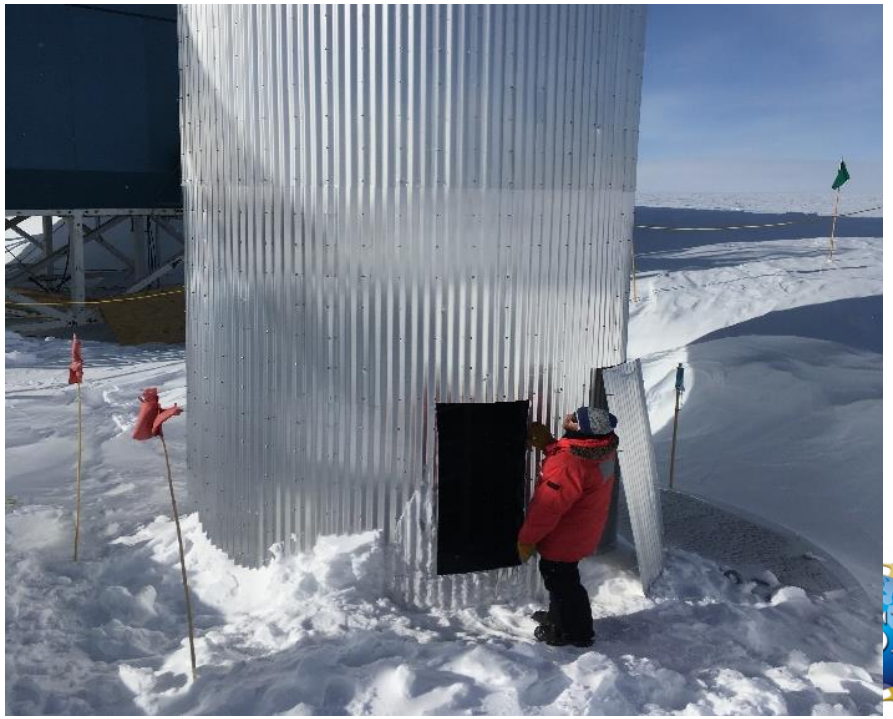




surface cables x7

On-site Investigation, 30 Dec. 2019

- Inspection team:
  - IceCube: J. Kelley, D. Tosi
  - ASC: S. Bruce, T. Ager, D. Clyde, P. Gougeon, G. Gordon, A. Fera
- Opened panel at base of tower for access
- Lift support to open / inspect cable bridge
- Installed a lead line across bridge down to the pit
- Complete entry to exit inspection



More photos/details in backup
Also a few pictures about scintillator/radio + ARA cables up the west tower in 2017

Field Season 3 Installation tasks & personnel

String preparation (1 DAQ expert + 1 in-kind helper):

- Test 800 sensors (SPAT)
- Stage instrumentation prior to installation

Installation proper list of tasks (Install lead + 4 in-kind per shift + 3 drillers):

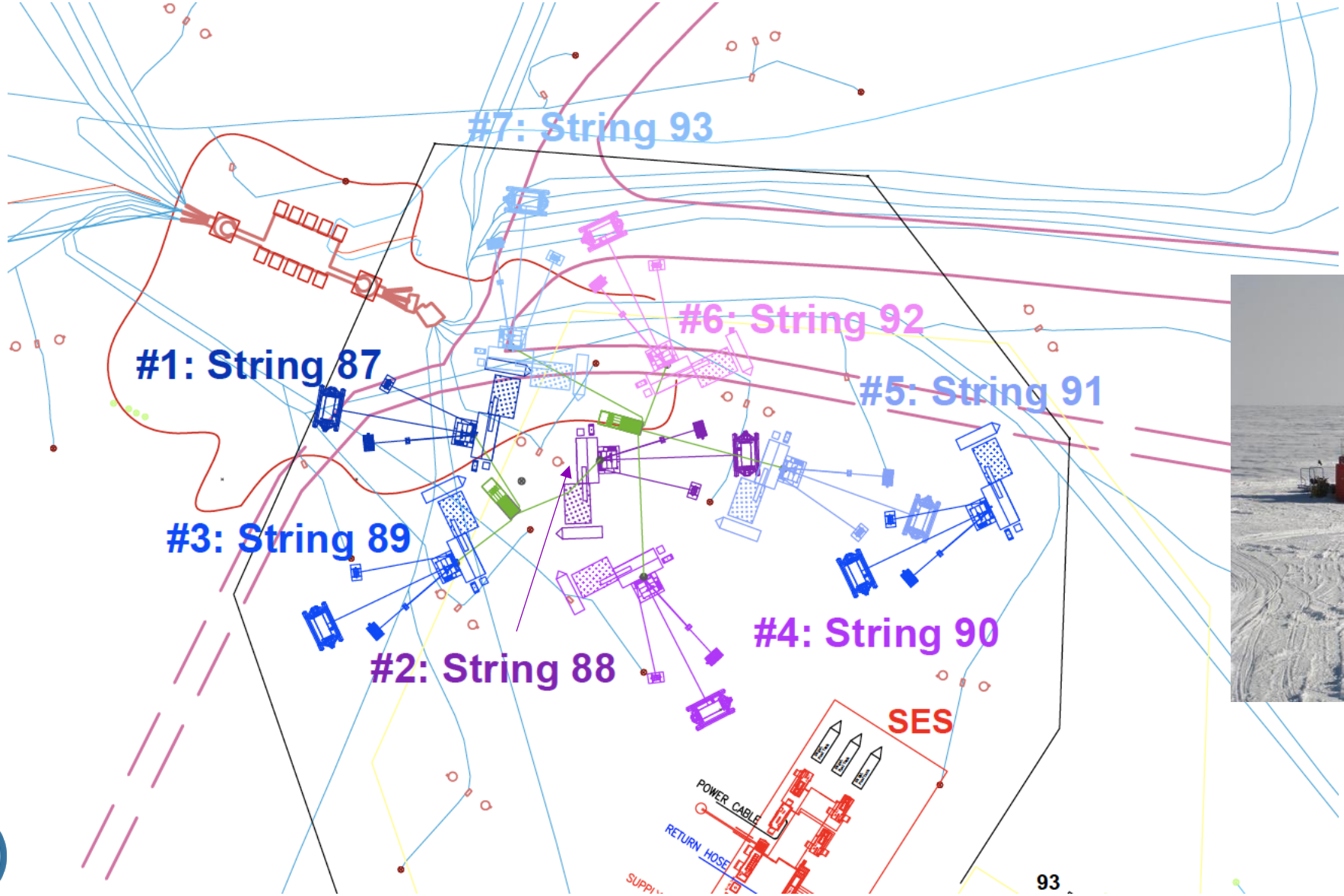
- Shift lead (1x)
- DOM suppliers (2x): sort sensors according to string deployment order in sensor handling facility
- DOM supplier TOS side (1x): preps the next sensor
- DOM installers (2x) : attach sensors to cable at the hole
- Winch operator (1x): operate TU-20 and hoist
- Logger (1x): Logs instrumentation,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

Cables specific tasks (1 CPT electronics SME + 1 DAQ SME)

- 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 (*).

Field Season 3 Drill Sequence

ASC/Upgrade map maintenance
part of 1.2.1 work



TOS1 in shades of blue
TOS2 in shades of pink

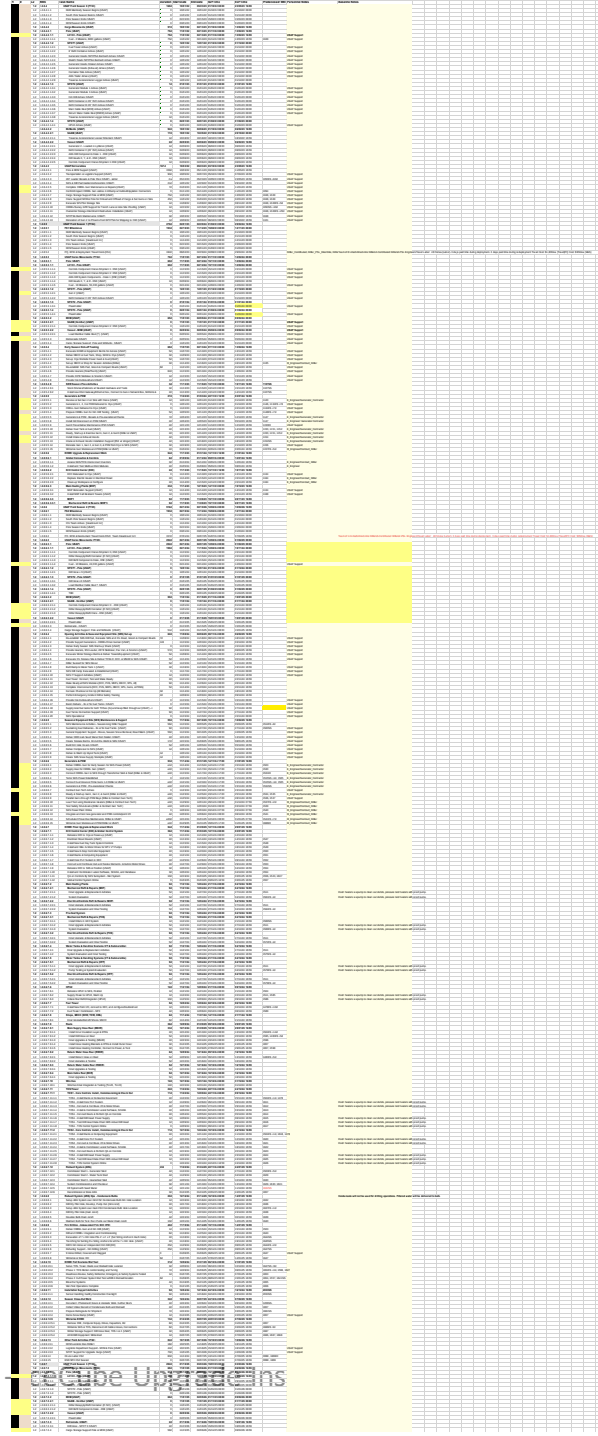
1.2.10 Cargo & ASC support

Installation cargo breakdown

	Point of Departure (Point of Origin)	volume [cu ft]	fraction of volume	weight [lbs]	fraction of weight
cables (SCAs, MCAs, BCAs, SJBs)	MSU (MSU)	5,628	13.9%	128,114	24.2%
D-Eggs	CHIBA (CHIBA)	2,505	6.2%	27,780	5.3%
mDOMs	DESY (DESY) / MSU (MSU)	2,756	6.8%	30,369	5.7%
calibration & special devices	UW (various)/ DESY (various)	566	1.4%	9,178	1.7%
dm-ice	YALE (YALE)	64	0.2%	1,500	0.3%
dust logger	UW (UW)	286	0.7%	4,200	0.8%
DOM Handling Facility	UW (UW)	1,280	3.2%	12,000	2.3%
hardware (rigging and weights)	UW (UW)	980	2.4%	12,502	2.4%
misc science	UW (UW)	128	0.3%	3,000	0.6%
ICL equipment	UW (UW)	304	0.8%	2,075	0.4%
installation equipment total	SEE ABOVE	14,497	35.8%	230,718	43.7%
Drill equipment total	UW (UW)	25,984	64.2%	297,708	56.3%
Logistics equipment total	UW (UW)	2	0.0%	10	0.0%
total		40,483	100.0%	528,436	100.0%

ASC support

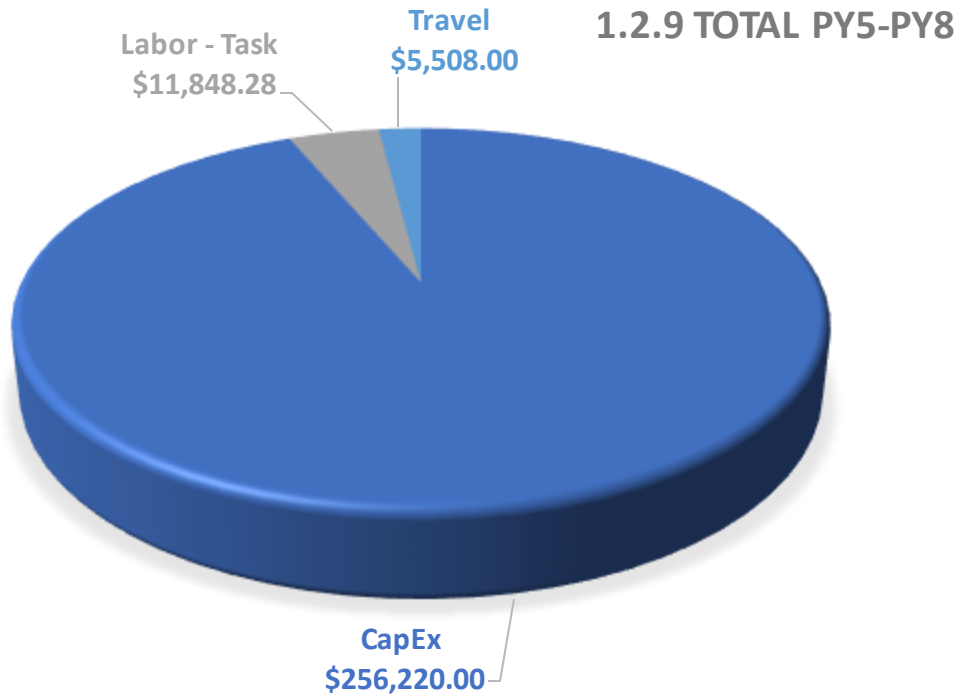
- Cargo movement
- Trenching for SCA and MCA
- TU-20 loading
- Sensor loading for testing
- ICL culver plate modifications

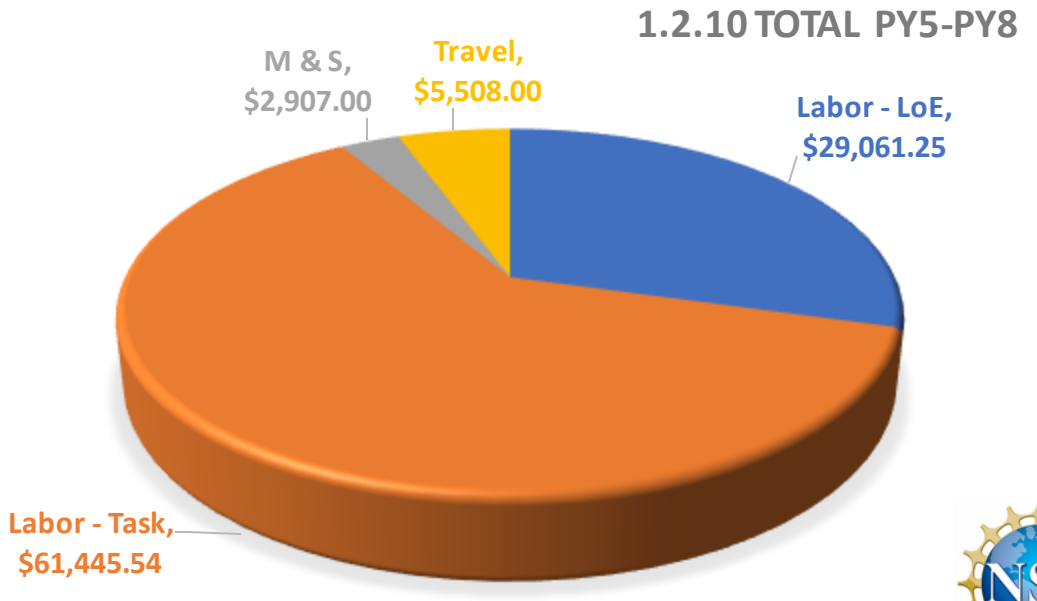


1.2.9 – 1.2.10 Cost

Cost & Main Cost Drivers

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





1.2.9 CapEx

WBS	Activity	Subtype	12mo Subtotal PY5	12mo Subtotal PY6	12mo Subtotal PY7	12mo Subtotal PY8	Estimating Technique	Contingency
1.2.9.1.3.2	Off-Ice Install: Procure Sensor Handling Equipment	CapEx	$8,453	$0	$0	$0	C - Engineering Buildup	C3
1.2.9.1.3.3	Off-Ice Install: Procure ESD Sensor Handling Equipment	CapEx	$5,549	$0	$0	$0	D - Expert Opinion	C4
1.2.9.2.8	Off-Ice Install: Procure Installation Hardware	CapEx	$108,000	$0	$0	$0	C - Engineering Buildup	C3
1.2.9.2.9	Off-Ice Install: Procure Installation Weights	CapEx	$9,900	$0	$0	$0	D - Expert Opinion	C4
1.2.9.3.2.1	Off-ice Install: IME ICL Quad Connectivity Tester Design, Prototype & Production (2023-24)	CapEx	$0	$4,800	$0	$0	D - Expert Opinion	C4
1.2.9.3.3.2	Off-ice Install: IME Depth Readout Development and System Integration (2022-23)	CapEx	$3,400	$0	$0	$0	D - Expert Opinion	C4
1.2.9.3.3.7	Off-Ice Install: Procure Pressure Sensors	CapEx	$0	$104,796	$0	$0	C - Engineering Buildup	C2
1.2.9.4.2.3	Off-Ice Install: Procure Tablets for Logbook	CapEx	$0	$5,967	$0	$0	D - Expert Opinion	C4
1.2.9.4.2.5	Off-Ice Install: Procure Laser Rangers & various Installation Supplies	CapEx	$0	$5,355	$0	$0	E - Extrapolation from Actuals	C3

Installation Hardware

Installation Kits Configuration Management Document

Shallow region installation kit					
assembly 8					
5/8" shackle	Peerless	8058605	Tulsa Chain	8058605	$ 8.49
coupler	Cartec		Tulsa Chain	CL07	$ 11.38
long chain shallow region	Laclede		Tulsa Chain	3 ft 9/32G80CUT	$ 11.88
assembly 2					
shortening clutch	Cartec	TVK 6-8	Tulsa Chain	CXX07	$ 37.13
short chain	Laclede		Tulsa Chain	2 ft 9/32G80CUT	$ 7.92
coupler	Cartec		Tulsa Chain	CL07	$ 11.38
lifting ring	Cartec	German: T	Tulsa Chain	AX13	$ 9.17
5/8" shackle	Peerless	8058605	Tulsa Chain	8058605	$ 8.49
assembly 6					
5/8" shackle	Peerless	8058605	Tulsa Chain	8058605	$ 8.49

Upgrade Cost Estimate

Name:	1.2.9.6.8 Installation Hardware
Parent WBS:	1.2.9 Installation off-ice
Description of Scope:	hardware for installation
Initials/Date:	D.T. 03/22/2022

WBS (if known)	Project Year (0-10)	Description	MATERIAL QTY	Spare	Total	Fabricate or Procure?	Procurement Details Manufacturer, Model, P/N, Vendor	Unit Price	Total Expected Price
1.2.9.2.8	PY5	Shalllow region installation kit	127	1	128	Procure	See Installation Kits CMD for part number list	$114.30	$14,630.40
	PY5	Physics region DOM 2-5 installation kit	420	1	421	Procure	See Installation Kits CMD for part number list	$49.64	$20,898.44
	PY5	Physics region DOM 1 installation kit	105	1	106	Procure	See Installation Kits CMD for part number list	$85.35	$9,047.10
	PY5	Physics region DOM 6 installation kit	105	1	106	Procure	See Installation Kits CMD for part number list	$82.58	$8,753.48
	PY5	Add-on Weight (Physics Region DOM 5)	63	0	63	Fabricate	weights available at Pole, finalize design to determine if appropriate	$558.00	$35,154.00
	PY5	Deep region short strings installation kit	24	1	25	Procure	See Installation Kits CMD for part number list	$58.81	$1,470.25
	PY5	Deep region long strings installation kit	15	1	16	Procure	See Installation Kits CMD for part number list	$27.15	$434.40
	PY5	Physics region DOWN YG connection installation kit	105	1	106	Procure	See Installation Kits CMD for part number list	$109.00	$11,554.00
	PY5	Physics region UP YG connection installation kit	105	1	106	Procure	should be simpler than UP, guessing 1/2 price	$54.50	$5,777.00
									$107,719.07

Pressure Sensors for depth monitoring

Paroscientific, Inc.

4500 148th Avenue N. E.
Redmond, WA 98052-5194
Telephone: (425) 883-8700
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January 11, 2022

University of Wisconsin – Madison
IceCube Neutrino Observatory
222 W Washington Ave.
Suite 500
Madison, WI 53705

Attention: Delia Tosi
Phone: 608-263-2067
Email: delia.tosi@icecube.wisc.edu

Subject: Request for Quotation – Paroscientific Digiquartz® Intelligent Depth Sensor
Reference: E-Mail of January 10, 2022

Dear Delia,

Thank you for your interest in Paroscientific Precision Pressure Products. We are pleased to provide the following quotation in response to the reference email:

Item	Qty	Model, P/N (SCD)	Description	Unit Price
1	1-7	Model 8CB4000-I P/N 1700-003-0 SCD 7613-001 Rev T (Copy Attached)	DIGIQUARTZ® INTELLIGENT DEPTH SENSOR, RANGE 0-6,000 PSIA (6,000M), INTELLIGENT ELECTRONICS, RS-232/RS-485 INTERFACE, STAINLESS STEEL HOUSING, OIL-FILLED.	$ 11,800.00

Notes:
-Quote No: 011122SS-UW

Planning on purchasing 7+1 spare, include 11% price increase over two years (purchase in PY6)

Response to Previous Reviews (Logistics Review 11/2021)

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 firn holes and cable trenches to CRREL and define the level of fidelity needed.	Delia Tosi	open		plan to CRREL and survey st 2022 That includes erance 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.

In progress since the snapshot

Summary

- Installation task similar to IceCube, with added complexity
- Upgrade relies on solid experience from Gen1
- Installation schedule & budget in Smartsheet
- Installation cargo & population (FS2/FS3) captured in master spreadsheet
- Personnel for FS2 identified; FS3 labor largely in-kind, recruiting to start by mid 2023

backup

1.2.10 Labor Hours

WBS	Activity	Resource ID	Subtype	LPY5	LPY6	LPY7	LPY8	Estimating Technique	Contingency
1.2.10.1.3	Install FS3: FS3 Off-Ice Installation Training: Drillers	TE	Labor - Task		0	0	288	0 D - Expert Opinion	C1
1.2.10.4.10	Installation: On-Ice Labor (FS2) (Installation Lead)	SC	Labor - LoE		0	0	396	0 D - Expert Opinion	C1
1.2.10.5.8	Installation: On-Ice Labor (FS3) (Installation Lead)	SC	Labor - Task		0	0	0	558 D - Expert Opinion	C1

8.1. Labor Estimate

The 1.2.10 WBS covers labor of the installation lead for the time spent in the field. This time is estimated based on the start and end date of on-ice activities and assumes a 9 hr/day, 6 days/week workweek. Each activity is linked to milestones such as cargo arrival, personnel arrival, and other activities to guarantee completion of deliverables by due dates. Additional labor included in this WBS is for specific installation training of drillers.

1.2.9 BOE

$248,522 spent to date

1. **WBS ID** 1.2.9 $273,576 total cost for this WBS

2. **WBS Name** Installation Off-ice

3. **Estimated by** Delia Tosi (University of Wisconsin)

4. **WBS Dictionary Description**

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 Travel

WBS	Activity	12mo Subtotal PY5	12mo Subtotal PY6	12mo Subtotal PY7	12mo Subtotal PY8	Estimating Technique	Contingency
1.2.9.3.2.1	Off-ice Install: IME ICL Quad Connectivity Tester Design, Prototype & Production (2023-24)	$0	$1,800	$0	$0	E - Extrapolation from Actuals	C1
1.2.9.3.3.2	Off-ice Install: IME Depth Readout Development and System Integration (2022-23)	$1,800	$0	$0	$0	E - Extrapolation from Actuals	C1

Two trips to MSU to test system on a full-length quad

1.2.9 Labor Hours

WBS1	Activity	Resource ID	Subtype	LPY5	LPY6	LPY7	LPY8	Estimating Technique	Contingency
1.2.9.3.3.2	Off-ice Install: IME Depth Readout Development and System Integration (2022-23)	EN-EE	Labor - Task		60	0	0	0 D - Expert Opinion	C3
1.2.9.3.3.3	Off-Ice Install: IME Depth Readout System Final Integration (2023-24)	EN-EE	Labor - Task		0	40	0	0 D - Expert Opinion	C3

1.2.10

1. **WBS ID** 1.2.10 $98,922 total cost for this WBS

2. **WBS Name** Installation Field Seasons

3. **Estimated by** Delia Tosi (University of Wisconsin)

4. **WBS Dictionary Description**

The Installation Field Season WBS 1.2.10 includes detailed activities list and on-site management of polar field season work required 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 WBS (1.6 and 1.4)

1.2.10 M&S

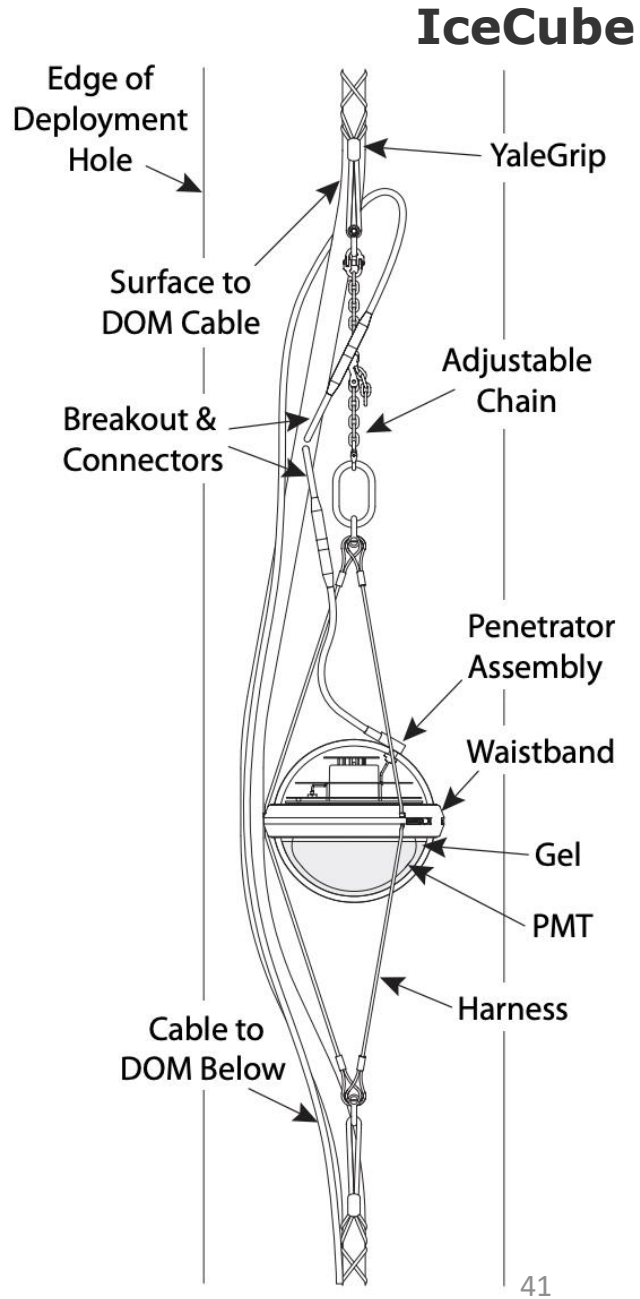
WBS	Activity	Subtype	12mo Subtotal PY5	12mo Subtotal PY6	12mo Subtotal PY7	12mo Subtotal PY8	Estimating Technique	Contingency
1.2.10.4.2	Install FS2: Install Team FS2 PQ Costs (Headcount 1)	M & S	$0	$700	$0	$0	E - Extrapolation from Actuals	C1
1.2.10.4.2	Install FS2: Install Team FS2 ECW Costs (Headcount 1)	M & S	$0	$250	$0	$0	E - Extrapolation from Actuals	C1
1.2.10.5.2	Install FS3: Install Team FS3 PQ Costs (Headcount 1)	M & S	$0	$0	$700	$0	E - Extrapolation from Actuals	C1
1.2.10.5.2	Install FS3: Install Team FS3 ECW Costs (Headcount 1)	M & S	$0	$0	$250	$0	E - Extrapolation from Actuals	C1

1.2.10 Travel

WBS	Activity	Subtype	12mo Subtotal PY5	12mo Subtotal PY6	12mo Subtotal PY7	12mo Subtotal PY8	Estimating Technique	Contingency
1.2.10.4.2	Install FS2: Install Team FS2 Deployment Travel Costs (Headcount 1)	Travel	$0	$0	$1,800	$0	E - Extrapolation from Actuals	C1
1.2.10.5.2	Install FS3: Install Team FS3 Deployment Costs (Headcount 1 + 9 in-kind)	Travel	$0	$0	$0	$1,800	E - Extrapolation from Actuals	C1

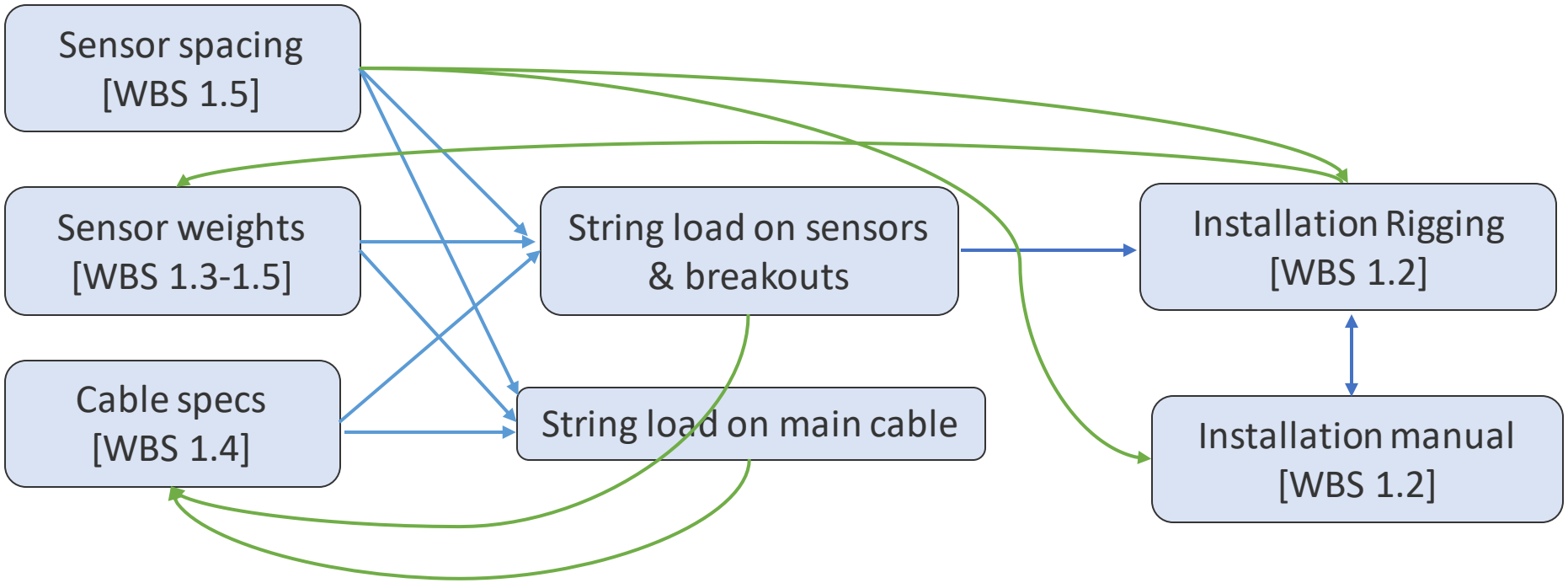
IceCube String Installation

- 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



1.2.9.2 Rigging & Installation Operations

Rigging hardware and installation operations are closely linked to each other and to string geometry and cable specs



Vertical Run

- Existing cables are supported by eye bolts + Yalegrips on vertical run

- Plan A: double up on eye bolts
  - proof-of-principle: DeepCore cables

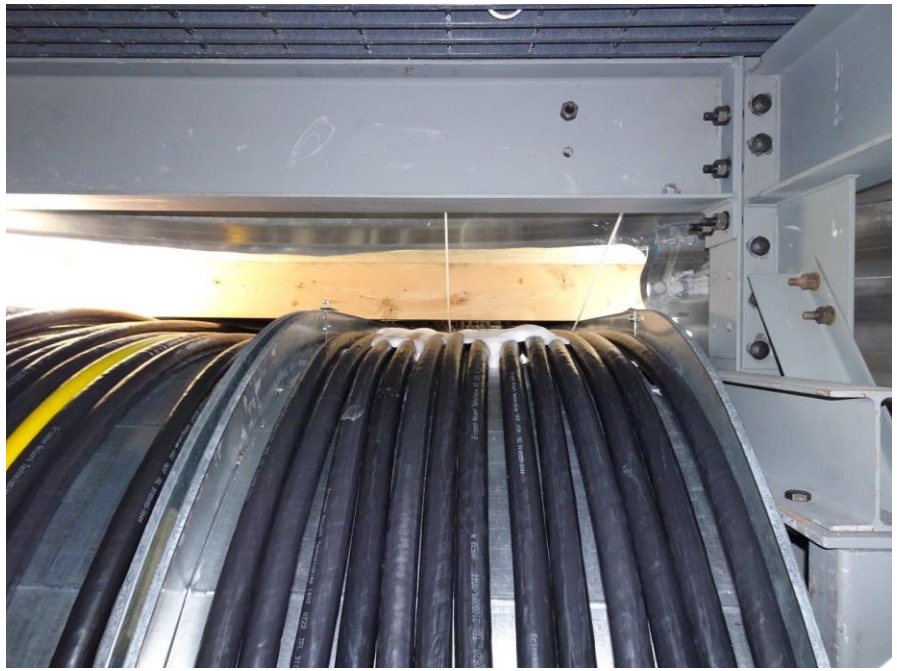
- Plan B: sling over tower crossbeam

looking up inside tower

eye bolts for hanging

Entry into Cable Bridge

- Cable bridge has two levels, each with own entry
- Original plan: 20 cables on each level
  - 10 each side
- DeepCore: 6 more added to top level



top right entry into cable bridge
(13 surface cables)

Cable Bridge

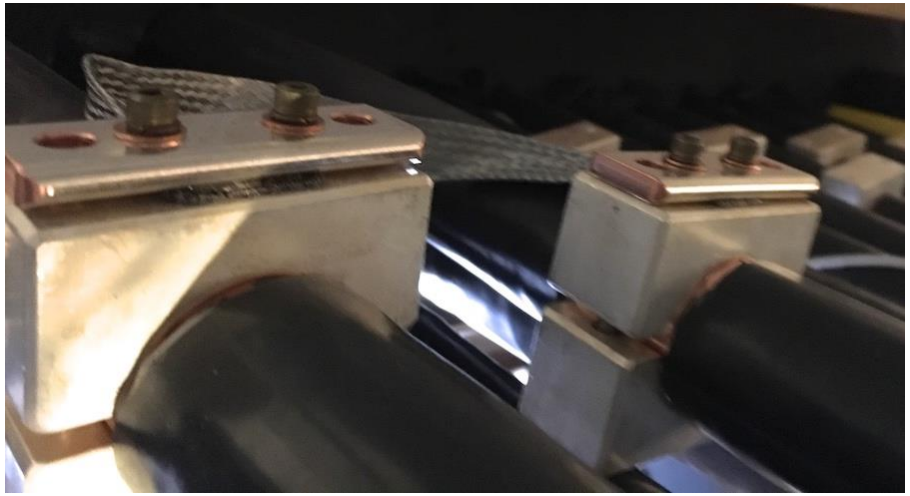
- top and side panels easily opened
  - panels do not overlap each other
- Cables lie flat in bridge tray
  - room for 7 additional cables on lower level

cable bridge lower level

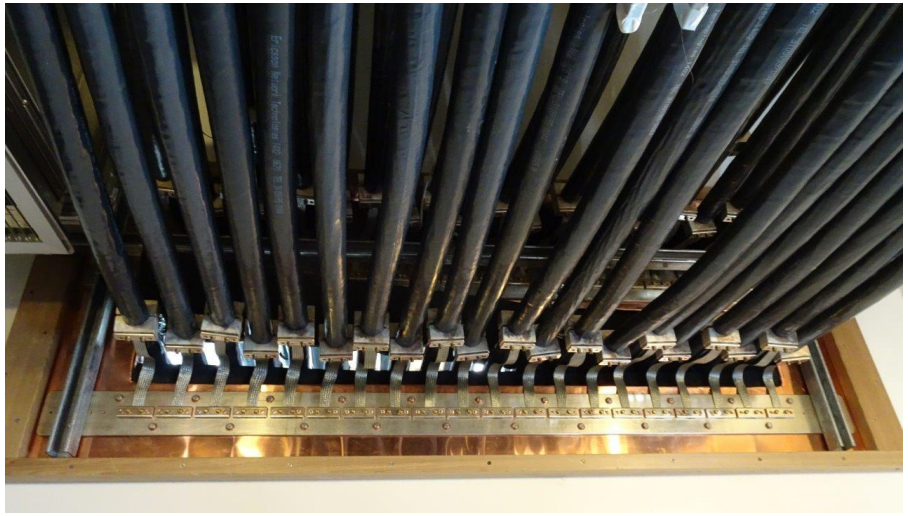
Entry into ICL

- Grounding clamp around cable shield connected to large copper plate w/ strap
- DeepCore cables added above other cables in upper row
- Plan A: similar addition in lower row for Upgrade cables

grounding clamps



cable entry / grounding plate

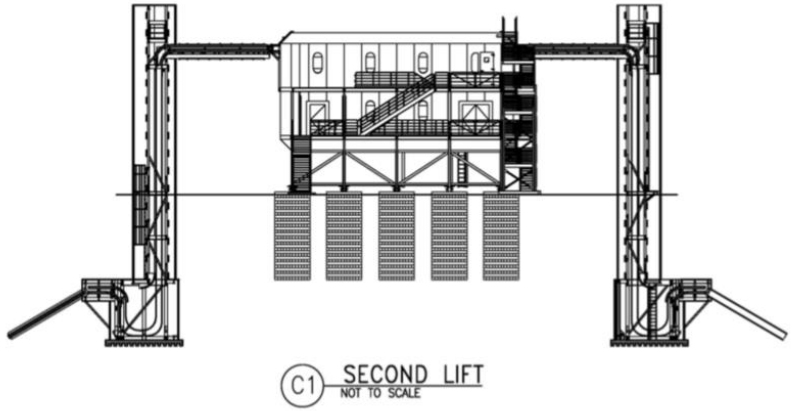


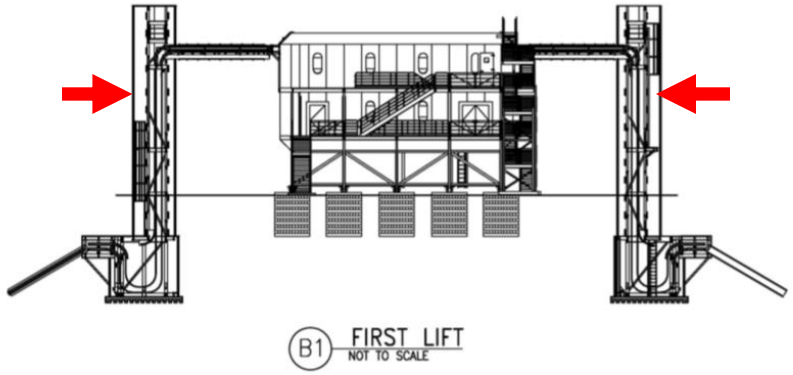
ICL Lift Impact

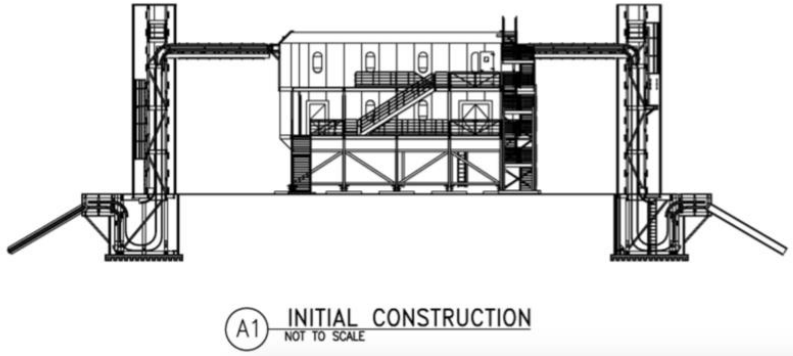
- Need to make sure any new cable additions don't impact future ICL lift

- Original drawings suggest middle section of tower extended
  - lower cable entry shouldn't affect this plan

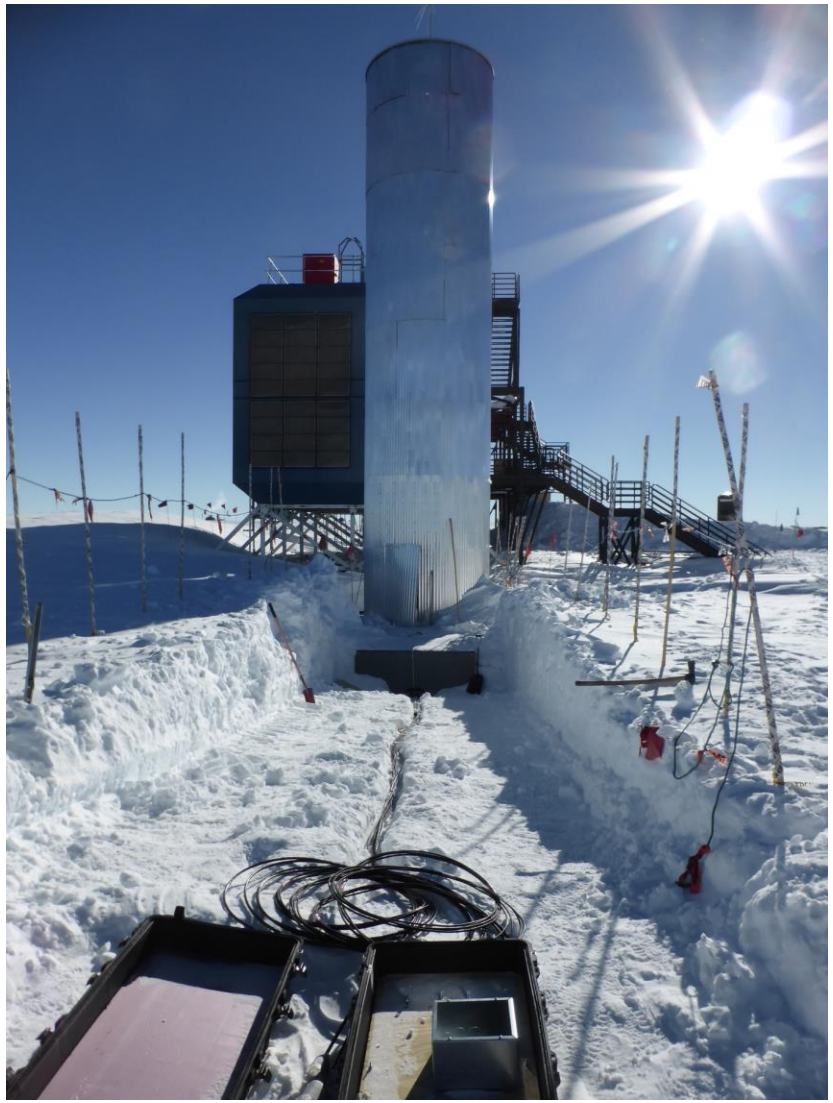
- No issues expected given we install with slack







Scintillator Cable Installation



west tower cable entry

culvert entry cable trays


CAT
953B