IceCube Upgrade Installation

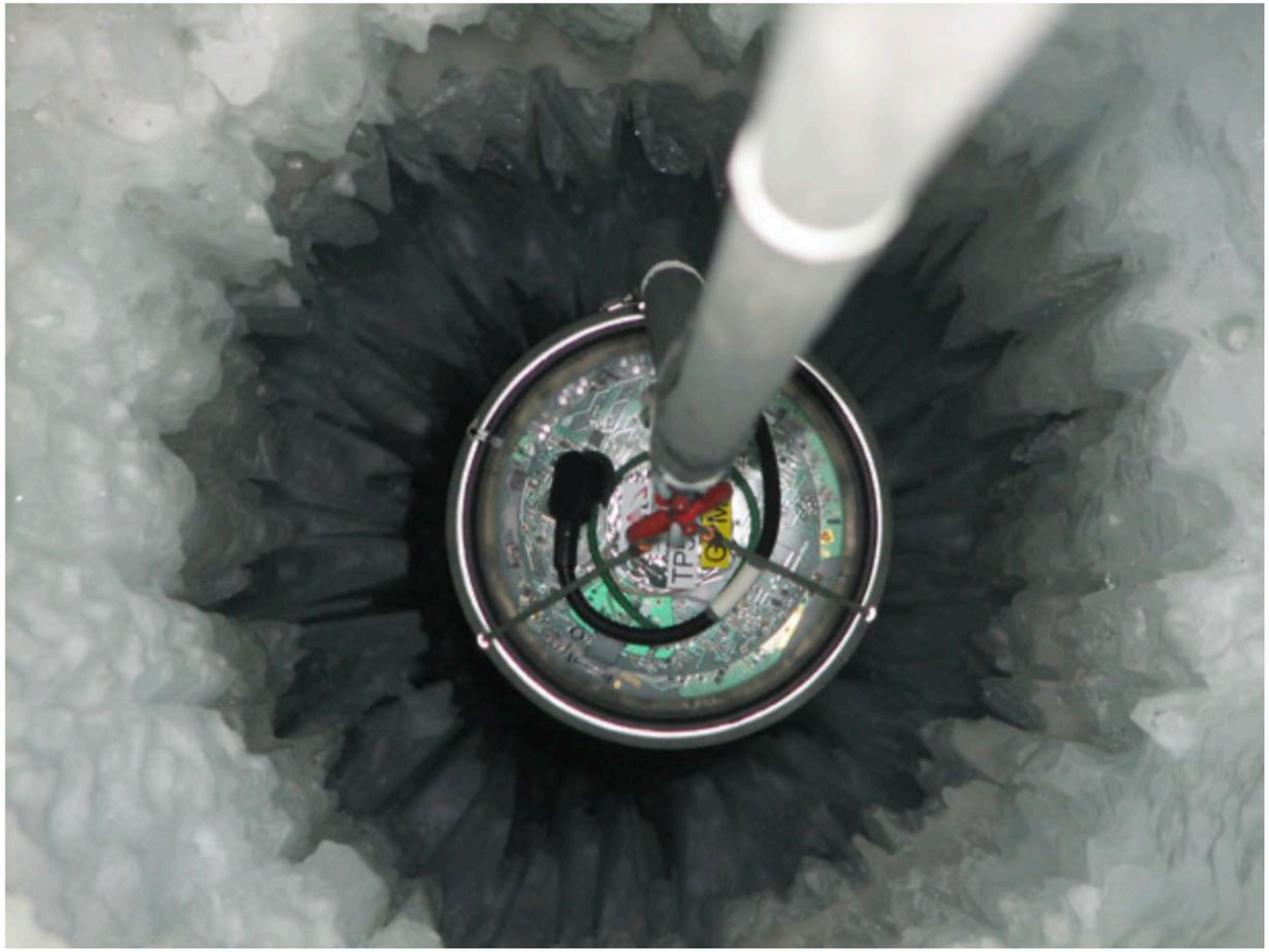
Breakout Session

IceCube Upgrade - Rebaseline Review
April 26-28, 2022

Delia Tosi – Installation Lead

Installation

- WBSs of interest: 1.2.1, 1.2.9, 1.2.10
- 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:

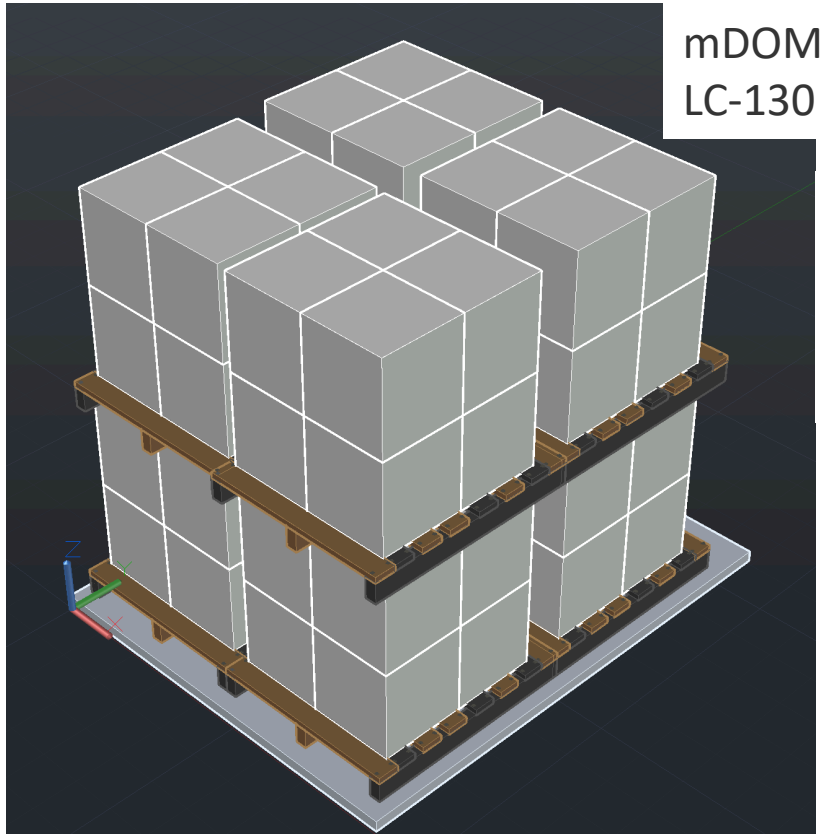
- Personnel and cargo arrival
- South Pole Acceptance Test (SPAT) ready
- Surface cable installation complete
- Readiness review
- Installation of each string

1.2.9 Installation Off-Ice

Technical Status & To-do

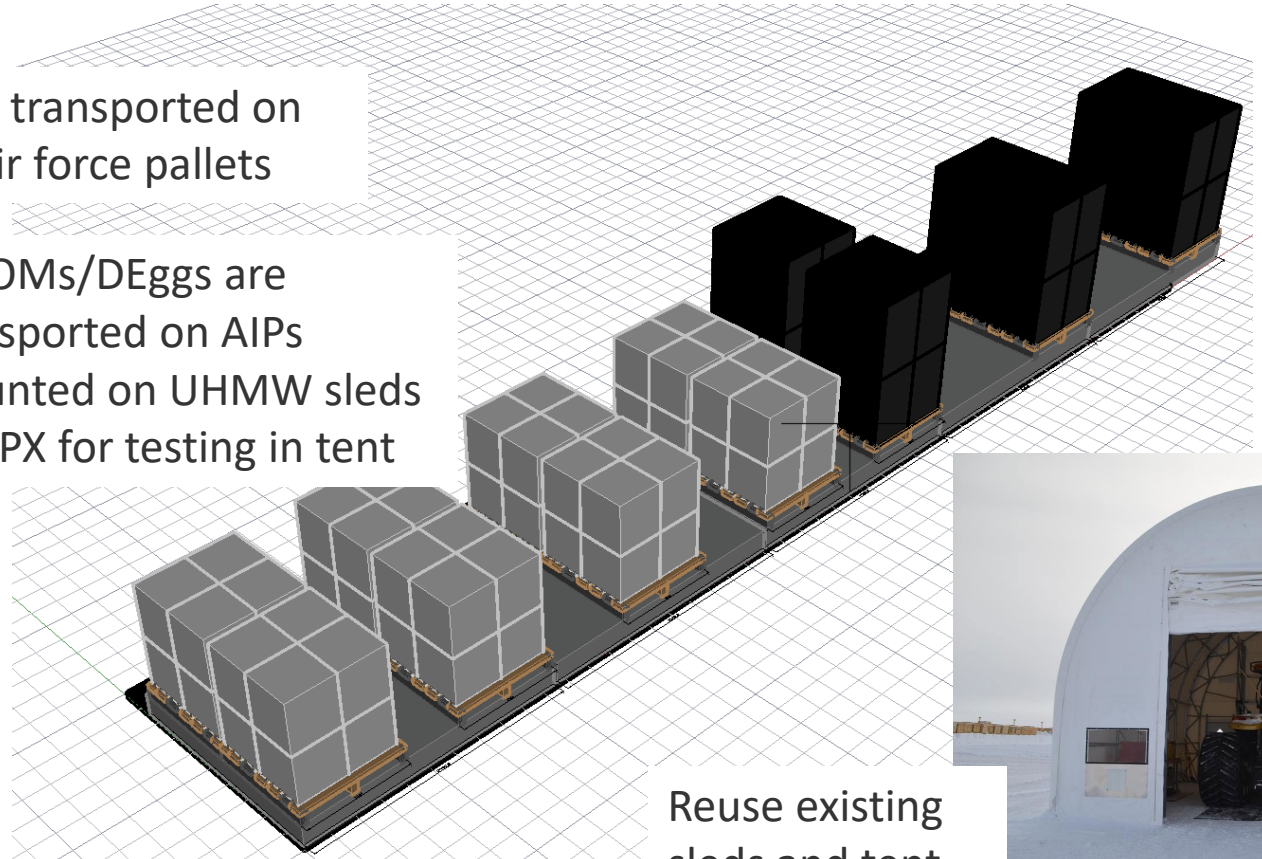
1.2.9.1 Sensor Handling

- 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

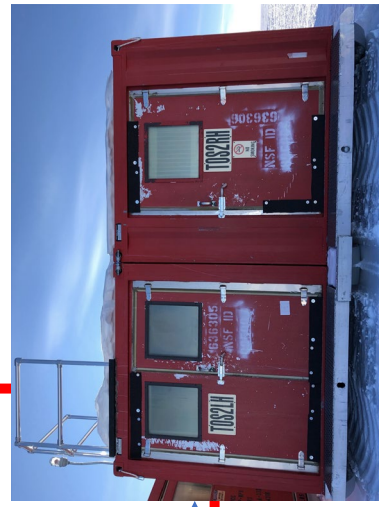
mDOMs/DEggs are transported on AIPs mounted on UHMW sleds at NPX for testing in tent



Reuse existing sleds and tent

1.2.9.1 Sensor Handling Facility

-Mobile building, on skis
-No power



Single door

Area reserved to storage of special devices

Lift table

358”

Lift’n buddy

Double door

231”

Sensor sled

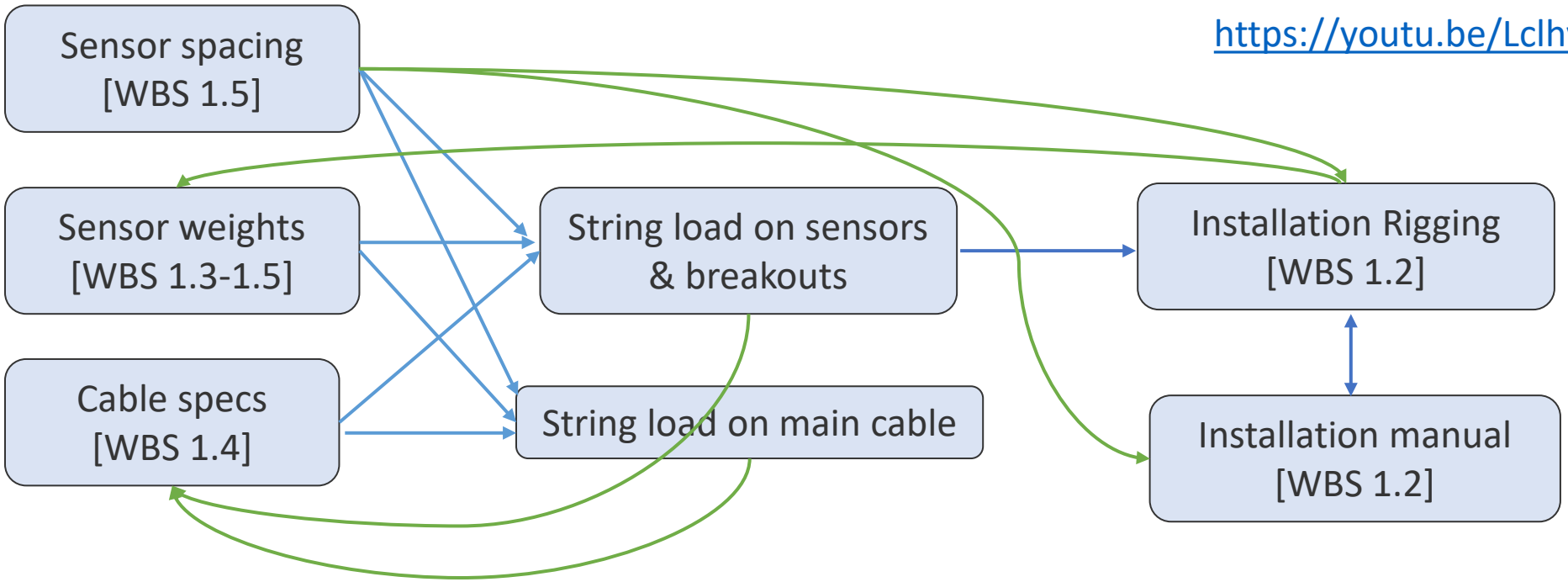
Deck mounted truck crane equipped with pallet forks

TOS, not on scale

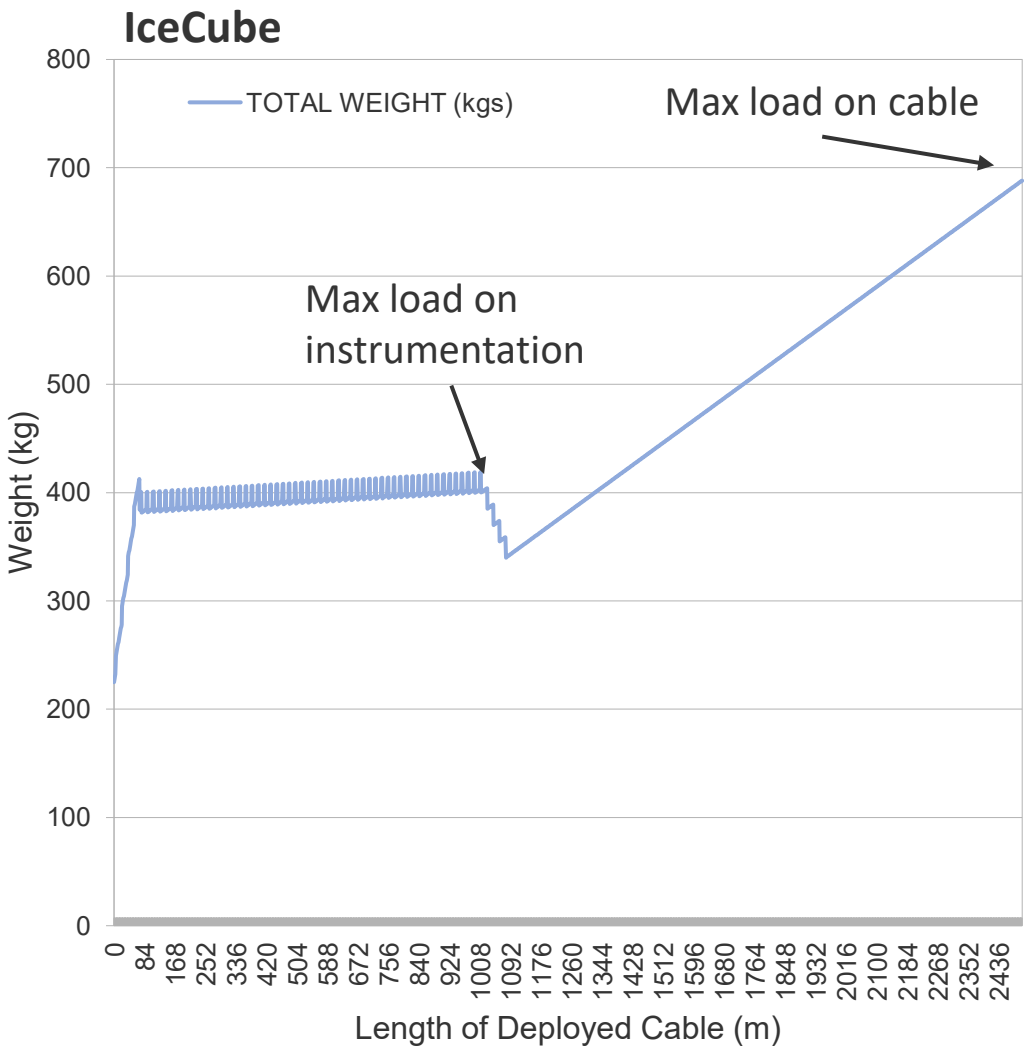
1.2.9.2 Rigging & Installation Operations

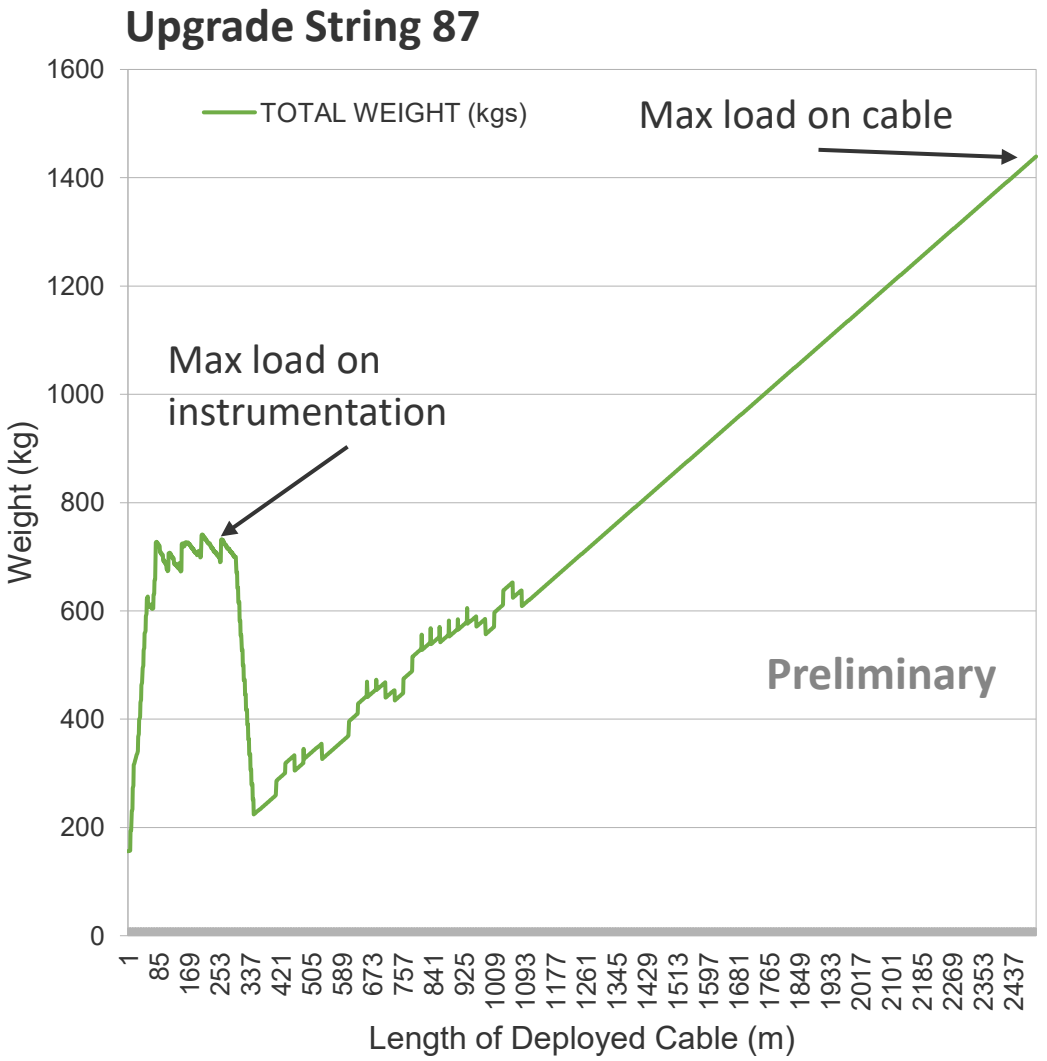
Rigging hardware and installation operations are closely linked to each other and to string geometry and cable specs

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

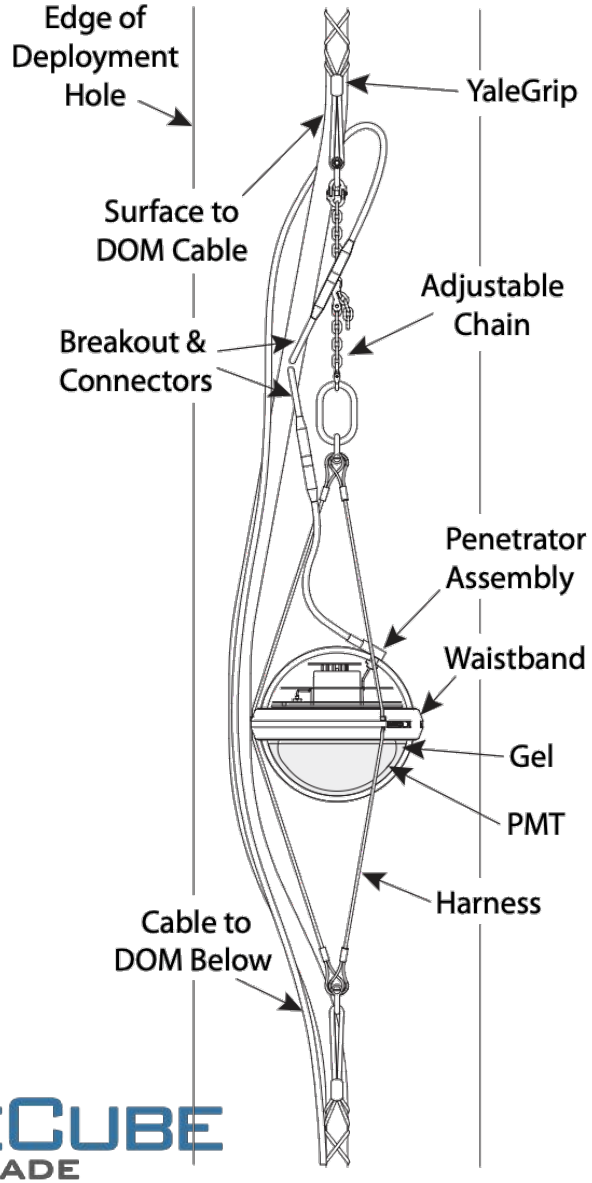


String Static Load Calculation (1.4-1.2)



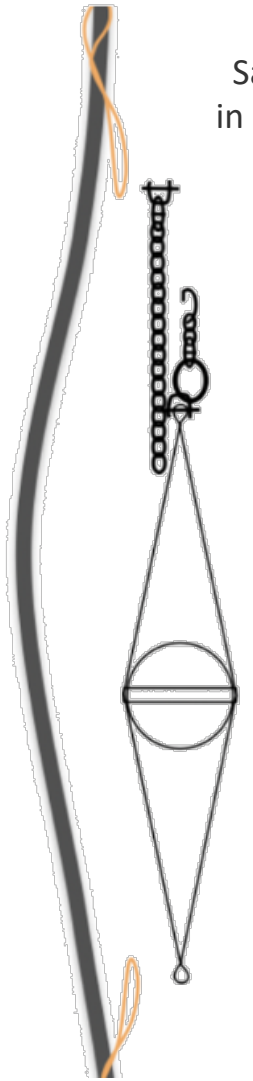


IceCube



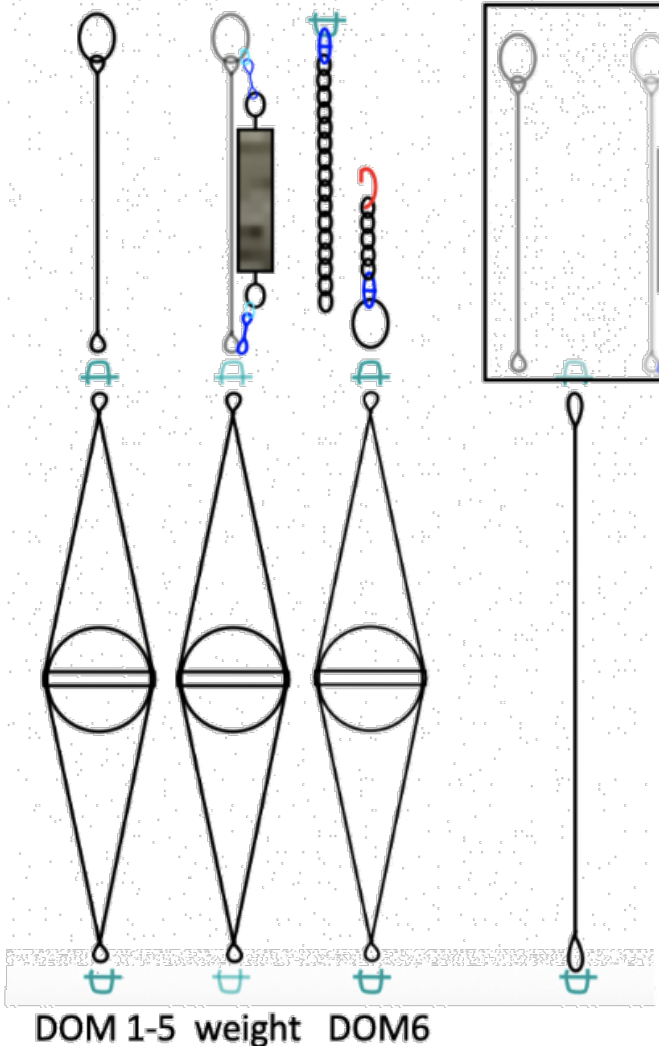
IceCube Upgrade

Shallow region

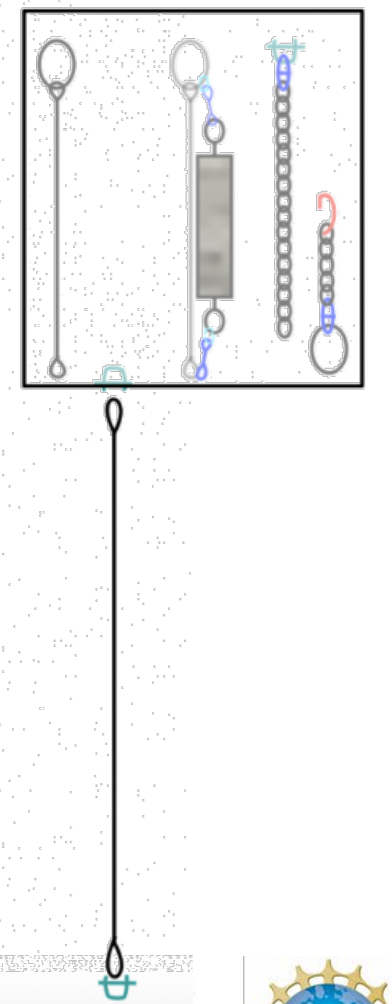


Same as in IceCube

Physics region

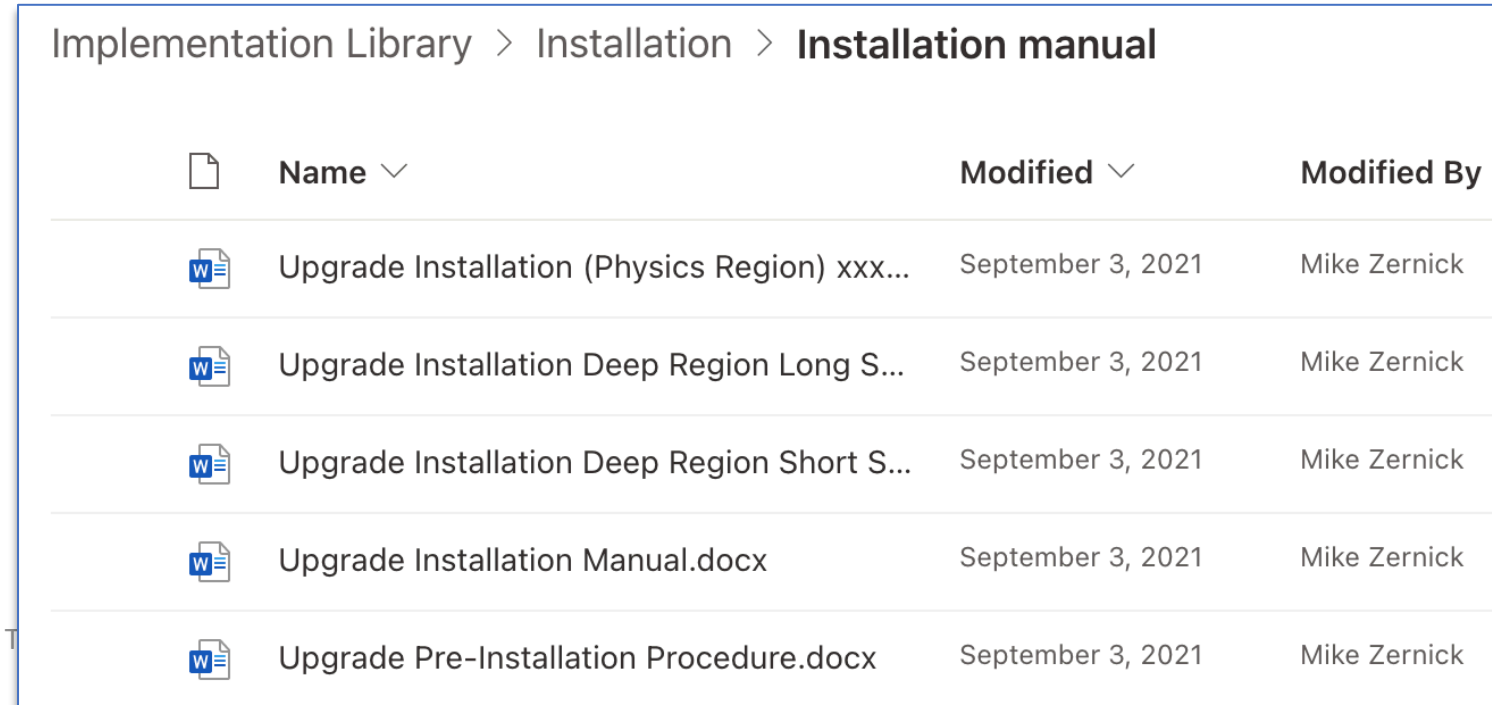


Special devices



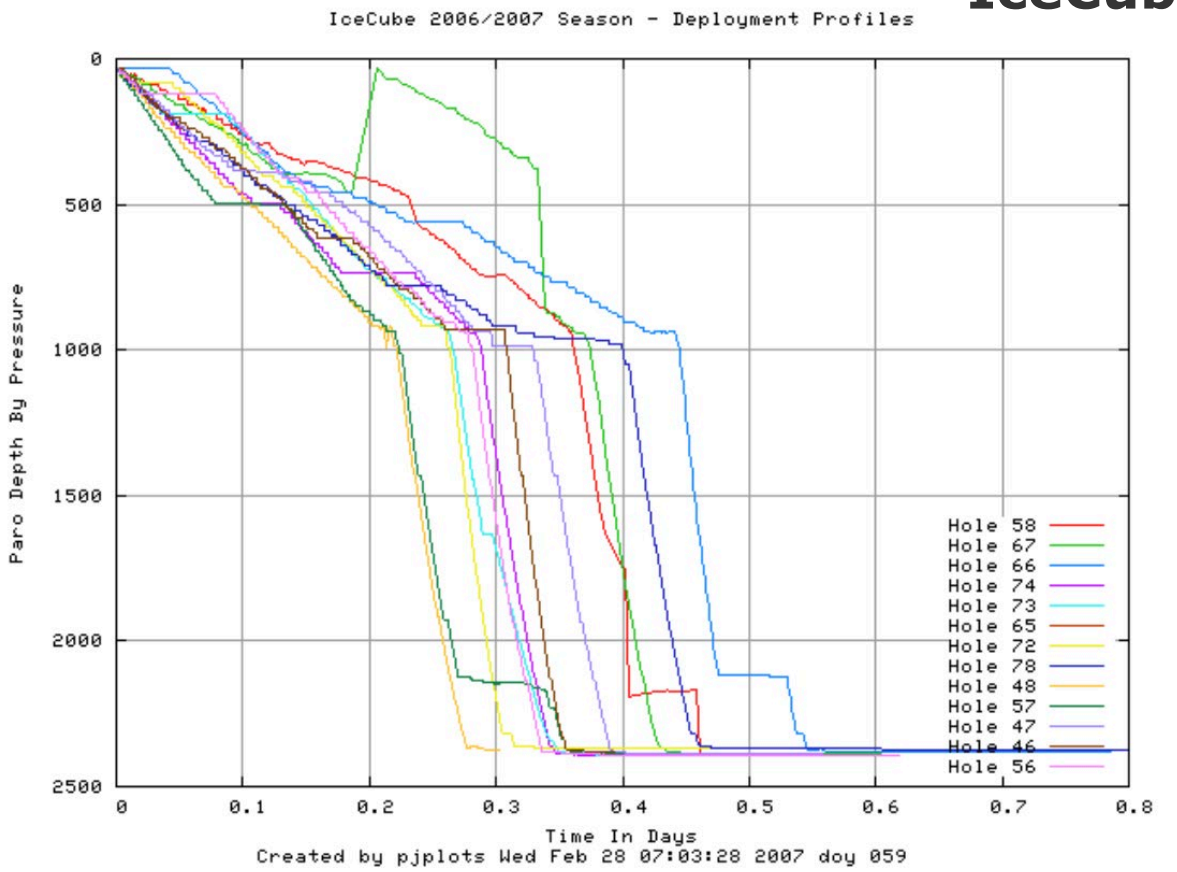
1.2.9.2 Rigging for Installation Summary

- Installation manual 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



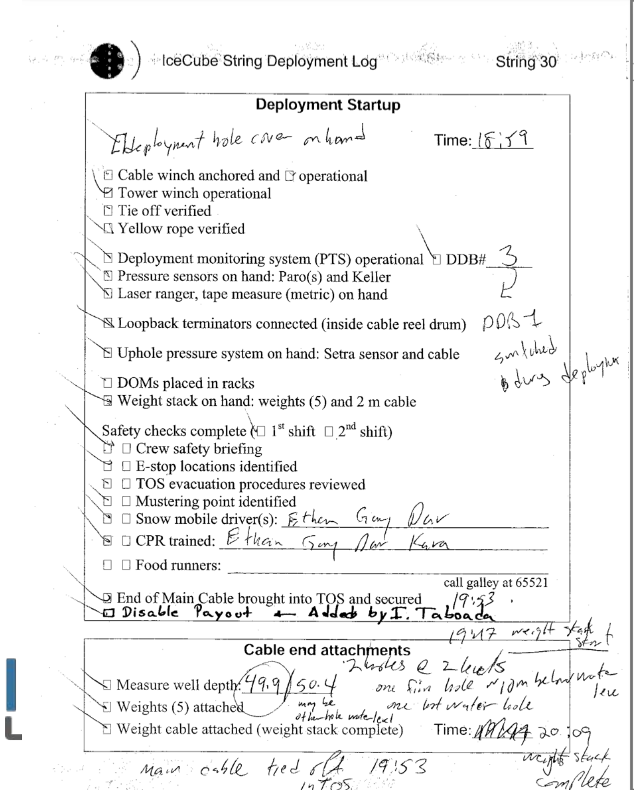
1.2.9.3 Installation Monitoring Equipment

- Suite of tools to be used in installation to test connectivity and monitor depth
- Similar concept to what done in 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



1.2.9.4 Logging & Calibration Support

- Support logging winch operations – as mentioned by D. Williams, submitting request to IDP in the next few weeks
- Logging tablets programmed to collect geometry information more efficiently than on paper


IceCube String Deployment Log String 30

Deployment Startup

Deployment hole cover on hand Time: 18:59

- Cable winch anchored and operational
- Tower winch operational
- Tie off verified
- Yellow rope verified
- Deployment monitoring system (PTS) operational DDB# 3
- Pressure sensors on hand: Paro(s) and Keller
- Laser ranger, tape measure (metric) on hand
- Loopback terminators connected (inside cable reel drum) DDB 1 switched during deployment
- Uphole pressure system on hand: Setra sensor and cable
- DOMs placed in racks
- Weight stack on hand: weights (5) and 2 m cable

Safety checks complete (1st shift 2nd shift)
- Crew safety briefing
- E-stop locations identified
- TOS evacuation procedures reviewed
- Mustering point identified
- Snow mobile driver(s): Ethan Gary Dar
- CPR trained: Ethan Gary Dar Kara
- Food runners:

call galley at 65521
- End of Main Cable brought into TOS and secured 19:53
- Disable Payout ← Added by I. Taboada

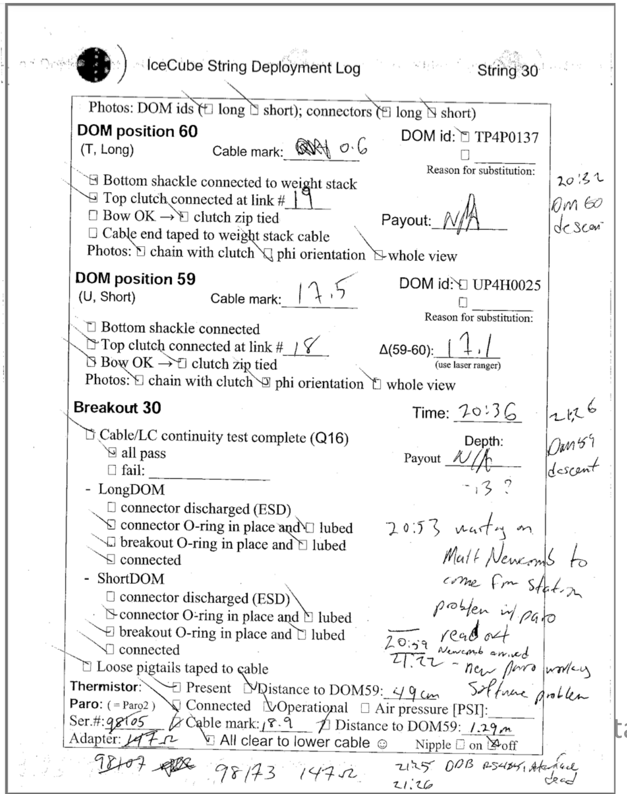
19:47 weight stack start

Cable end attachments

- Measure well depth: 49.9 / 50.4
- Weights (5) attached
- Weight cable attached (weight stack complete) Time: 20:09

main cable tied off 19:53 in TOS

weight stack complete


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

- LongDOM
  - connector discharged (ESD)
  - connector O-ring in place and lubed
  - breakout O-ring in place and lubed
  - connected
- ShortDOM
  - connector discharged (ESD)
  - connector O-ring in place and lubed
  - breakout O-ring in place and lubed
  - connected
- Loose pigtails taped to cable

20:53 waiting on Matt Newcomb to come from station

Thermistor: Present Distance to DOM59: 49 cm

Paro: (= Paro2) Connected Operational Air pressure [PSI]:

Ser.#: 98105 Cable mark: 18.9 Distance to DOM59: 1.29 m

Adapter: 147Ω All clear to lower cable ☺ Nipple on off

98107 98173 147Ω

DEEP LOGGING WINCH
Operations and Maintenance Manual

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’)

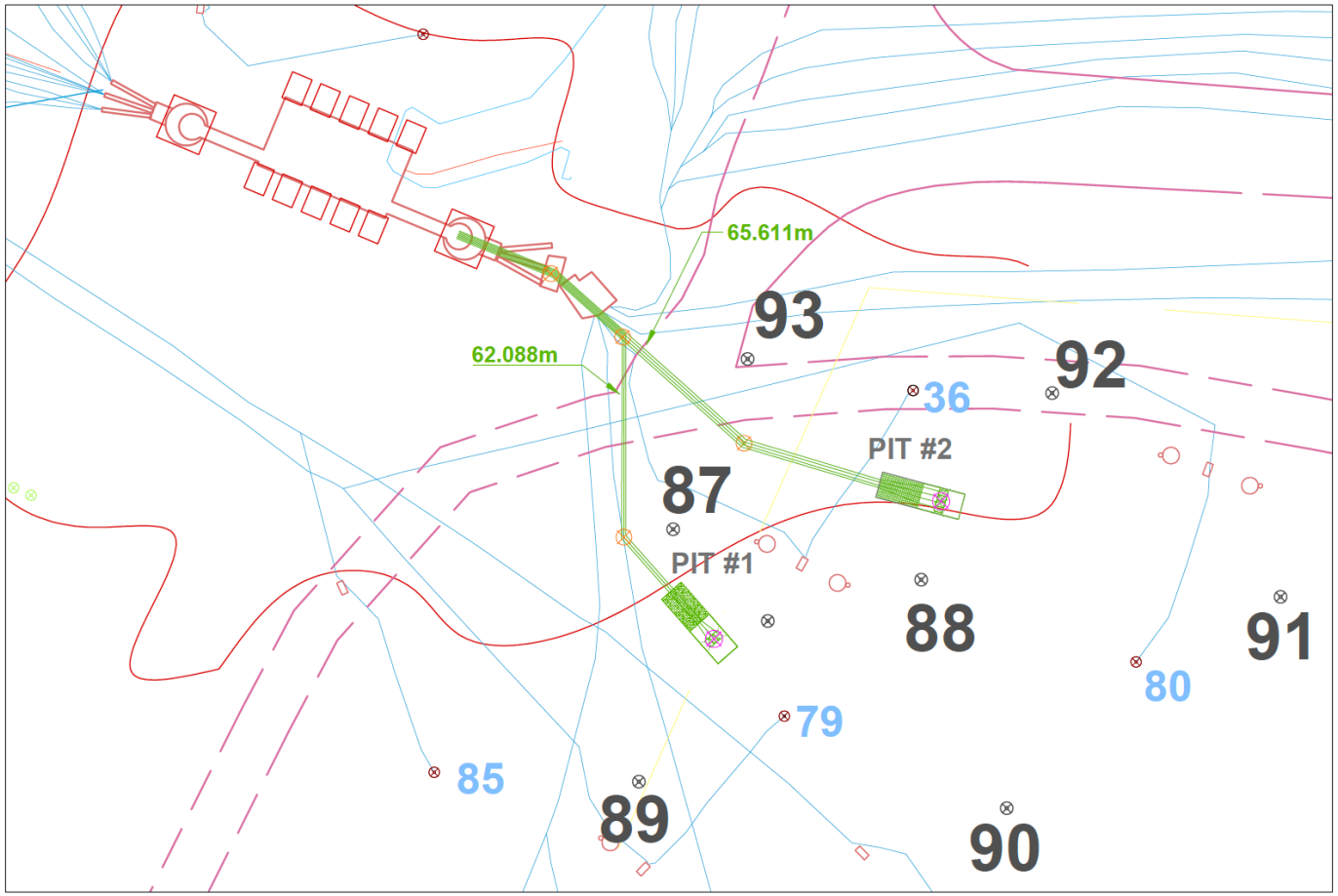
- It was used for deployment training every year during IC construction
- Will be used to practice procedures in as much as detail as possible.

1.2.10 Installation Field Activities

Tasks & Population

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



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 plus 3 drillers):

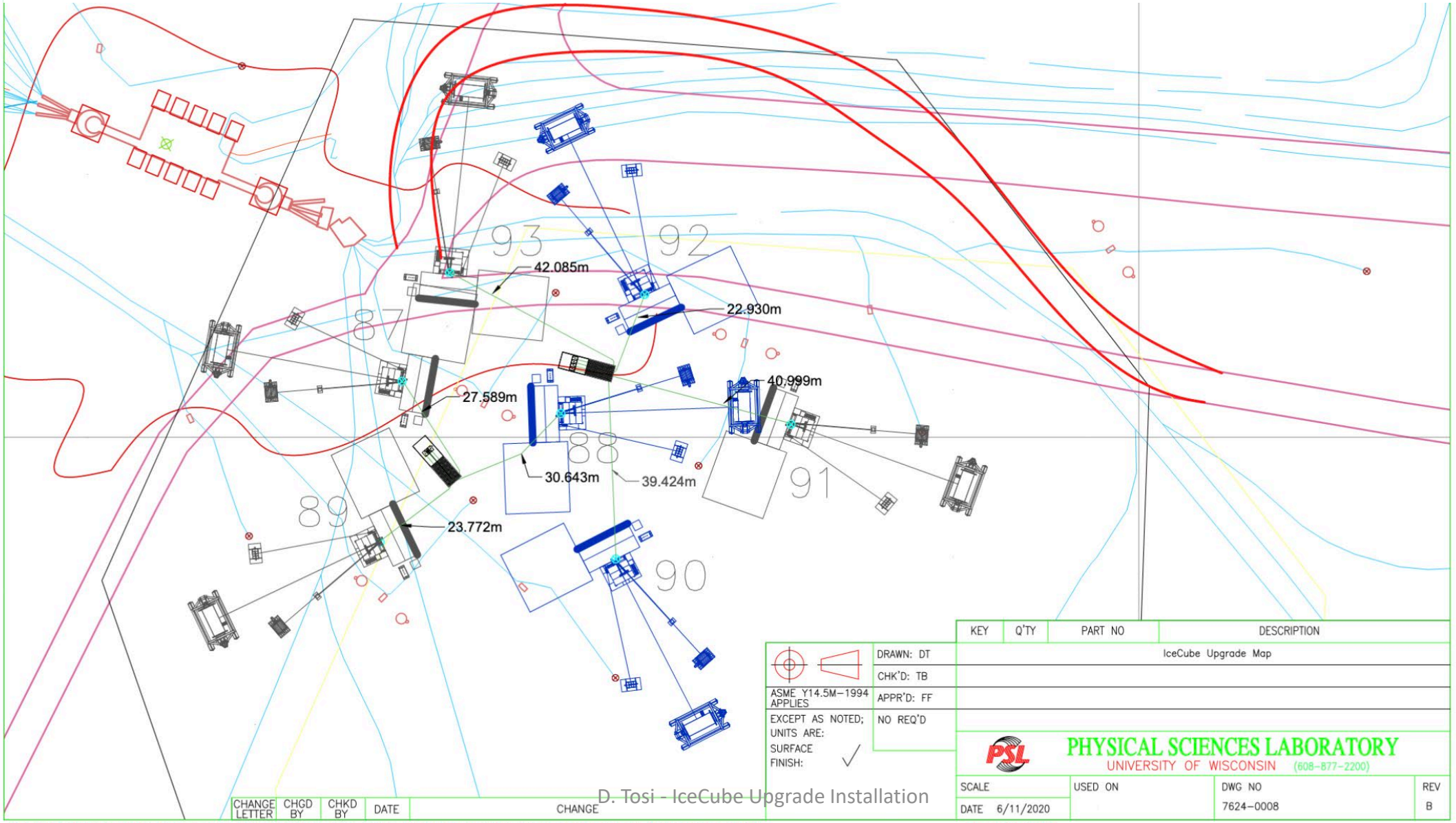
- Shift lead (1x)
- DOM suppliers (2x): sort sensors according to string deployment order in sensor handling facility
- DOM supplier TOS side (1x): preps the next sensor
- DOM installers (2x) : attach sensors to cable at the hole
- Winch operator (1x): operate TU-20 and hoist
- Logger (1x): Logs instrumentation,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



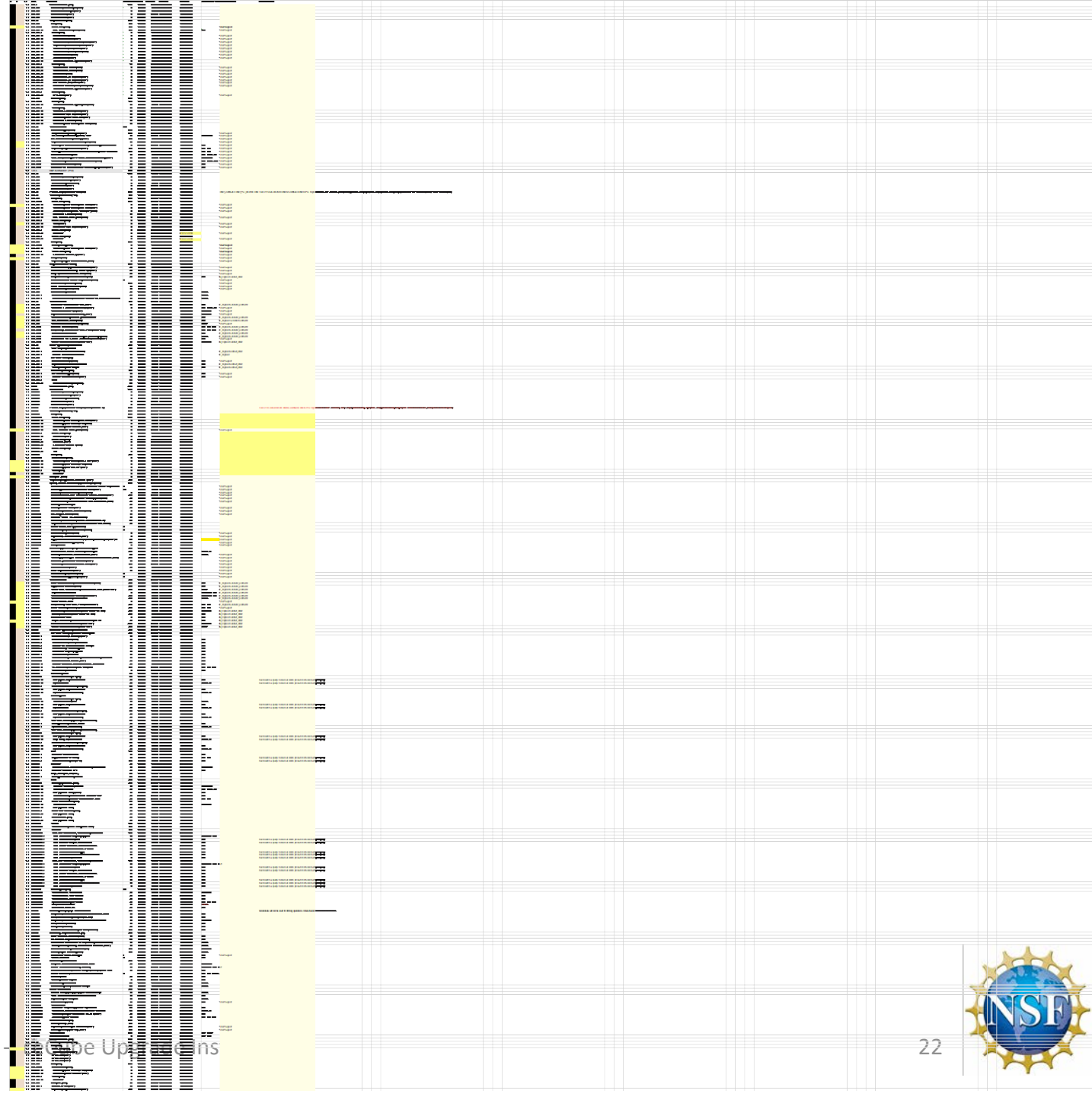
1.2.10 Cargo & ASC support

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

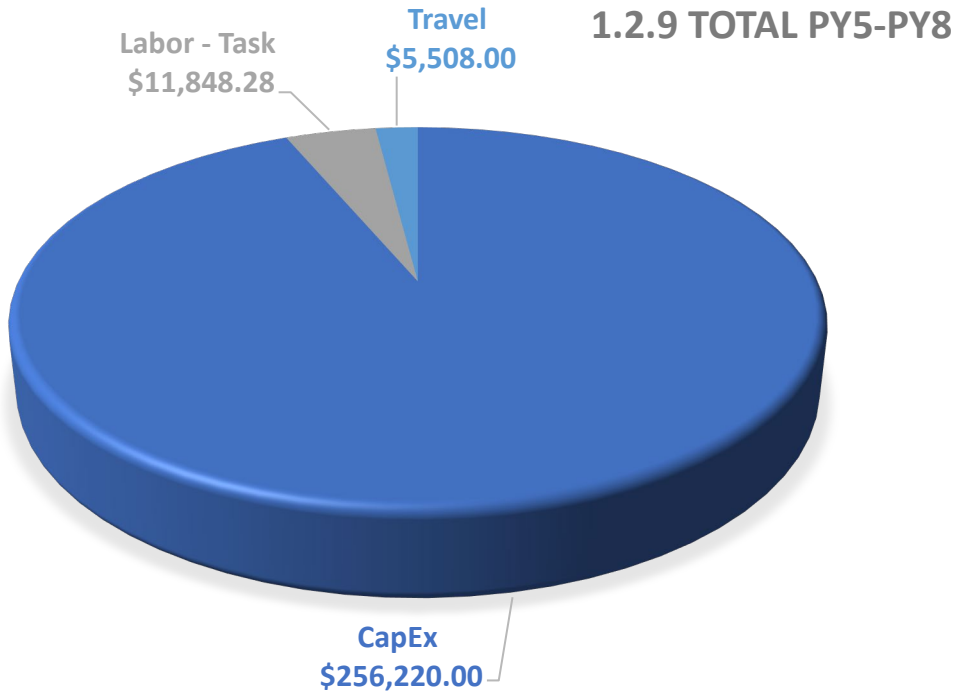
- Cargo movement
- Trenching for SCA and MCA
- TU-20 loading
- Sensor loading for testing
- ICL culver plate modifications

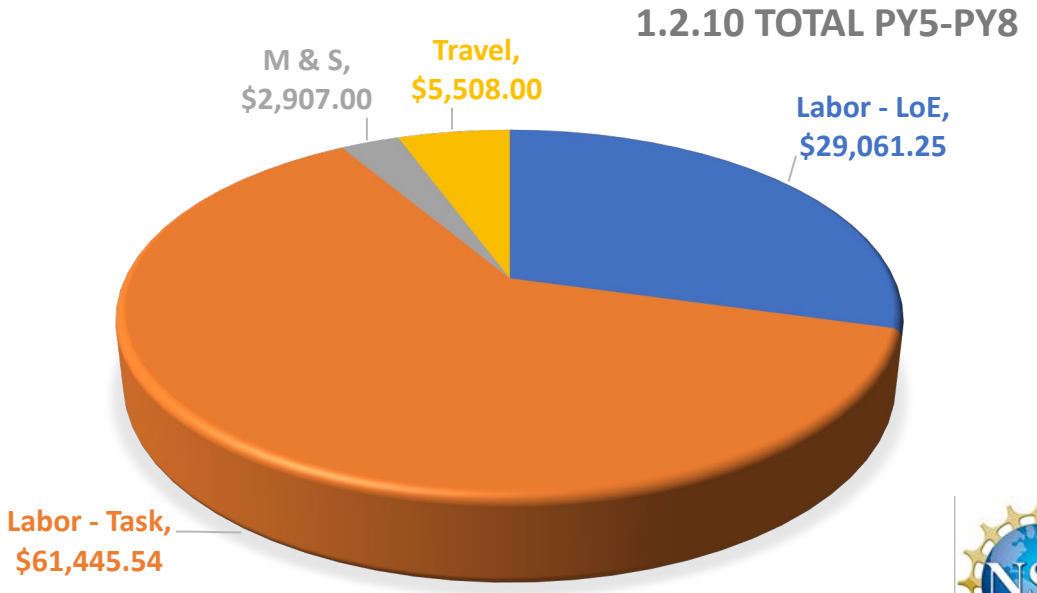


1.2.9 – 1.2.10 Cost

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

			MATERIAL						
WBS (if known)	**Project Year** (0-10)	**Description**	**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

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

Paroscientific, Inc.

4500 148th Avenue N. E. Facsimile: (425) 867-5407
Redmond, WA 98052-5194 Email: smith@paroscientific.com
Telephone: (425) 883-8700 Internet:http://www.paroscientific.com

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

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.

backup

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

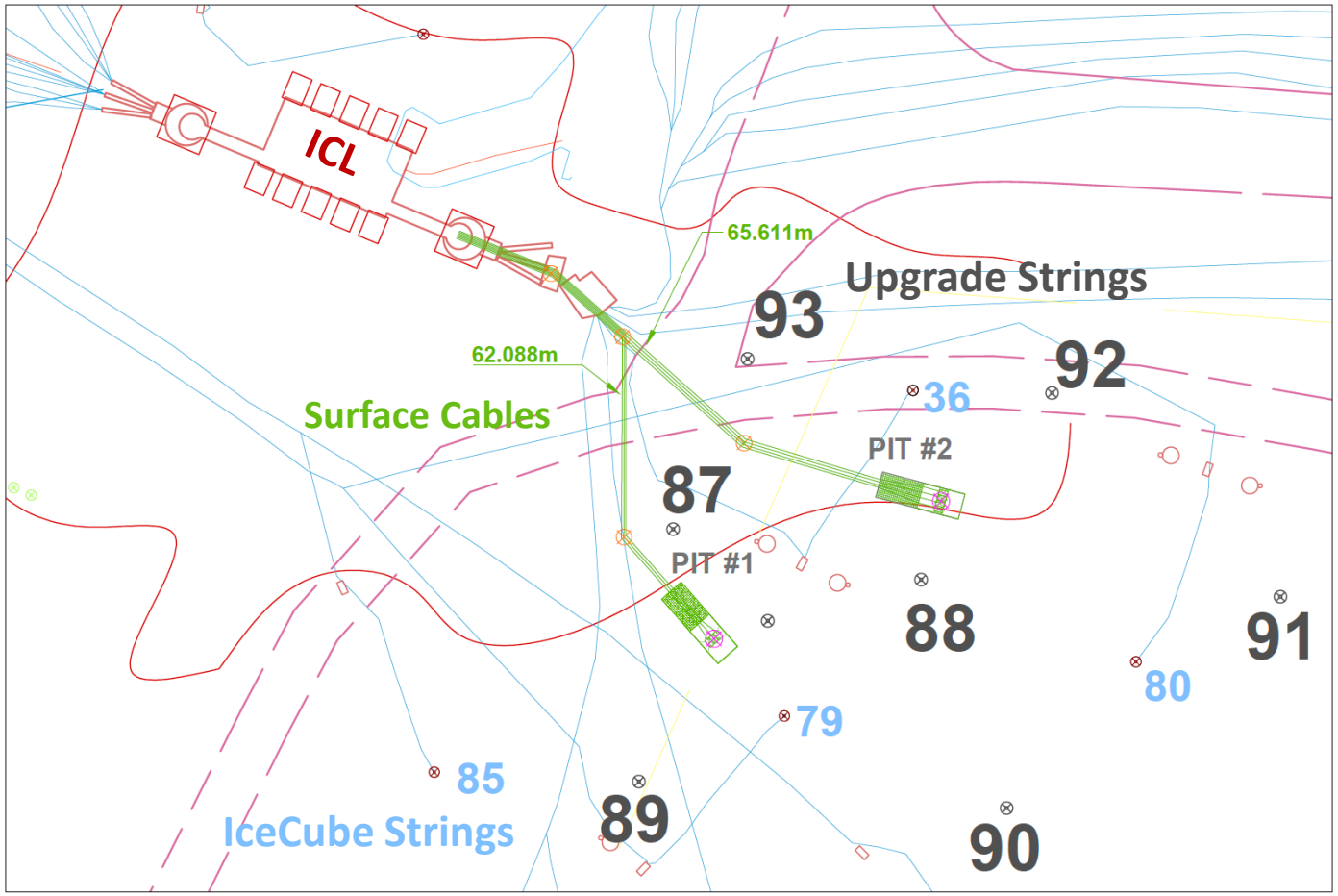
WBS	Activity	Subtype	12mo Subtotal PY5	12mo Subtotal PY6	12mo Subtotal PY7	12mo Subtotal PY8	Estimating Technique	Contingency
1.2.10.4.2	Install FS2: Install Team FS2 PQ Costs (Headcount 1)	M & S	$0	$700	$0	$0	E - Extrapolation from Actuals	C1
1.2.10.4.2	Install FS2: Install Team FS2 ECW Costs (Headcount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

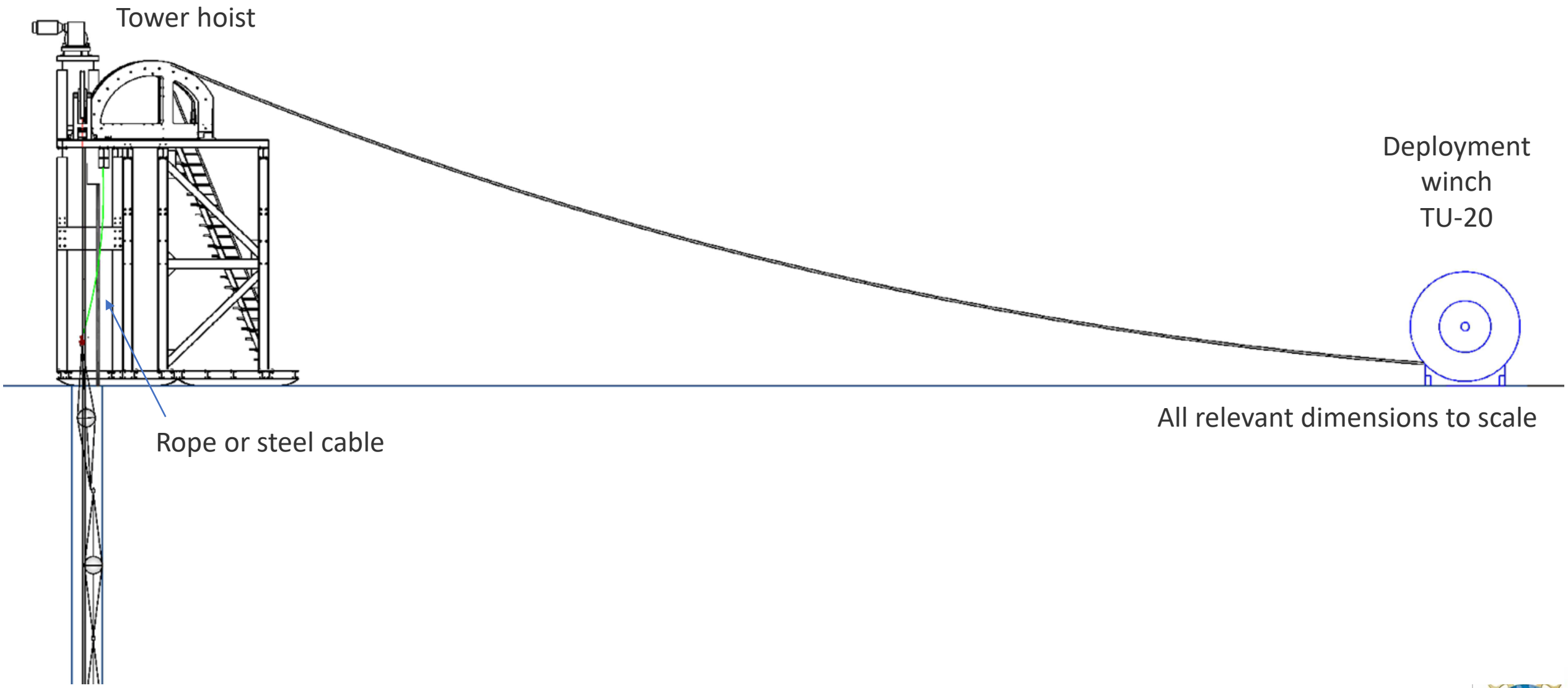
Field Season 2 activities (personnel)

- 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



(*)ASC support

String Installation Step-by-Step



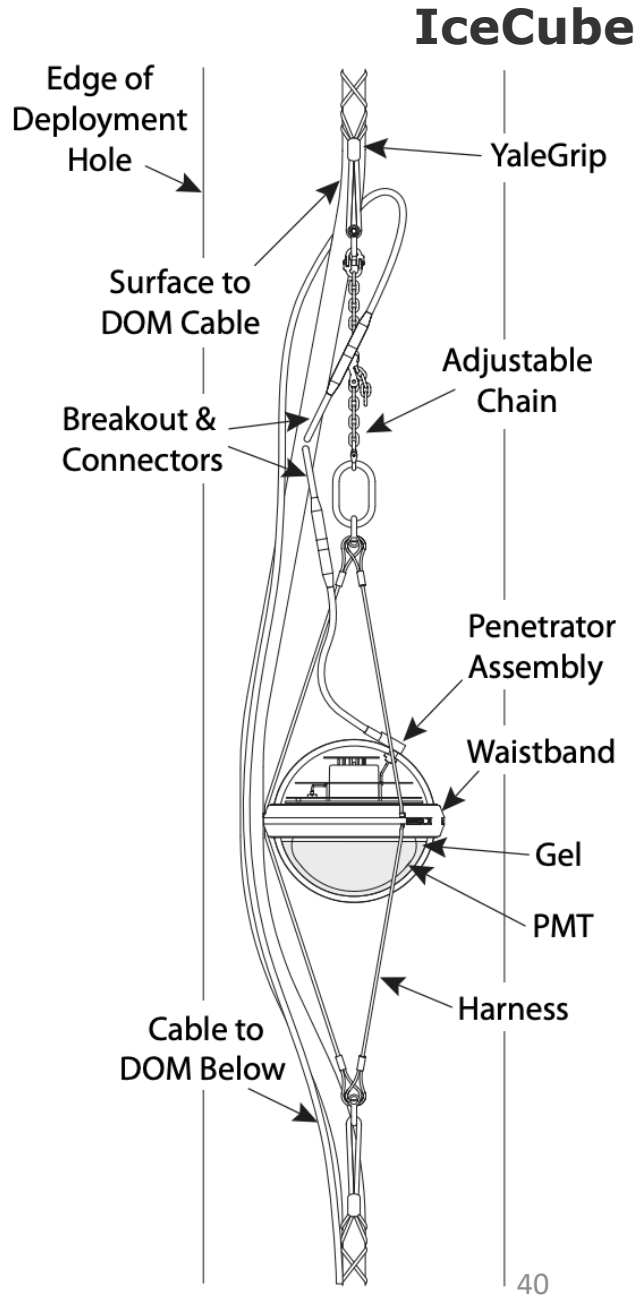
Training at PSL

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

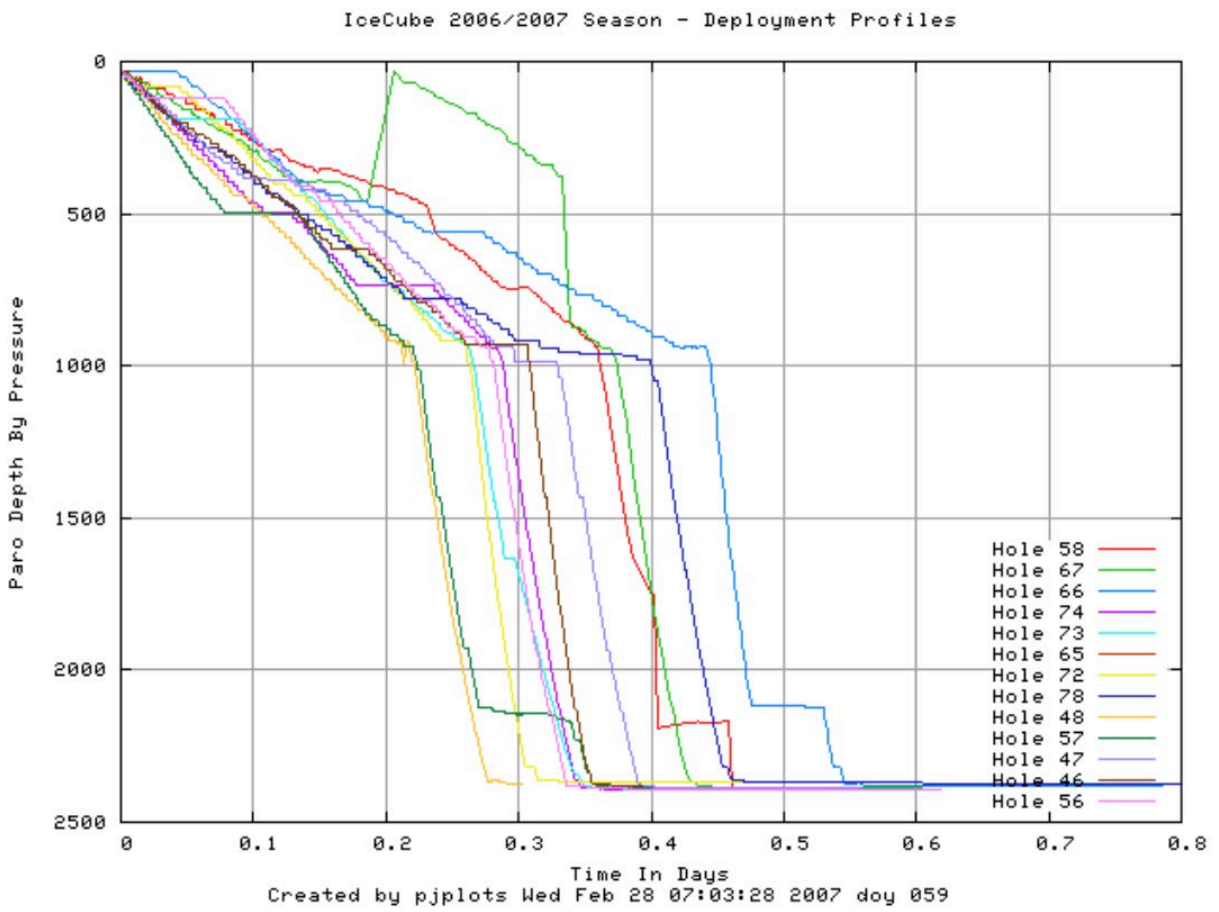


Deployment time

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*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