IceCube Upgrade Installation Overview, Cargo and Population

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Installation Lead

Upgrade Logistics Review
November 3-5, 2021

Speaker Bio

Background

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

Assistant scientist at UW Madison/WIPAC since 2013

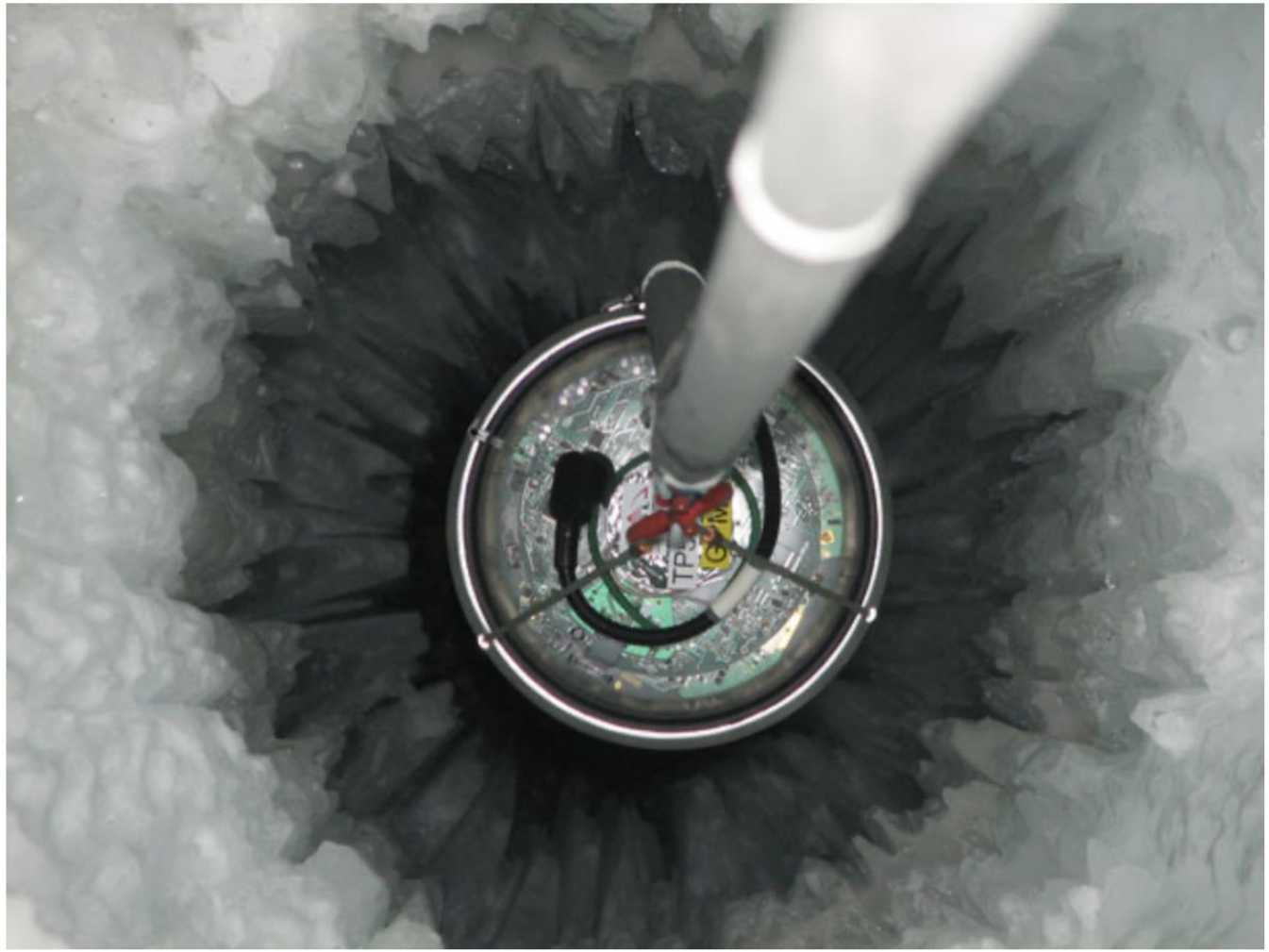
- *IceTop enhancement (scintillator panels & radio antennas)*
- *Borehole logging (SPICE, etc)*
- *IceCube Upgrade installation lead*
- *RNO-G drilling and installation*
- *Broad field experience*

Polar experience

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

Outline

- Installation task introduction
- IceCube Gen1
- IceCube Upgrade
  - Differences wrt IceCube Gen1
  - Installation cargo
  - Installation labor

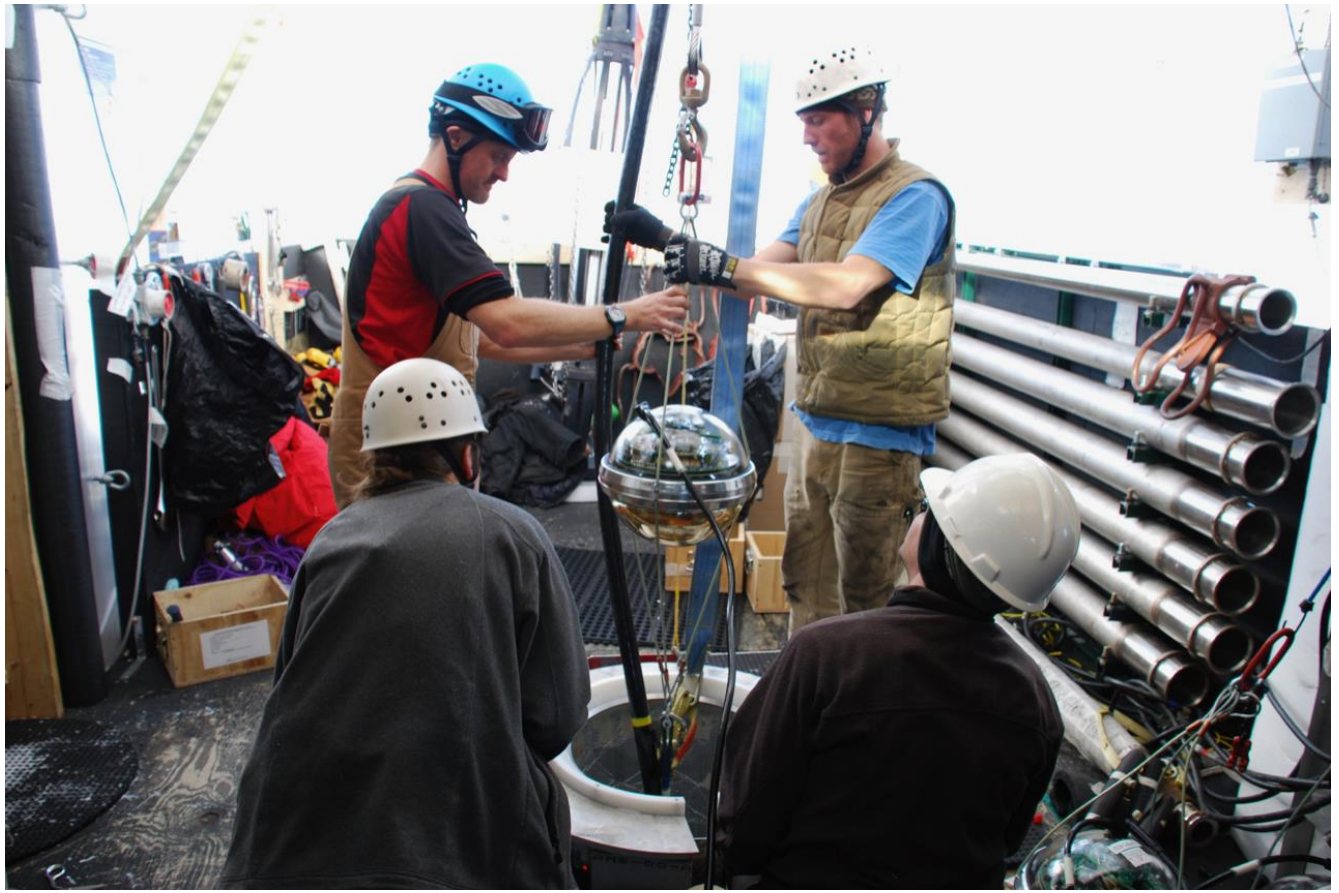


IceCube Upgrade Installation (WBS 1.2.9)

- **<u>Task</u> (same as in IceCube):**
  Connect the sensors (*) to pre-defined cable breakout and lower the string in the water-filled, freshly drilled hole to their final positioning.

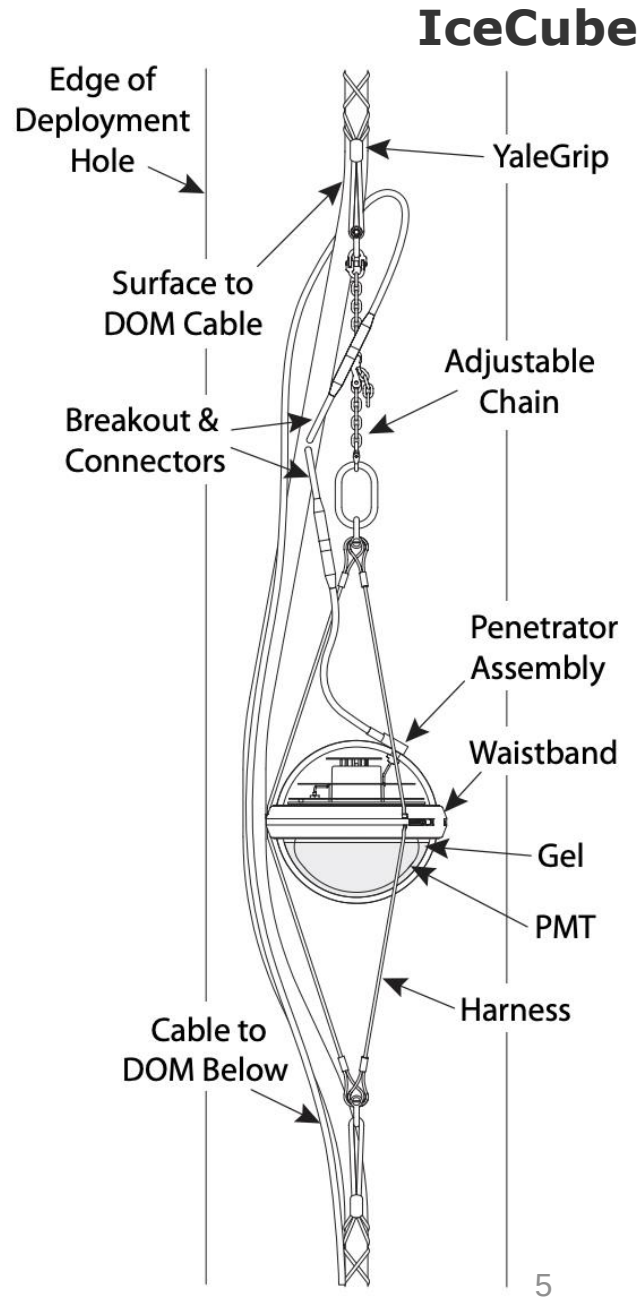
  (*) sensors = optical sensors, calibration devices, special devices
  in all these slides

- Note: historically “Installation” has been called “Deployment”. We try to use the term installation to remove ambiguity between sensor installation and people deployment, but one should be aware of the double meaning if looking at older documents.

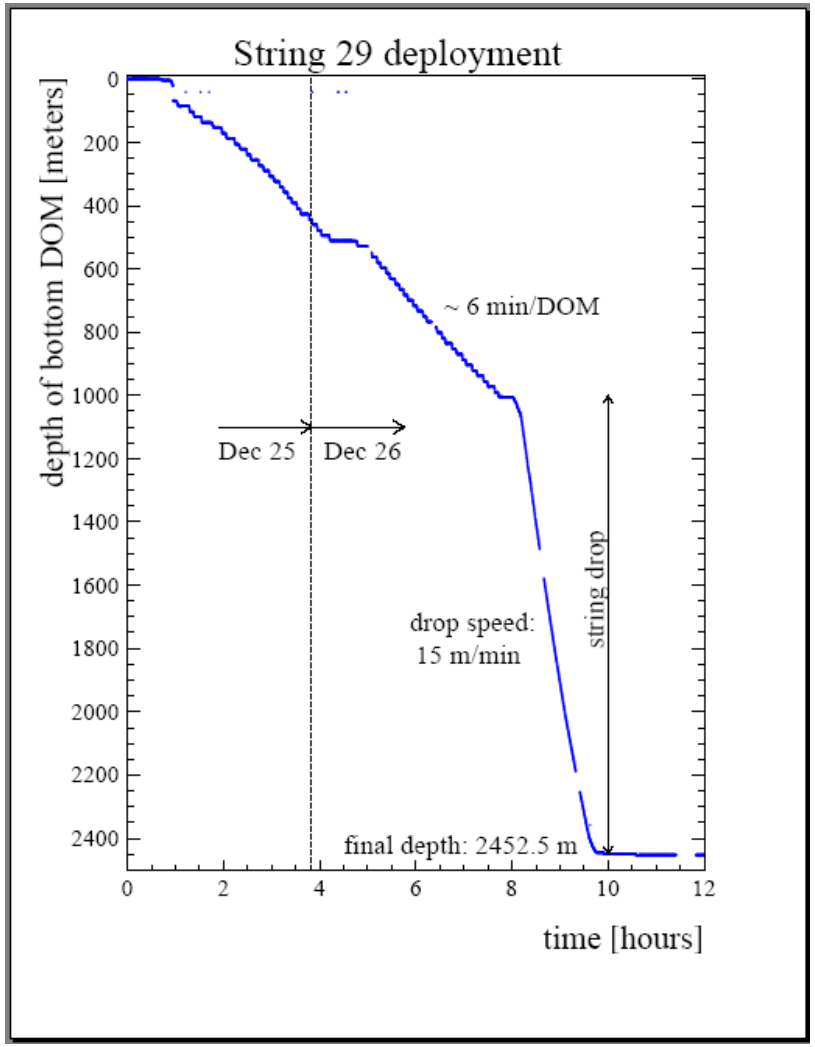


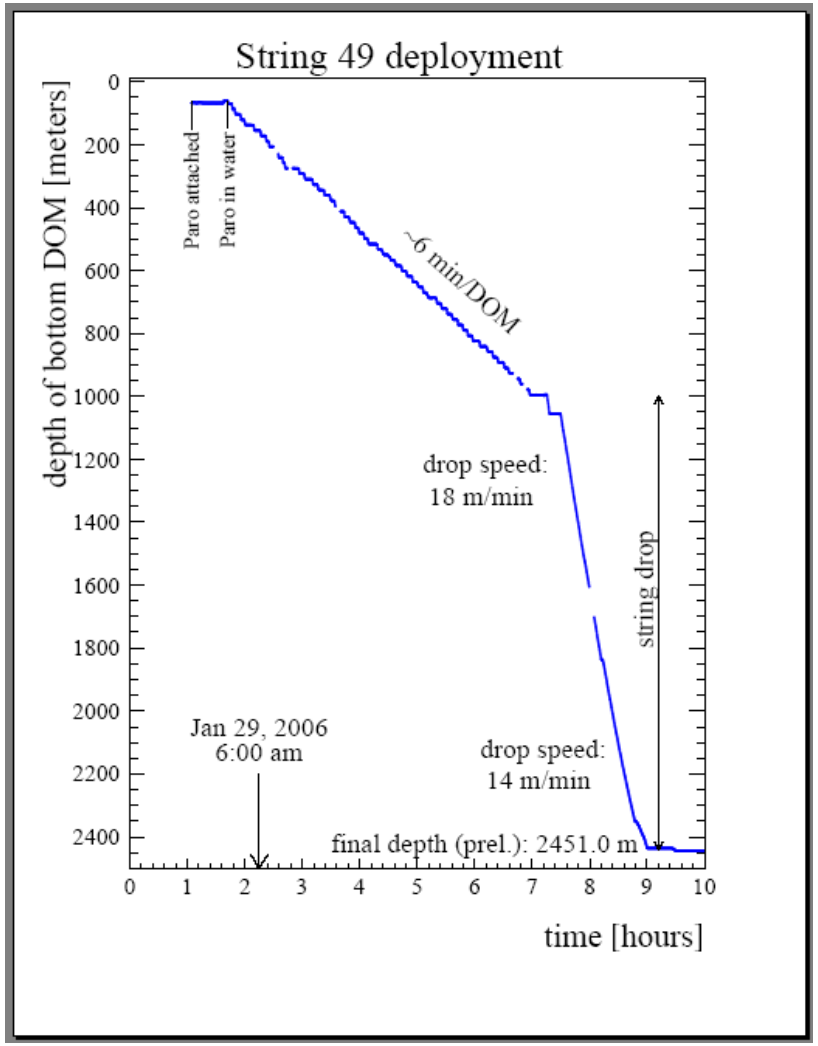
IceCube String Installation

- 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

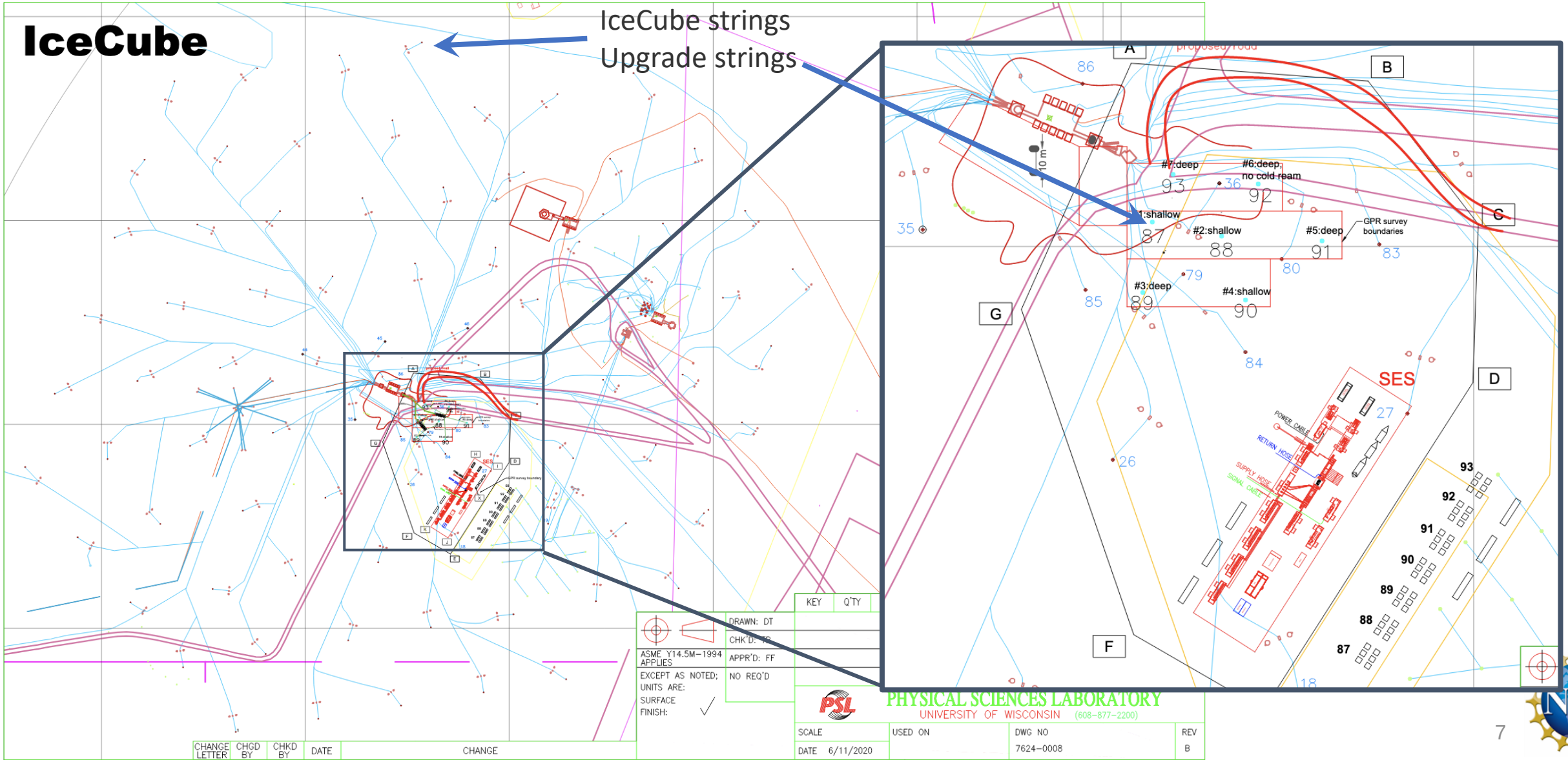


IceCube installation speed (2005-2006)

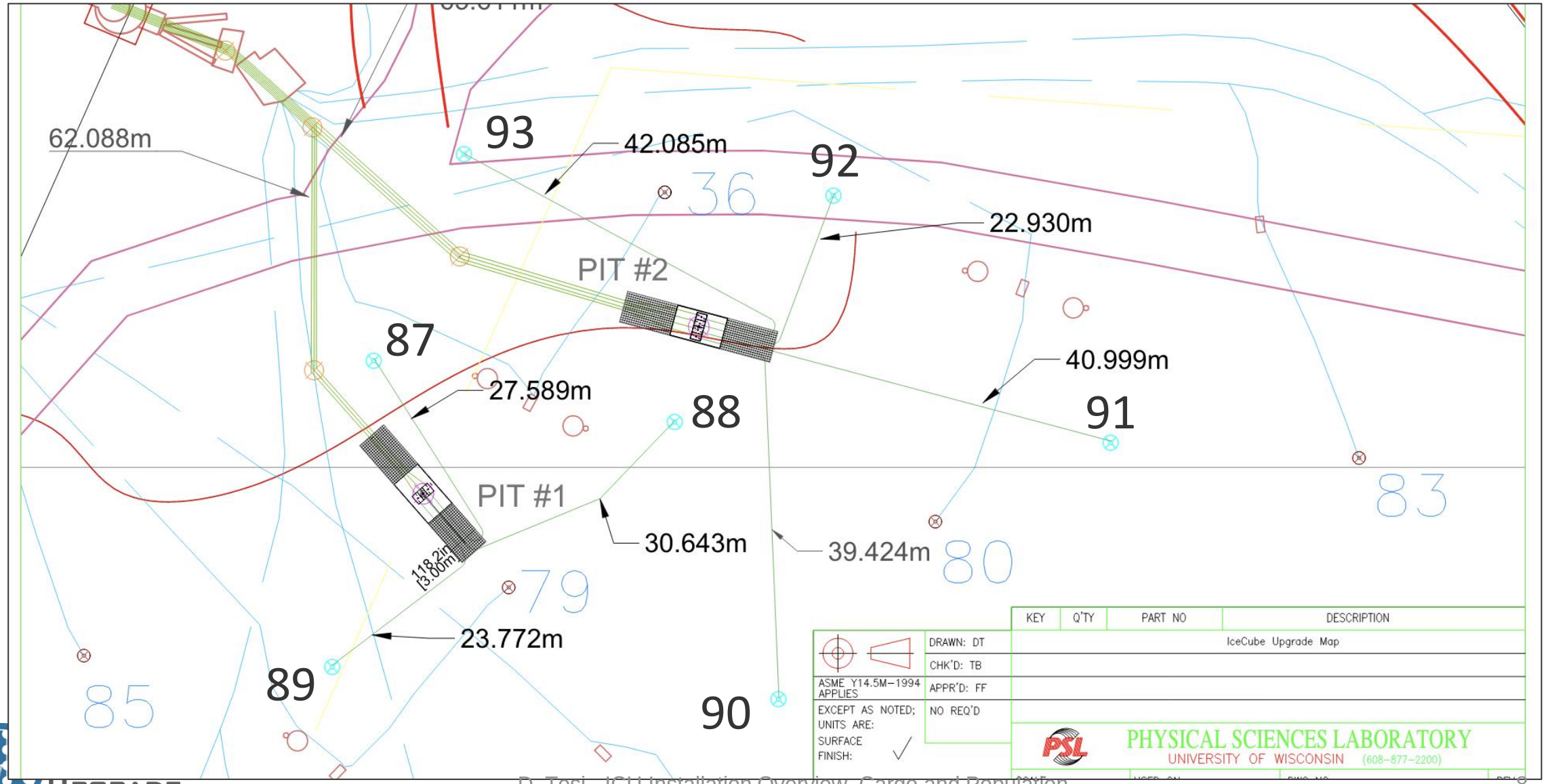




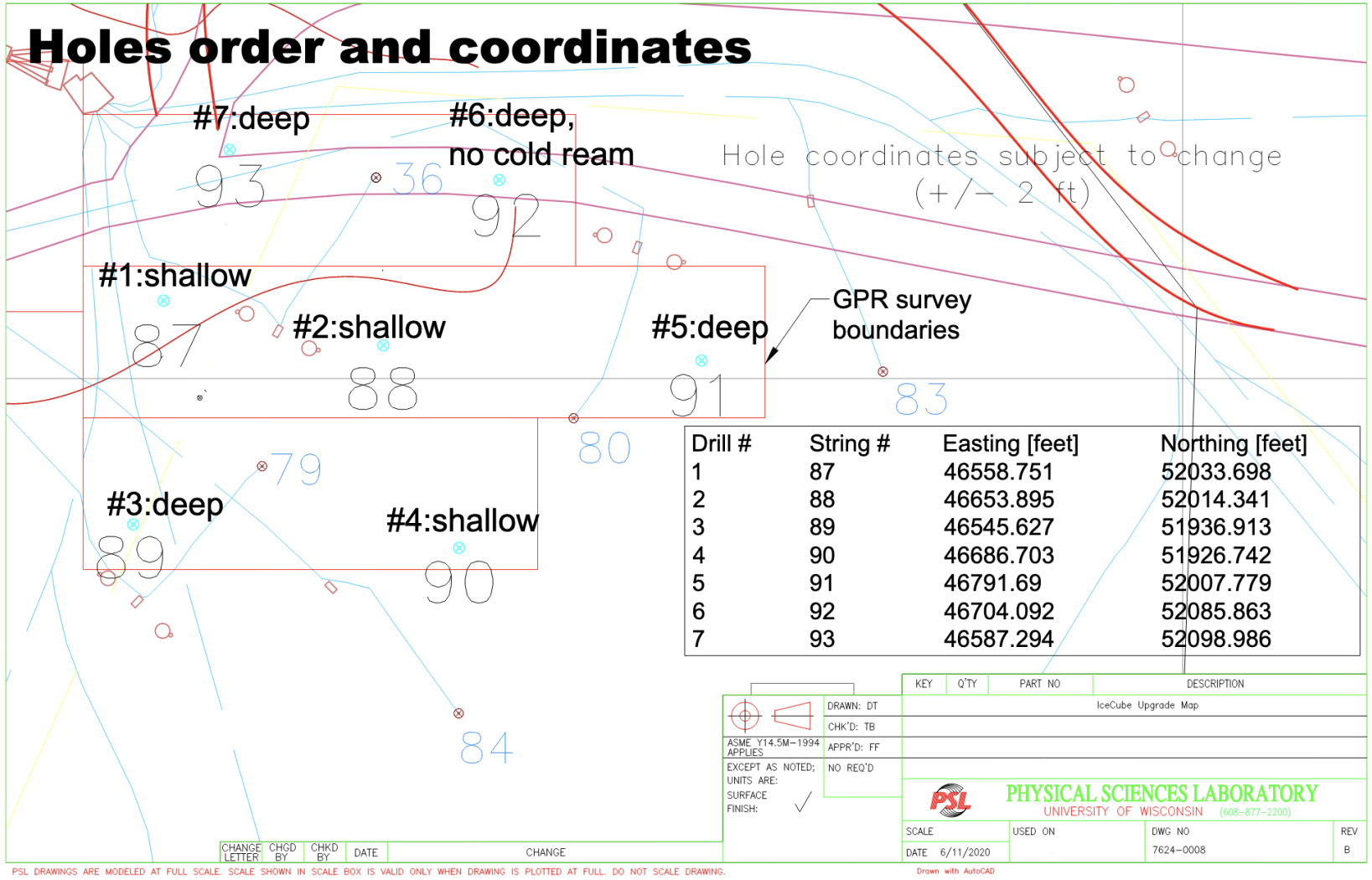
IceCube vs Upgrade surface geometry



Surface cables, Junction Boxes, Pits, Main cables

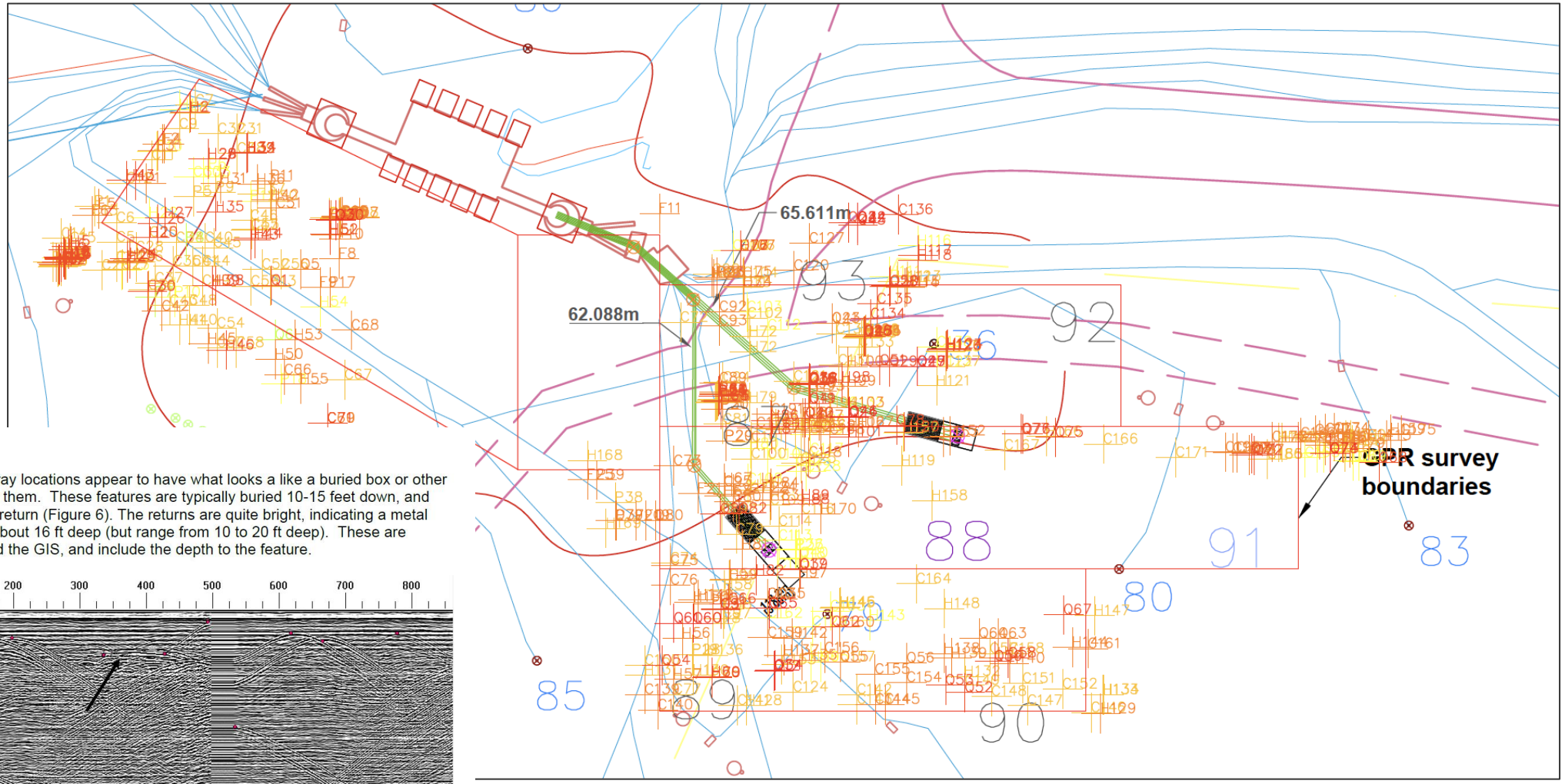


Drilling/Installation order, hole depth



Drill #	String #	Easting [feet]	Northing [feet]
1	87	46558.751	52033.698
2	88	46653.895	52014.341
3	89	46545.627	51936.913
4	90	46686.703	51926.742
5	91	46791.69	52007.779
6	92	46704.092	52085.863
7	93	46587.294	52098.986

GPR 12/2019 returns

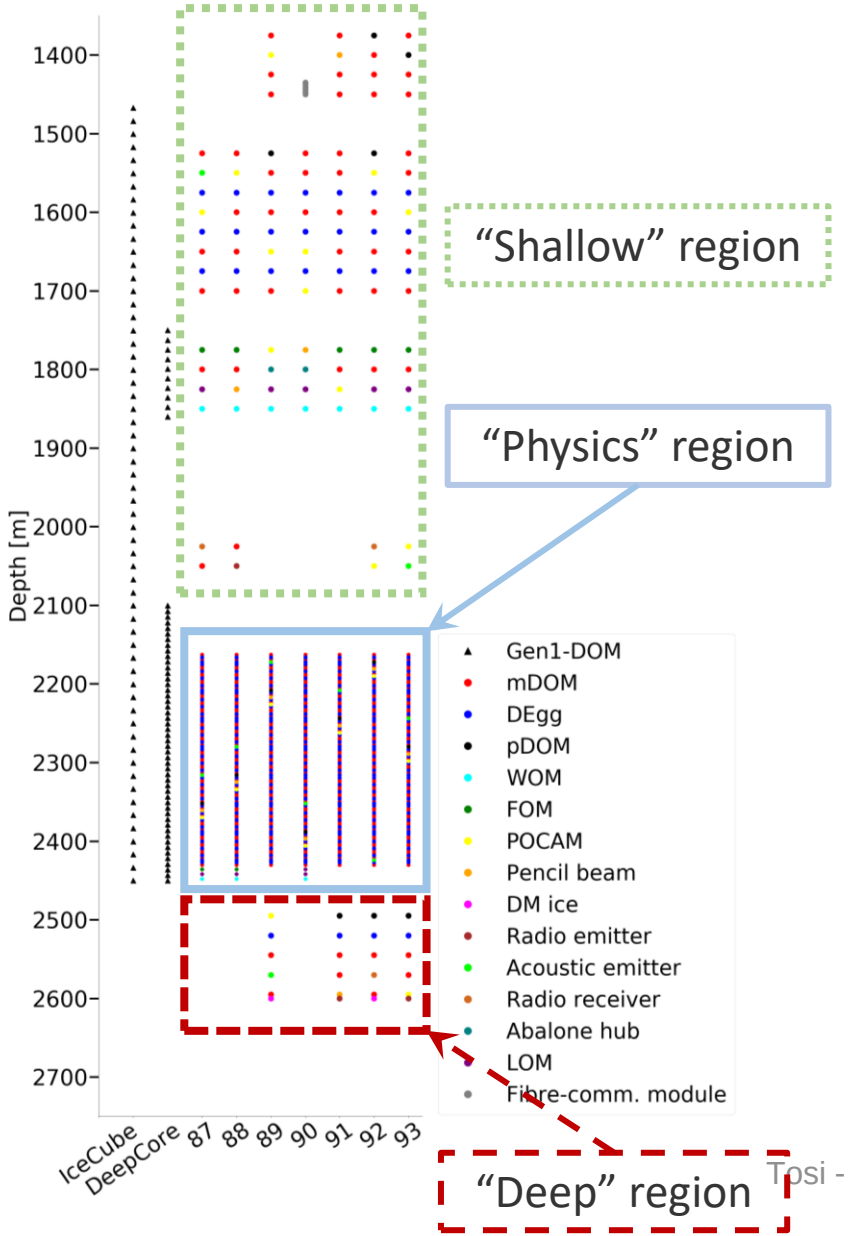


Flat surfaces

Some of the IceCube array locations appear to have what looks a like a buried box or other horizontal structure near them. These features are typically buried 10-15 feet down, and appear as an elongated return (Figure 6). The returns are quite bright, indicating a metal object, and are usually about 16 ft deep (but range from 10 to 20 ft deep). These are indicated in the table and the GIS, and include the depth to the feature.

Figure 6. Flat surface/wide response in GPR data at depth of 15 ft.

IceCube vs Upgrade vertical geometry

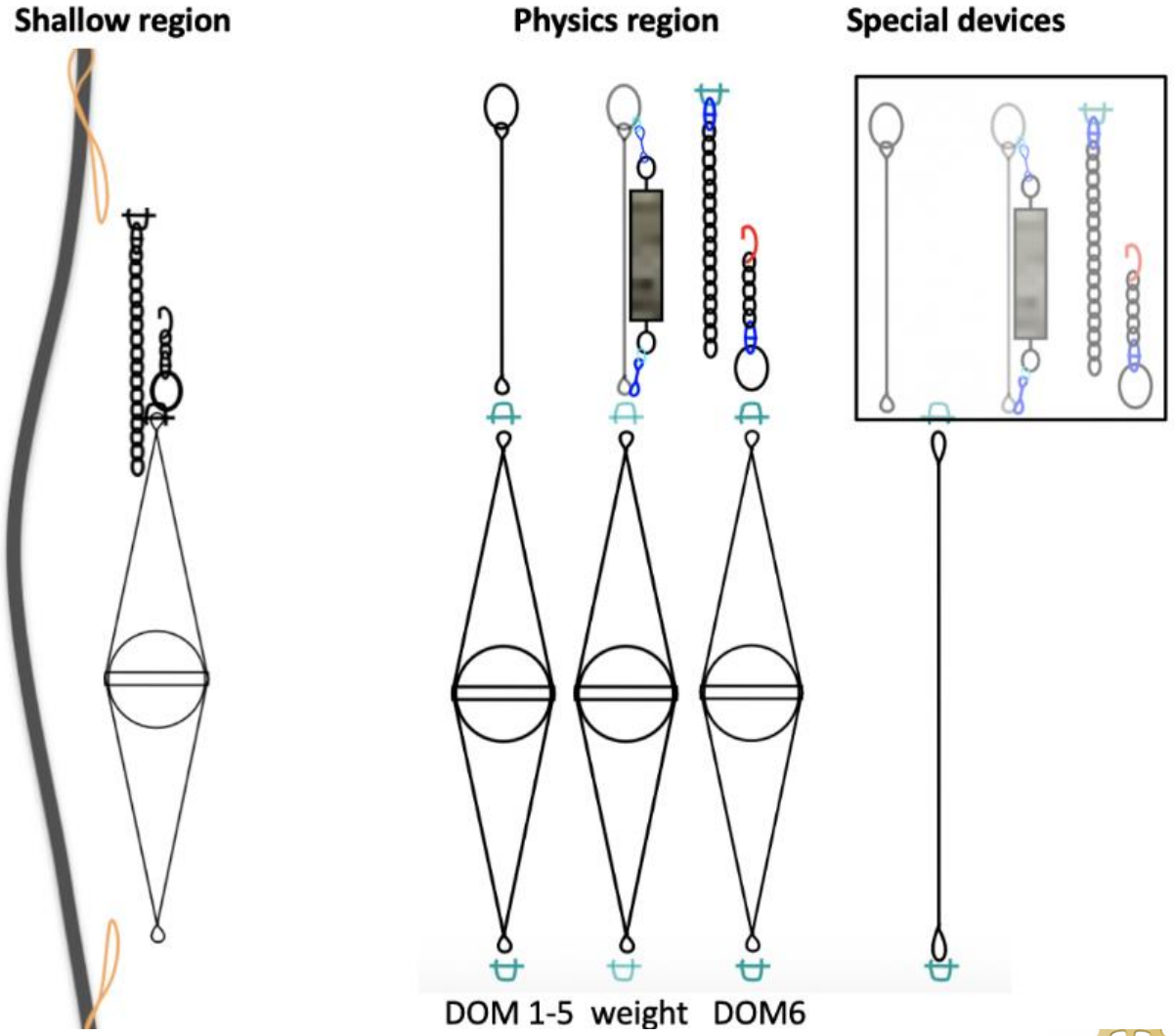


Type	String	87	88	89	90	91	92	93	Total
Optical modules	mDOM	59	57	57	53	60	58	58	402
679	D-Egg	39	41	40	38	40	39	40	277
Calibration devices	pDOM	1	1	2	1	2	4	3	14
61	POCAM	2	2	5	3	2	3	4	21
	Pencil Beam (PB)	1	2	1	2	3	1	1	11
	Acoustic Module (AM)	2	1	2	1	1	1	2	10
	Swedish Camera (SWE))	1	1	0	1	0	1	1	5
R&D devices	Long Optical Module (LOM)	0	1	2	1	3	3	2	12
56	DM-ice	0	1	0	1	0	0	0	2
	Radio Pulser (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

Upgrade String Installation

- More sensors (typically 110/string)
- Many more types of sensors:
  - mDOM (in counts of 53 to 60 per string)
  - D-Eggs (in counts of 38 to 41 per string)
  - A dozen types among calibration and special devices
- Max load: 850 kg
- Shallow/Physics/Deep regions are instrumented with different spacing
- Spacing between sensors from 25 m down to ~ 3m in physics area

→Higher complexity, different procedure, foresee longer time for installation (20-24 hours)



Installation Time Estimate

Installation Time Estimate Per String

Item	time / task	unit	# times task is repeated	time (h)
Specialties				
Setup time	90	min	1	1.5
Transition from Deep to Physics	20	min	1	0.3
Transition from Physics to Shallow	10	min	1	0.2
Extra time for DOM #5/#6 with weight and rigging	2.5	min	30	1.3
Instruments				
Target time for DEgg/mDOM [minute]	7	min	100	11.7
Extra time for the first 3 DOMs of each type	6	min	6	0.6
Target time for each special devices	10	min	18	3.0
Extra time for the first of each special device	5	min	8	0.7
Time to deploy DM ice	30	min	1	0.5
Cable				
Cable to be deployed with BCA management (deep + shallow)	6	m/min	500	1.4
Cable to be deployed without BCA management	8	m/min	500	1.0
Cable during drop	11	m/min	1450	2.2
Total time				**24.3**

Approximations:

- No distinction between long/short string
- Considered a complex scenario (with DM ice, and a large variety of special devices)

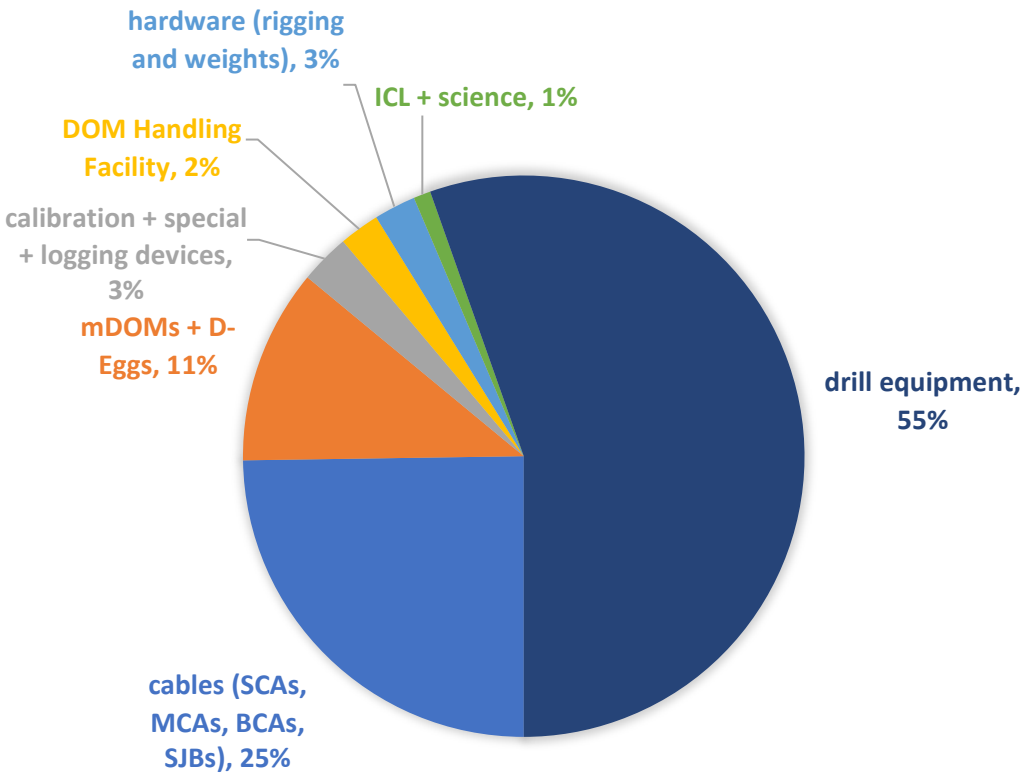
Questions?

Next up:
cargo, people for installation

Cargo

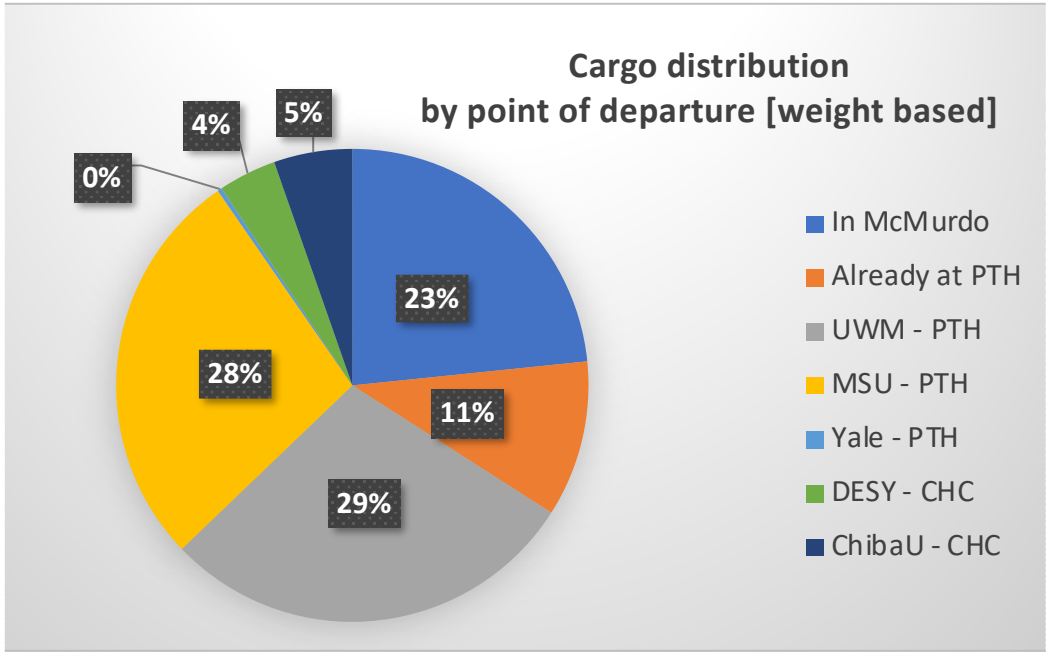
Cargo fraction

- Installation equipment: 45% by weight, 36% by volume



	volume [cu ft]	fraction of volume	weight [lbs]	fraction of weight
cables (SCAs, MCAs, BCAs, SJBs)	5,615	14.0%	128,112	24.8%
mDOMs + D-Eggs	5,189	13.0%	58,149	11.2%
calibration + special + logging devices	909	2.3%	14,878	2.9%
DOM Handling Facility	1,280	3.2%	12,000	2.3%
hardware (rigging and weights)	980	2.5%	12,500	2.4%
ICL + science	432	1.1%	5,075	1.0%
installation equipment	14,404	36.0%	230,714	44.6%
drill equipment	25,591	64.0%	286,758	55.4%
total	39,996	100.0%	517,472	100.0%

Installation cargo origin



	Point of Departure (Point of Origin)	volume [cu ft]	fraction of volume	weight [lbs]	fraction of weight
cables (SCAs, MCAs, BCAs, SJBs)	MSU (MSU)	5,615	14.0%	128,112	24.8%
D-Eggs	CHIBA (CHIBA)	2,480	6.2%	27,780	5.4%
mDOMs	DESY (DESY) / MSU (MSU)	2,709	6.8%	30,369	5.9%
calibration & special devices	UW (various)/ DESY (various)	562	1.4%	9,178	1.8%
dm-ice	YALE (YALE)	64	0.2%	1,500	0.3%
dust logger	UW (UW)	283	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	2.5%	12,500	2.4%
misc science	UW (UW)	128	0.3%	3,000	0.6%
ICL equipment	UW (UW)	304	0.8%	2,075	0.4%
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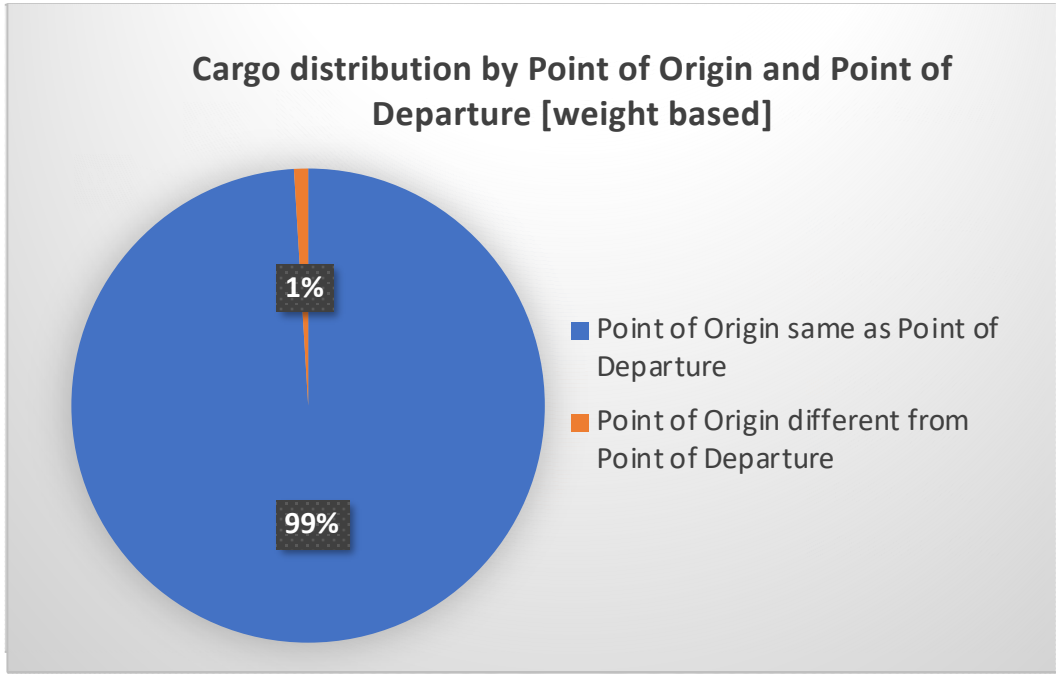

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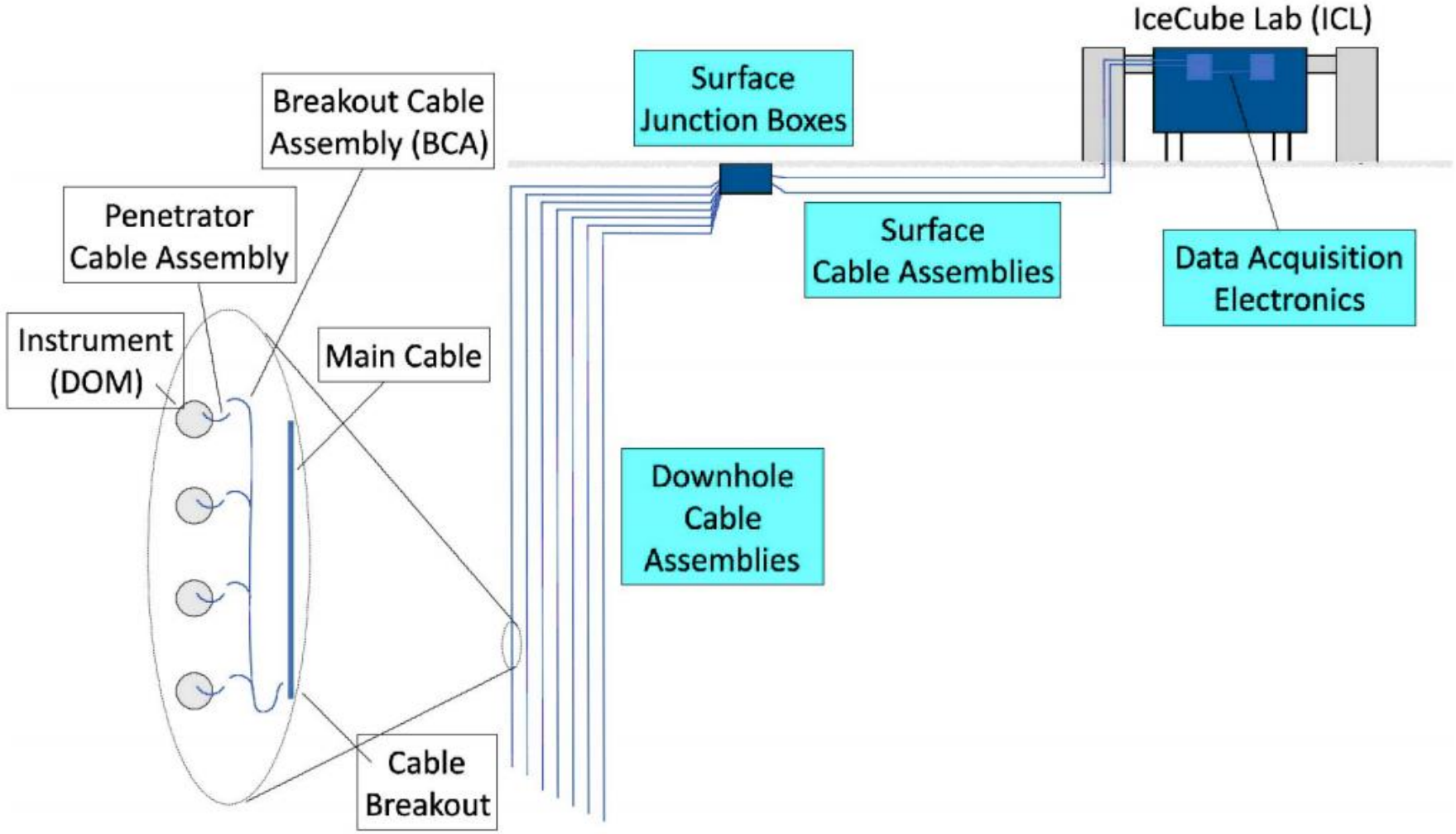
Surface and Downhole Cable Assembly

25% of total weight



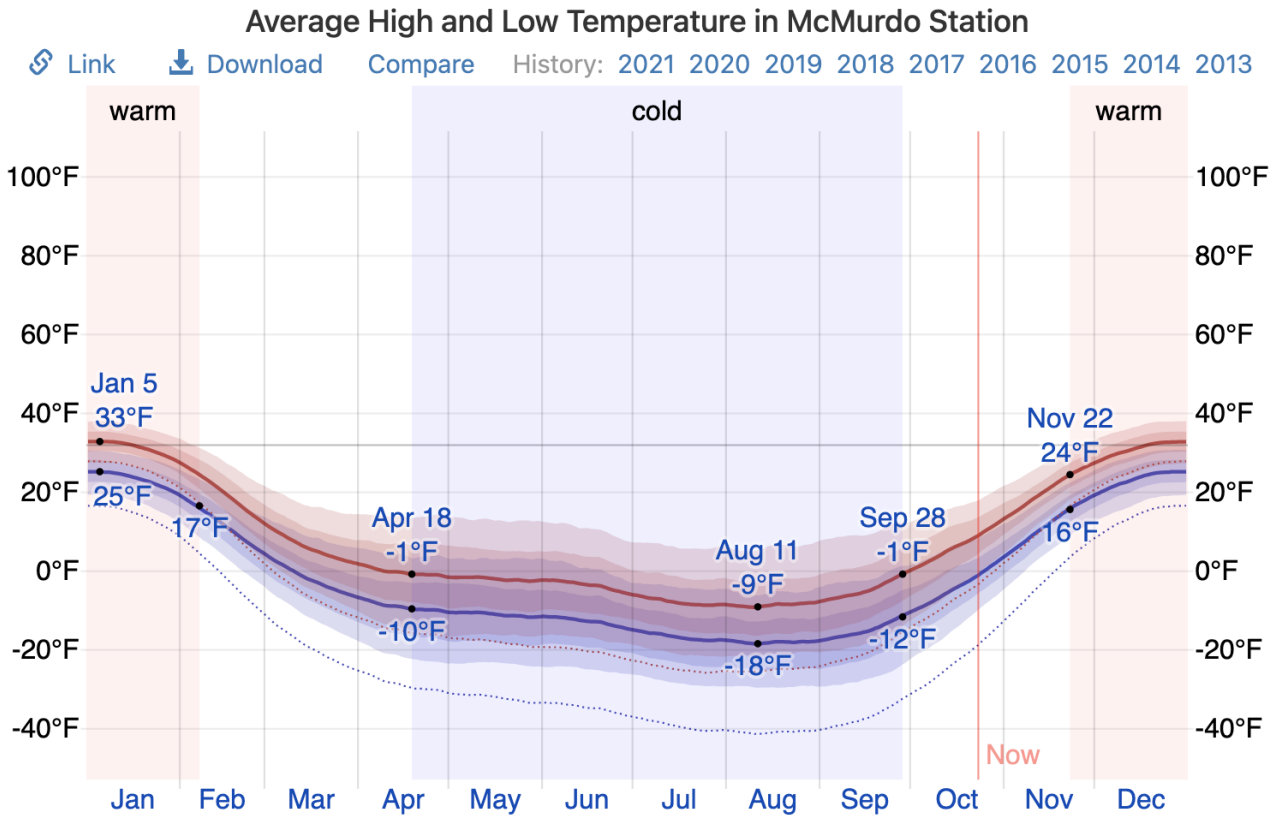
Surface and Downhole Cable Assembly Status

- Surface cable assemblies already produced – will be traveling via vessel and can be stored in McMurdo
  - This cable does not deploy in water, so even if microcracks develop consequences would be minimal

- Main cable assembly temperature rating still to be verified – no vendor would guarantee storage temperature below -40℃ but it is likely to be ok for a few days at temperatures below. (minimum temperature recorded in McMurdo is -56℃ (-68.8℉) but it's very rare

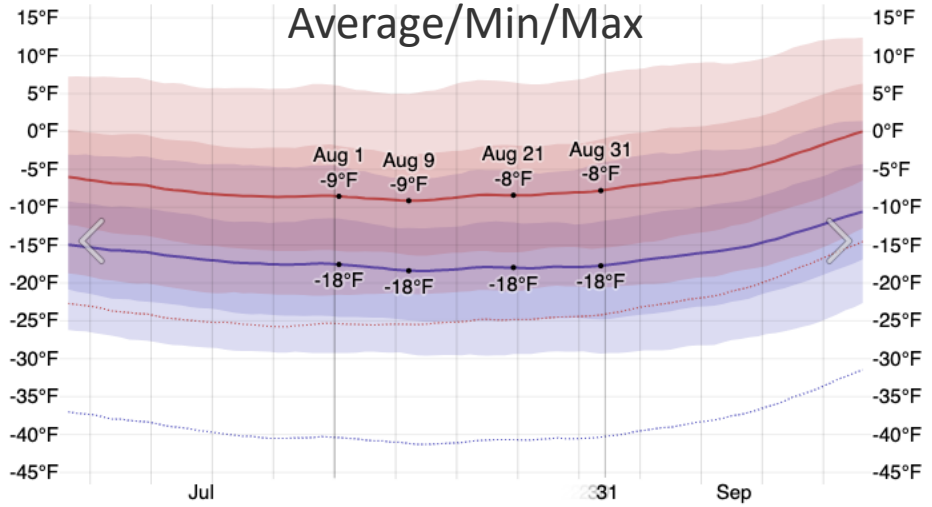
McMurdo winter temperatures

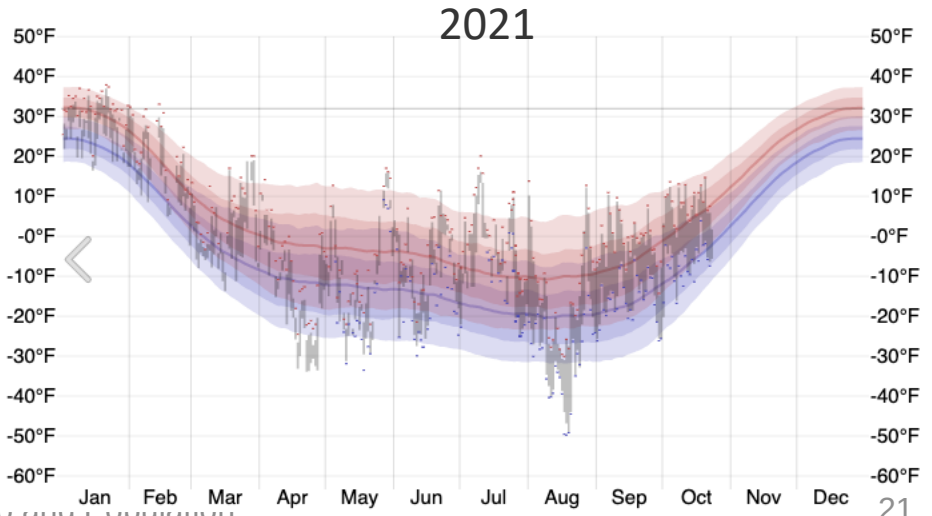
@WeatherSpark



The daily average high (red line) and low (blue line) temperature, with 25th to 75th and 10th to 90th percentile bands. The thin dotted lines are the corresponding average perceived temperatures.

Average	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
High	31°F	20°F	6°F	-0°F	-2°F	-4°F	-8°F	-9°F	-4°F	7°F	21°F	31°F
Temp.	28°F	16°F	1°F	-5°F	-7°F	-8°F	-13°F	-13°F	-11°F	1°F	17°F	28°F
Low	23°F	12°F	-2°F	-9°F	-11°F	-13°F	-17°F	-18°F	-15°F	-4°F	12°F	24°F





Instrumentation & baseline plan

- Each string has
  - mDOMs
  - D-Eggs
  - Calibration devices
  - Special devices

String	87	88	89	90	91	92	93		TOTAL
mDOMs	59	57	57	53	60	58	58		402
D-Eggs	39	41	40	38	40	39	40		277
Calibration Devices	6	6	8	7	6	6	8		47
Special Devices	9	10	8	16	13	12	9		77
Total	113	114	113	114	119	115	115		803

- Optical sensors (mDOMs, D-Eggs) logistics is the most important piece (related to installation cargo) given they make most of the volume, weight, number of items
- Instrumentation for first two strings to be tested and stored at Pole one year ahead to reduce risk on start of drilling operations

String	87-88	89-93	TOTAL
mDOMs	116	286	402
D-Eggs	80	197	277
Calibration Devices	12	35	47
Special Devices	19	58	77
Total	227	576	803

- Sensors designed with minimum storage temperature of -40C → cannot be stored in McMurdo over winter. This means no USAP vessel.

Key Component: Air Force pallet

463L Air Force Pallet

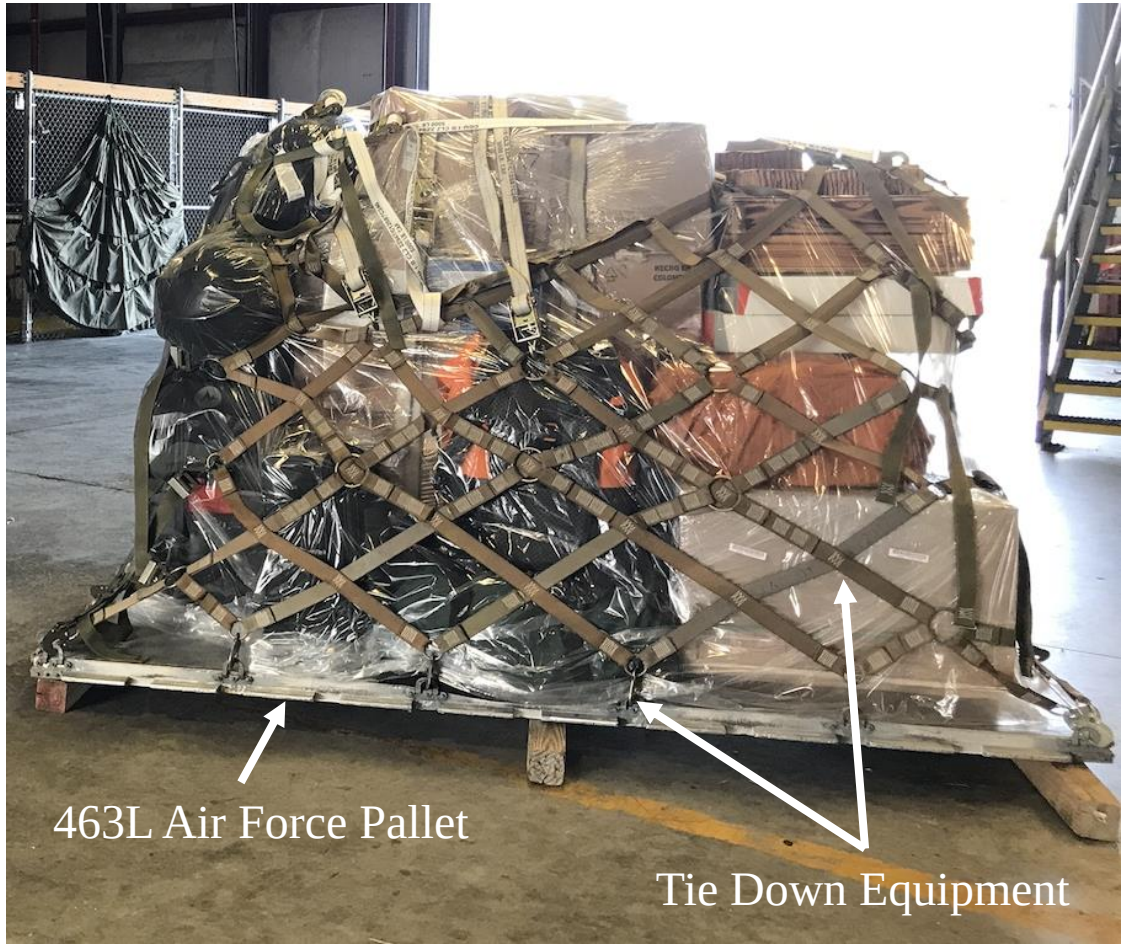
- External dimensions are: 108"W X 88"L X 2.25”H
- Pallet weight: 300 lbs
- Max load capacity 9700 lbs (including Tie Down Equipment “TDE”)

463L pallets can be linked together into pallet trains up to 5 pallets long (LC-130) - requires special handling so it should be avoided if possible

- Max usable footprint (T1 pallet)*: 102” W x 88” L
- Max usable footprint (T2 pallet)*: 102” W x 176” L

*includes 6-inch walkway on W dimension (108”→ 102")

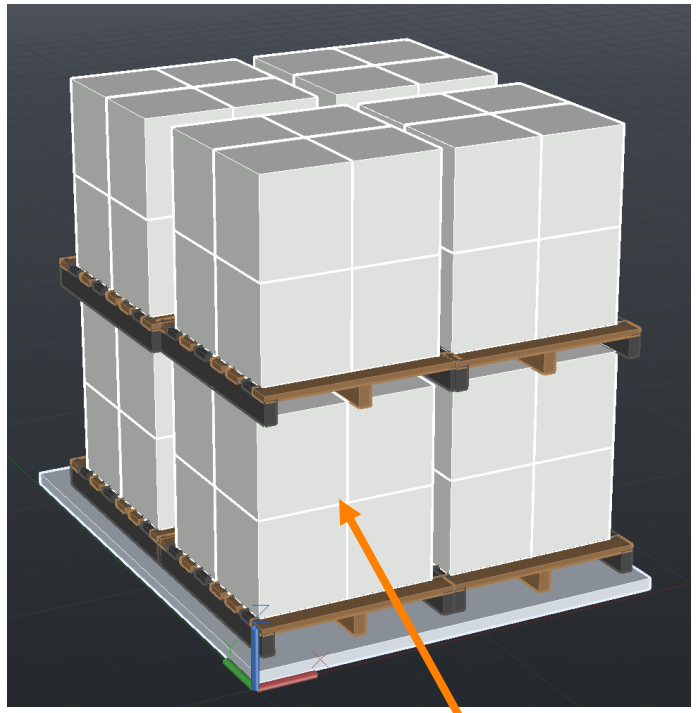
- Max height of 102” H (96” is preferred for loading ease)
- The dimensions above INCLUDE user provided wood/plastic pallet



HTTPS://WWW.AARCORP.COM/463L-HCU-6/E-PALLET/

mDOMs on USAP airlift (CHC→NPX)

This assembly is done in CHC for C-17/C-130 transport: all the mDOMs for one string (including spares) will fit on one single 463L



Single pallet prepared at shipping location:
8 mDOMs
US standard pallet 40”x48” = EUR2 1000mmx1200mm,
4-way (not shown in the graphic above)
ISPM-15: heat treated for export

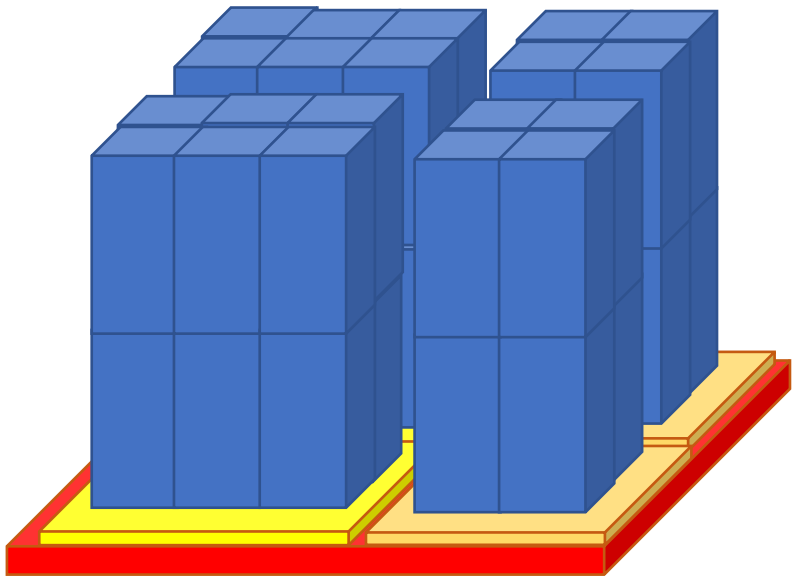
Assumptions:
Box size is 456x456x480 mm → ~18”x18”x19”
number of mDOMs/string is 57-60
mDOM weight: 28 kg (boxed)

64 mDOMs/one Air Force pallet (spares included)
Penetrator hole side vs pallet side: TBD

Similar to what was done in Gen1

D-Egg packaging proposed solution (CHC→NPX)

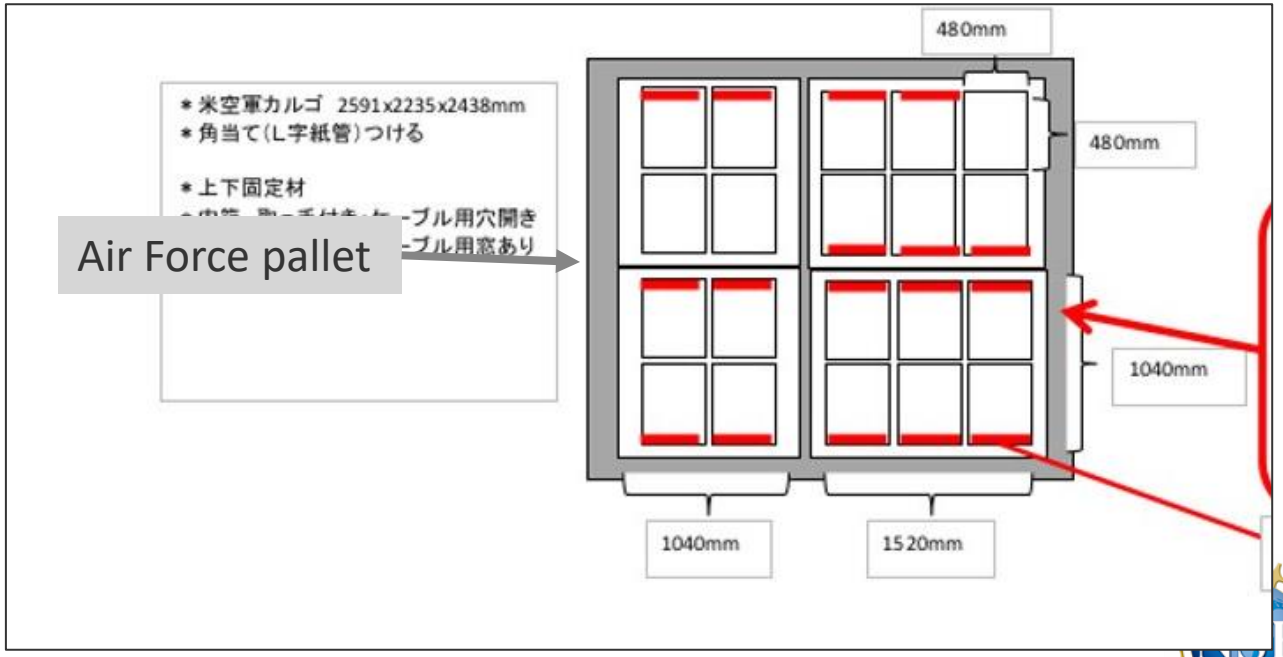
This assembly is done in CHC for C-17/C-130 transport: all the D-Eggs for one string (including spares) will fit on one single 463L



Single pallets prepared at shipping location:
8x D-Eggs, 12x D-Eggs
4-way (not shown in the graphic above)
ISPM-15: heat treated for export or plastic

Assumptions:
Box size is 18.5”x18.5”x30”(480 mm x 480 mm x 770 mm)
number of D-Eggs/string is 38-41
D-Egg weight: 33 kg (boxed)

40 D-Eggs / Air Force pallet



Total number of air force pallets for one string

- mDOMs: 8x8 mDOMs (64) [actual]
- D-Eggs: 2 x 8 + 2 x 12 D-Eggs (40 D-Eggs) [actual]
- Cable: 1 main cable spool [preliminary]
- crates with special/calibr. devices and miscellaneous [estimated]

==========

= 4 x air force pallets per string, height not fully occupied

mDOMs + D-Eggs Shipping Plan Summary

08 / 2023

280 D-Eggs (+ spares) from Chiba to CHC
14x8 D-Eggs/pallet + 14x12 D-Eggs/pallet
Travel to CHC in dedicated (40ft and 20ft) containers

08 / 2023

128 mDOMs from DESY to CHC

= 116 to be deployed + 12 spares
= 16 EUR-2 pallets (8 mDOMs/pallet)
Travel to CHC in dedicated 20ft HC container (can fit 20 pallets)
will be assembled to (2) 463L pallets in CHC

08 / 2024

96 mDOMs from DESY to CHC

= 12 EUR-2 pallets (8 mDOMs/pallet)
Travel to CHC in dedicated 20ft HC container (can fit 20 pallets)
will be assembled to (1.5) 463L pallets in CHC

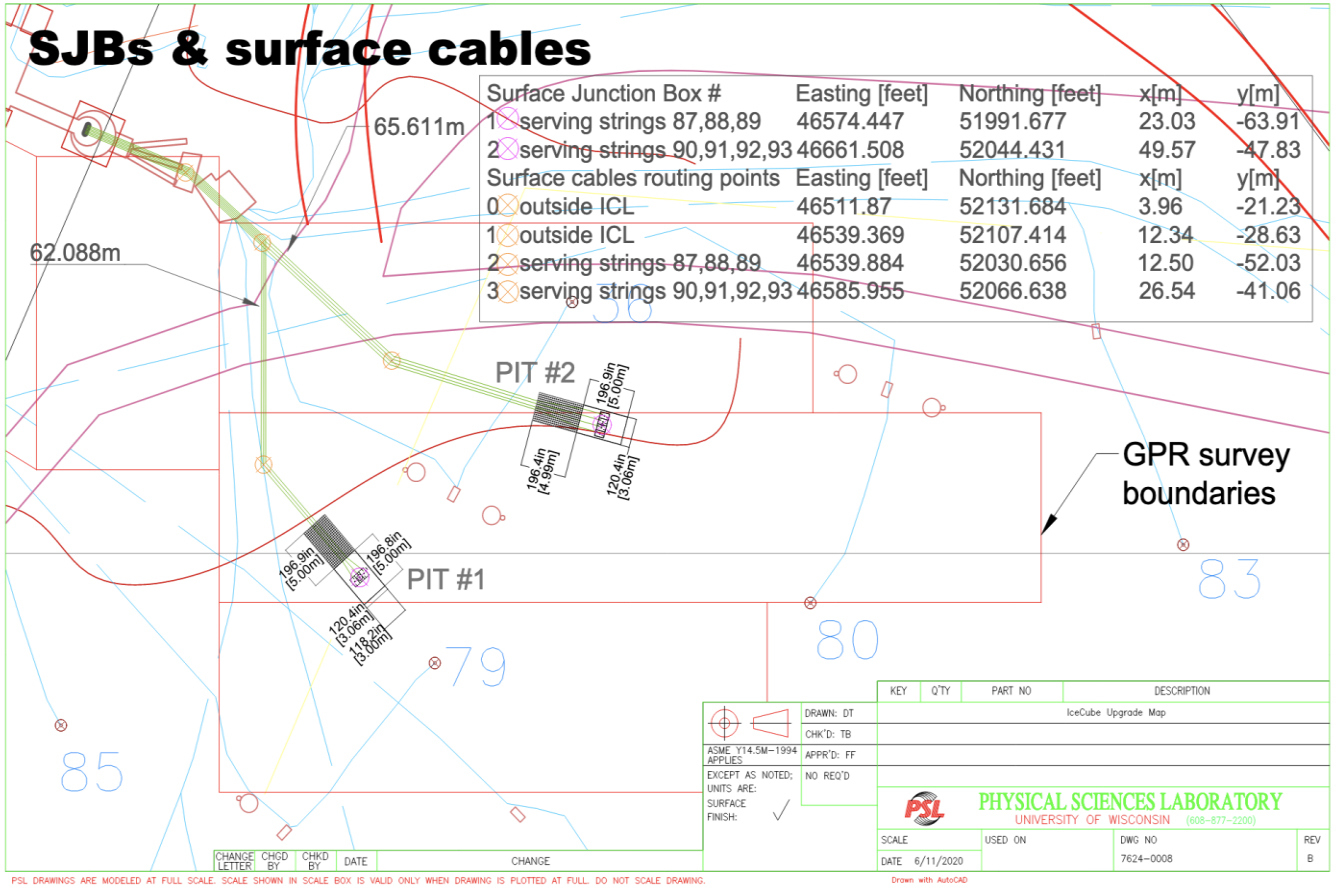
200 mDOMs from MSU to PTH

= 190 to be deployed + 10 spares
= 25 EUR-2 pallets (8 mDOMs/pallet)
Travel to CHC in dedicated container (2x20ft HC or 1x40ft HC)
will be assembled to (3) 463L pallets + 1 add. EUR-2 pallets

Population

FS2: installation/CPT activities

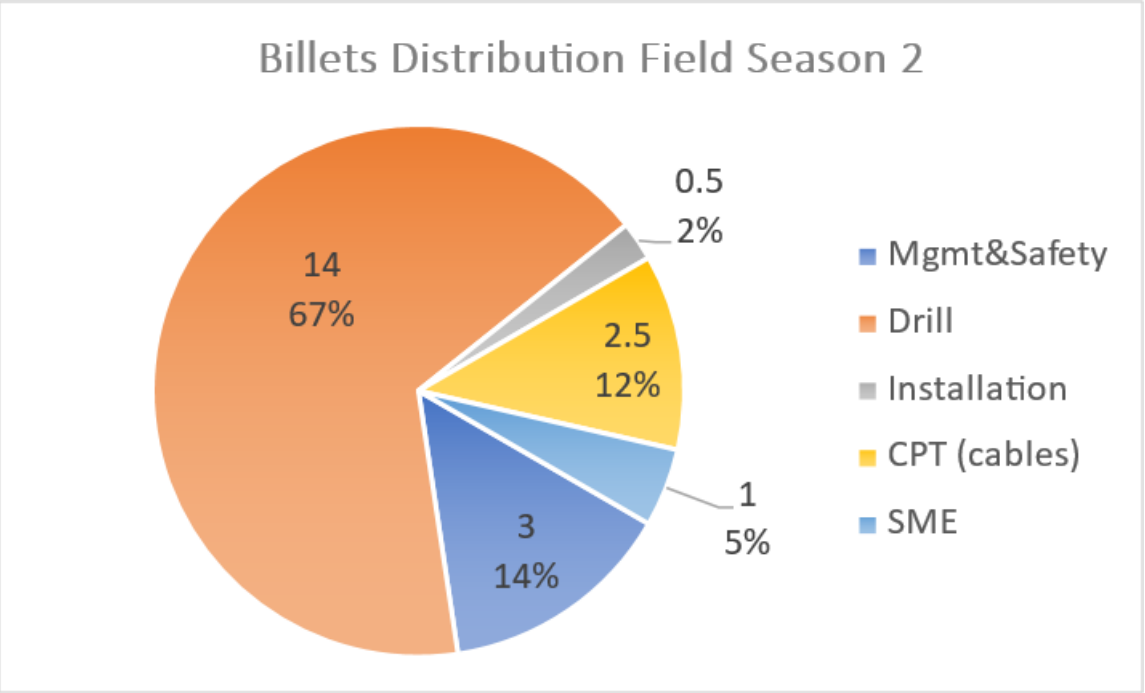
- Install surface cables and surface junction boxes
  - prepare west tower for cabling (*)
  - pull 7 surface cables into ICL (*)
  - install SJBs and connect surface cables to the SJBs
  - install SJB season covers and trench backfill (*)
  - install patch panels into ICL
  - install surface cable grounding 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
- Installation equipment inventory
- Sensors Handling and Testing
  - DOM Handling Facility Construction(*)
  - Setup testing setup
  - Receive and test two strings worth of sensors



(*)ASC support

Installation & CPT Population Overview FS2

- 0.5 shift for installation (split with CAT specialist)
- 0.5 shift for South Pole Acceptance Testing SME (split with Project Engineer, accounted for as cable personnel)
- 2x 0.5 shifts for CPT (ICL side)
- 2x 0.5 shifts for CPT (cables)



FS3: installation/CPT activities

String prep:

- Sensor Testing (2 people < 10 hours / string including moving, connecting & disconnecting sensors)
- Staging of sorted sensors, special devices, and breakout cable assemblies in the sensor handling facility next to the TOS

Installation proper list of tasks (per shift):

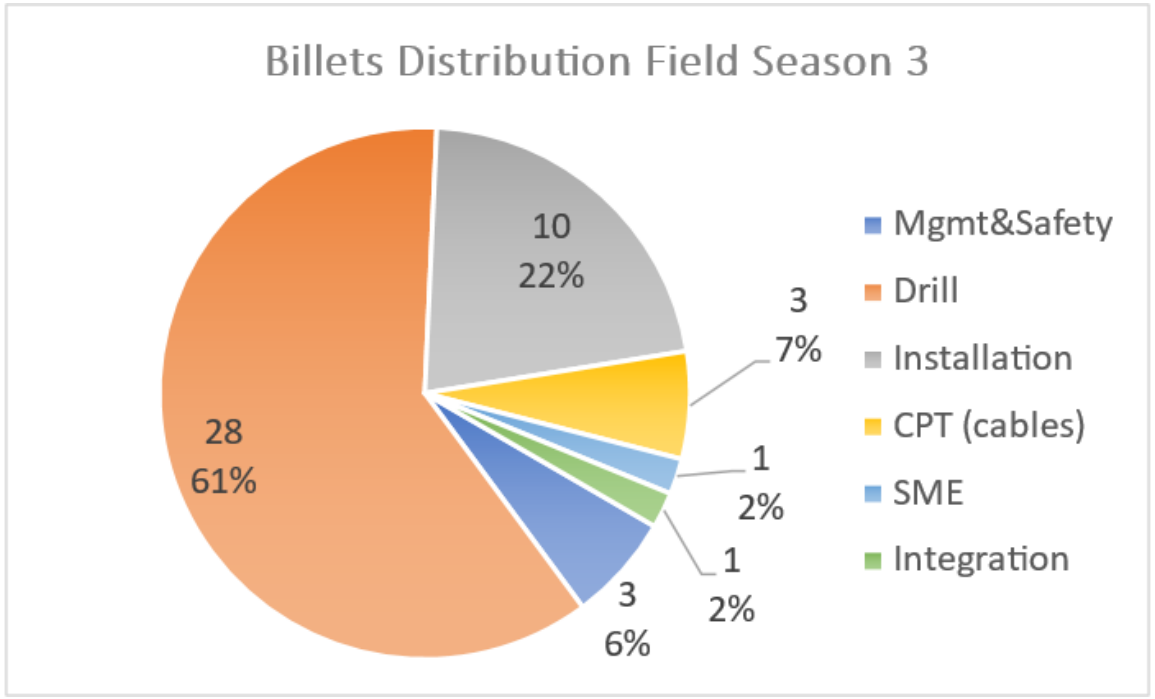
- Shift lead (1x)
- DOM suppliers (2x): sort sensors according to string deployment order in sensor handling facility
- DOM supplier TOS side (1x): preps the next sensor
- DOM installers (2x) : attach sensors to cable at the hole
- Winch operator (1x): operate TU-20 and hoist
- Logger (1x): Logs instrumentation,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

CPT related tasks

- 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 (*).

Installation & CPT Population Overview FS3

- 10 dedicated installers
  - 5/shift + 3 borrowed drillers/shift
  - 1 on project, 9-in kind
- 1 SPAT SME
- CPT:
  - 1 cable expert (field side)
  - 1 Project Engineer (shared with other tasks)
  - 1 cable expert (ICL side)
- Integration/Commissioning
  - 1 DAQ expert



Summary

- Cargo related to installation is 45% of the total
- Biggest shipping items are:
  - Cables (25% of total by weight):
    - Surface cable assemblies can and will be shipped via USAP vessel and stored in McMurdo overwinter
    - Downhole cable assemblies can most likely follow the same path (we plan so for now)
  - D-Egg/mDOMs (11% of total by weight)
    - Two strings-worth of sensors will be stored in cryo to reduce risk on start of drilling
    - Rest cannot be stored in McMurdo but needs to travel via comsur + airlift
- Installation population effort sums to 1 person in YR2 and 10 dedicated people in YR3
- Additional personnel for DOM testing (1), Cable installation (2) and integration (1) in YR3
- Effort similar to Gen1 (string-base)

IceCube / Upgrade team 2019-2020
Photo by Yuya Makino

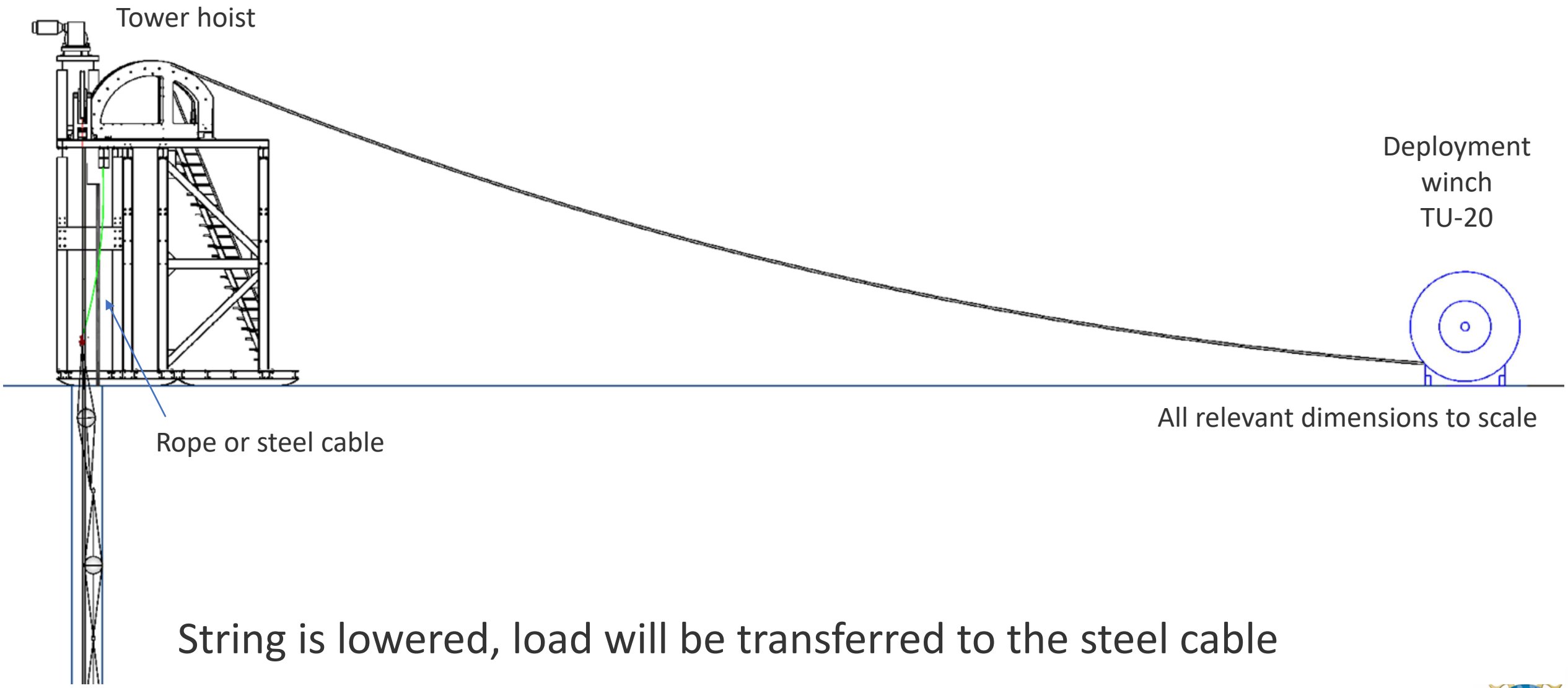
Backup Slides

Off-ice installation tasks

Tasks in the project years prior to deep drilling/installation:

- Maintaining IceCube/Upgrade map (hole locations with reference to as-built)
- Define (with engineering support) load requirements based on string geometry, well depth, sensor weights and volumes, cable weight and volume
- Interface with engineering team to establish parameters for the thermal modeling of each hole based on each string configuration (hole size requirements based on bottom sensor depth, logging, hot/cold reaming)
- Make sure that all the optical sensors, calibration devices (CDs) and special devices (SDs) are designed in a way that is compatible with the installation process and the load requirements
- Develop sensors logistics from shipping to receiving at the South Pole
- Develop and test the installation procedure backup
- Procure installation hardware
- Coordinate overwinter storage needs at the South Pole
- Assemble and train two installation teams for the on-ice activities

DOM string lowered, load transferred to rope



String is lowered, load will be transferred to the steel cable

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’)

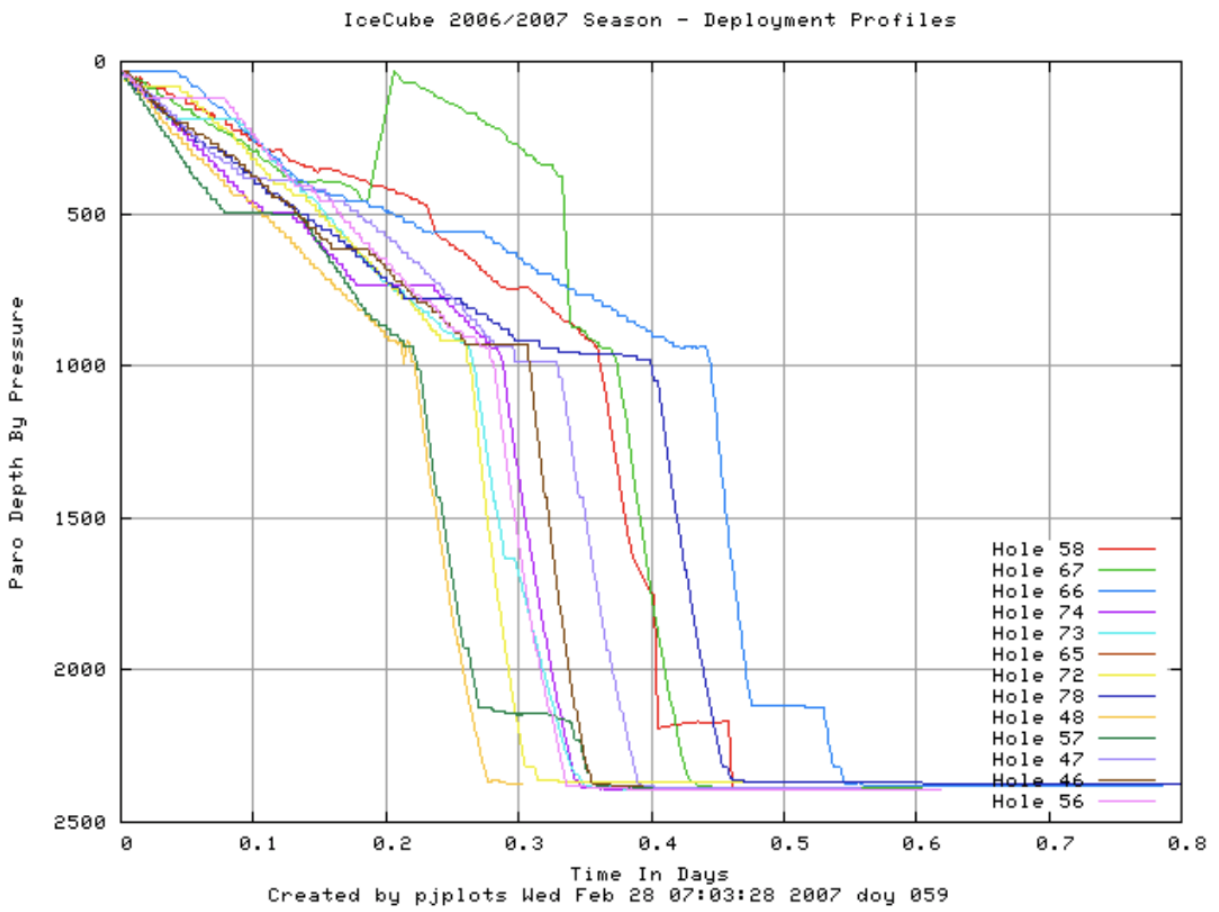
- It was used for deployment training every year during IC construction
- Will be used to practice procedures in as much as detail as possible.

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



Shallow region

Quad	87	88	89	90	91	92	93	Depth	distance to next sensor
1		mDOM	RP		mDOM	pDOM	mDOM	1375	25
		DEgg	POCAM		PB	mDOM	pDOM	1400	25
	DEgg	DEgg	mDOM		mDOM	mDOM	mDOM	1425	10
				FTS				1435	3
				FTS				1438	3
				FTS				1441	3
				FTS				1444	3
				FTS				1447	3
	mDOM	mDOM	mDOM	FTS	mDOM	mDOM	mDOM	1450	75
2	mDOM	mDOM	pDOM	mDOM	mDOM	pDOM	mDOM	1525	25
	AM	POCAM	FOM	mDOM	mDOM	POCAM	mDOM	1550	25
	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	1575	25
	POCAM	mDOM	mDOM	mDOM	mDOM	mDOM	POCAM	1600	25
3	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	1625	25
	mDOM	mDOM	POCAM	POCAM	mDOM	mDOM	mDOM	1650	25
	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	1675	25
	mDOM	mDOM	mDOM	POCAM	mDOM	mDOM	mDOM	1700	75
4	FOM	FOM	POCAM	PB	FOM	FOM	FOM	1775	25
	mDOM	mDOM	mDOM	RP	mDOM	mDOM	mDOM	1800	25
	FOM	PB	AH	AH	POCAM	WOM	WOM	1825	25
	mDOM	LOM	LOM	LOM	LOM	LOM	LOM	1850	125
5	mDOM							1975	25
								2000	25
	RR	mDOM				RR	POCAM	2025	10
					FTS			2035	3
					FTS			2038	3
					FTS			2041	3
					FTS			2044	3
					FTS			2047	3
	mDOM	RP			FTS	POCAM	AM	2050	113

Physics region

Quad	87	88	89	90	91	92	93	Depth	distance to next sensor
6	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2163	3
	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	2166	3
	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2169	3
	DEgg	DEgg	AM	DEgg	DEgg	pDOM	DEgg	2172	3
	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	2175	3
	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2178	3
7	mDOM	mDOM	mDOM	mDOM	mDOM	PB	mDOM	2181	3
	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	2184	3
	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2187	3
	mDOM	mDOM	mDOM	mDOM	mDOM	POCAM	mDOM	2190	3
	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	2193	3
	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2196	3
8	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2199	3
	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	2202	3
	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2205	3
	DEgg	DEgg	pDOM	DEgg	AM	DEgg	DEgg	2208	3
	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	2211	3
	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2214	3
9	mDOM	mDOM	PB	mDOM	mDOM	mDOM	mDOM	2217	3
	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	2220	3
	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2223	3
	mDOM	mDOM	POCAM	mDOM	mDOM	mDOM	mDOM	2226	3
	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	2229	3
	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2232	3
10	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2235	3
	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	2238	3
	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2241	3
	DEgg	DEgg	DEgg	DEgg	pDOM	DEgg	AM	2244	3
	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	2247	3
	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2250	3
11	mDOM	mDOM	mDOM	mDOM	PB	mDOM	mDOM	2253	3
	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	2256	3
	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2259	3
	mDOM	mDOM	mDOM	mDOM	POCAM	mDOM	mDOM	2262	3
	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	2265	3
	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2268	3
12	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2271	3
	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	2274	3
	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2277	3
	DEgg	AM	DEgg	DEgg	DEgg	DEgg	pDOM	2280	3
	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	2283	3
	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2286	3

Quad	87	88	89	90	91	92	93	Depth	distance to next sensor
13	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	PB	2289	3
	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	2292	3
	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2295	3
	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	POCAM	2298	3
	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	2301	3
	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2304	3
14	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2307	3
	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	2310	3
	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2313	3
	AM	pDOM	DEgg	DEgg	DEgg	DEgg	DEgg	2316	3
	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	2319	3
	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2322	3
15	mDOM	PB	mDOM	mDOM	mDOM	mDOM	SWE	2325	3
	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	2328	3
	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2331	3
	mDOM	POCAM	mDOM	mDOM	mDOM	mDOM	mDOM	2334	3
	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	2337	3
	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2340	3
16	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2343	3
	SWE	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	2346	3
	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2349	3
	pDOM	DEgg	DEgg	AM	DEgg	SWE	DEgg	2352	3
	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	2355	3
	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2358	3
17	PB	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2361	3
	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	2364	3
	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2367	3
	POCAM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2370	3
	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	2373	3
	mDOM	SWE	mDOM	mDOM	mDOM	mDOM	mDOM	2376	3
18	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2379	3
	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	2382	3
	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2385	3
	DEgg	DEgg	DEgg	pDOM	DEgg	DEgg	DEgg	2388	3
	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	2391	3
	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2394	3
19	mDOM	mDOM	mDOM	PB	mDOM	mDOM	mDOM	2397	3
	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	2400	3
	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2403	3
	mDOM	mDOM	mDOM	POCAM	mDOM	mDOM	mDOM	2406	3
	DEgg	DEgg	DEgg	SWE	DEgg	DEgg	DEgg	2409	3
	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2412	3
20	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2415	3
	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	2418	3
	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2421	3
	DEgg	DEgg	DEgg	DEgg	DEgg	AM	DEgg	2424	3
	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	DEgg	2427	3
	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	mDOM	2430	12

Deep region

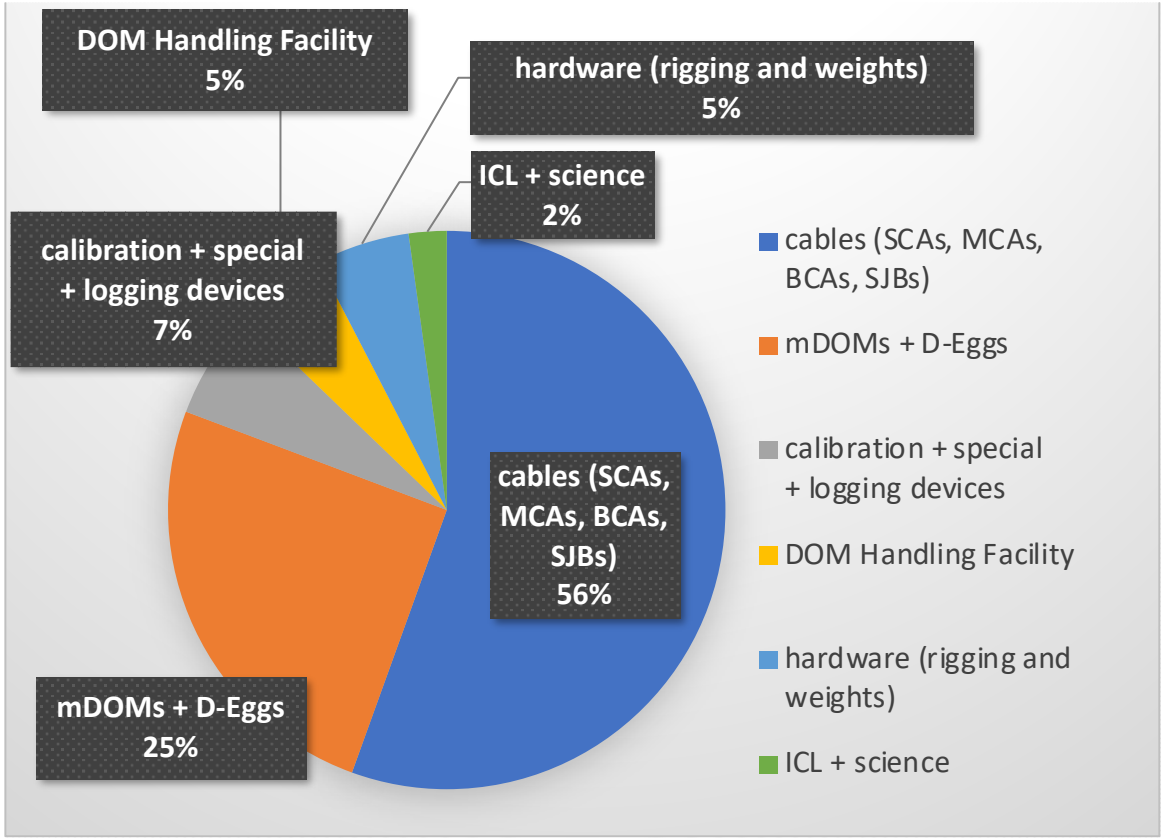
3 short strings

Quad	87	88	89	90	91	92	93	Depth	distance to next sensor
	WOM	WOM		WOM				2442	3
	WOM	WOM		WOM				2445	3
21	WOM	WOM		WOM				2448	3
	WOM	WOM		WOM				2451	3
	mDOM	DM ice		DM ice				2454	0
22	PS	PS		PS				2454	0
	WS							2454	
			mDOM		mDOM	mDOM	mDOM	2475	25
			LOM		LOM	LOM	LOM	2500	25
21			POCAM		pDOM	pDOM	pDOM	2525	25
			DEgg		DEgg	RR	DEgg	2550	25
			AM		PB	DEgg	POCAM	2575	25
			mDOM		LOM	LOM	RP	2600	0
22			PS		PS	PS	PS	2600	0
			WS		WS	WS	WS	2600	

4 long strings

Cargo fraction (only installation)

- Installation equipment: 45% by weight, 36% by volume



installation cargo percentages

	volume [cu ft]	fraction of volume	weight [lbs]	fraction of weight
cables (SCAs, MCAs, BCAs, SJBs)	5,615	14.0%	128,112	24.8%
mDOMs + D-Eggs	5,189	13.0%	58,149	11.2%
calibration + special + logging devices	909	2.3%	14,878	2.9%
DOM Handling Facility	1,280	3.2%	12,000	2.3%
hardware (rigging and weights)	980	2.5%	12,500	2.4%
ICL + science	432	1.1%	5,075	1.0%
installation equipment	14,404	36.0%	230,714	44.6%
drill equipment	25,591	64.0%	286,758	55.4%
total	39,996	100.0%	517,472	100.0%