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

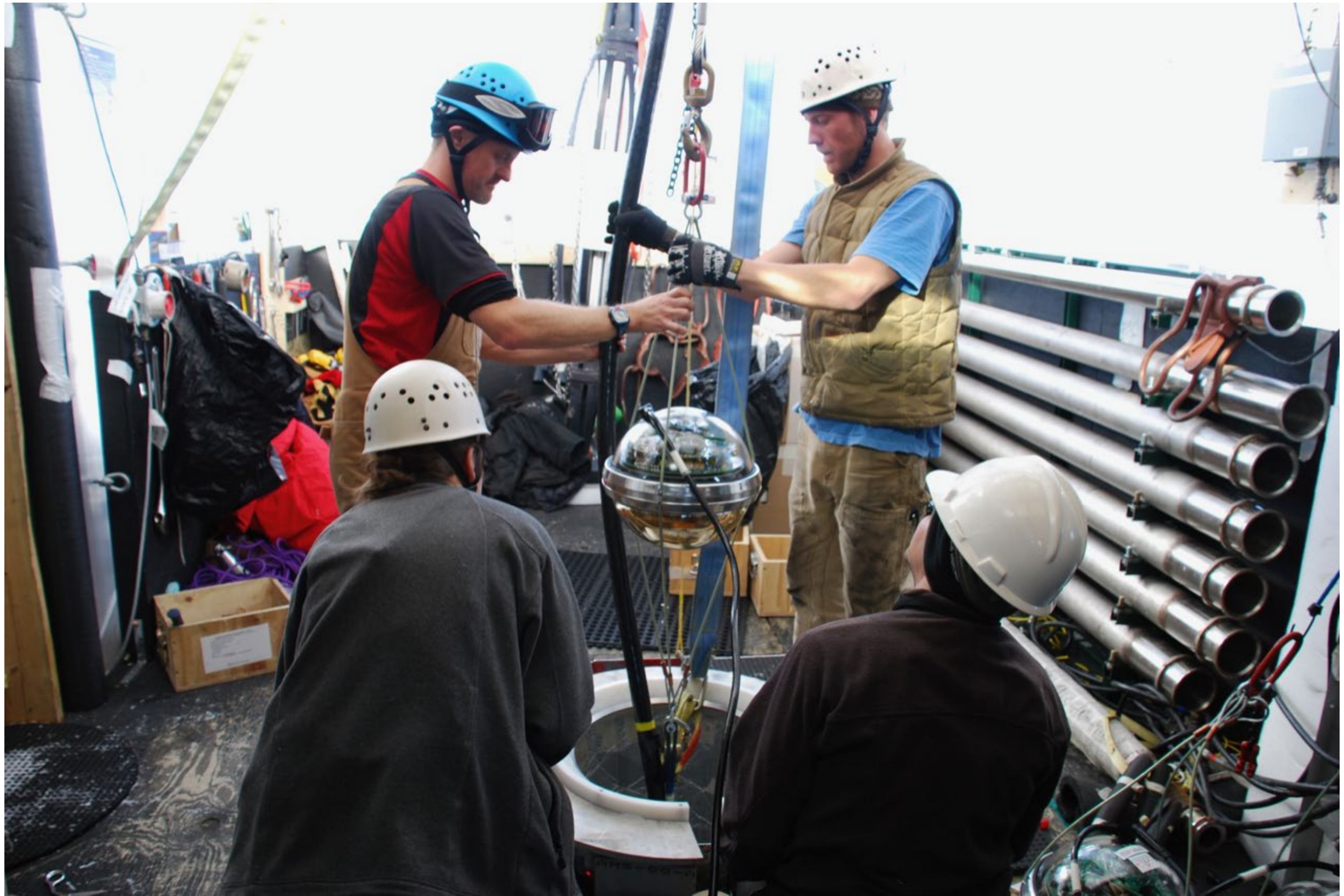
- IceTop enhancement (scintillator panels & radio antennas)
- Borehole logging (SPICE, etc)
- IceCube Upgrade installation lead
- RNO-G drilling and installation
- Broad field experience

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

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

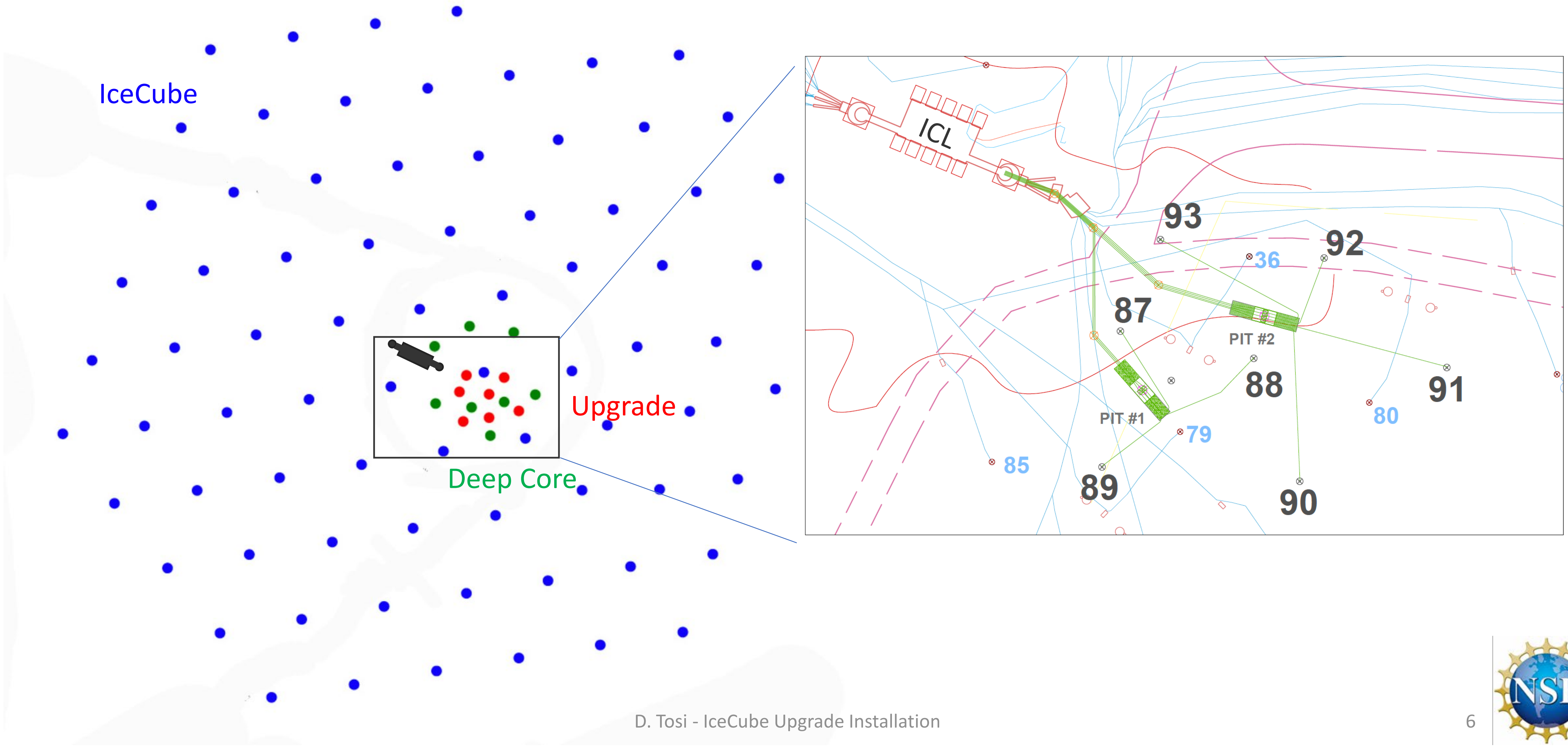
Field specific installation activities in 1.2.10:
Detailed activities list and on-site management of polar field season work for installation; on-ice installation activities, including pre-installation activities and installation proper activities coordinated with deep drilling; […]

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

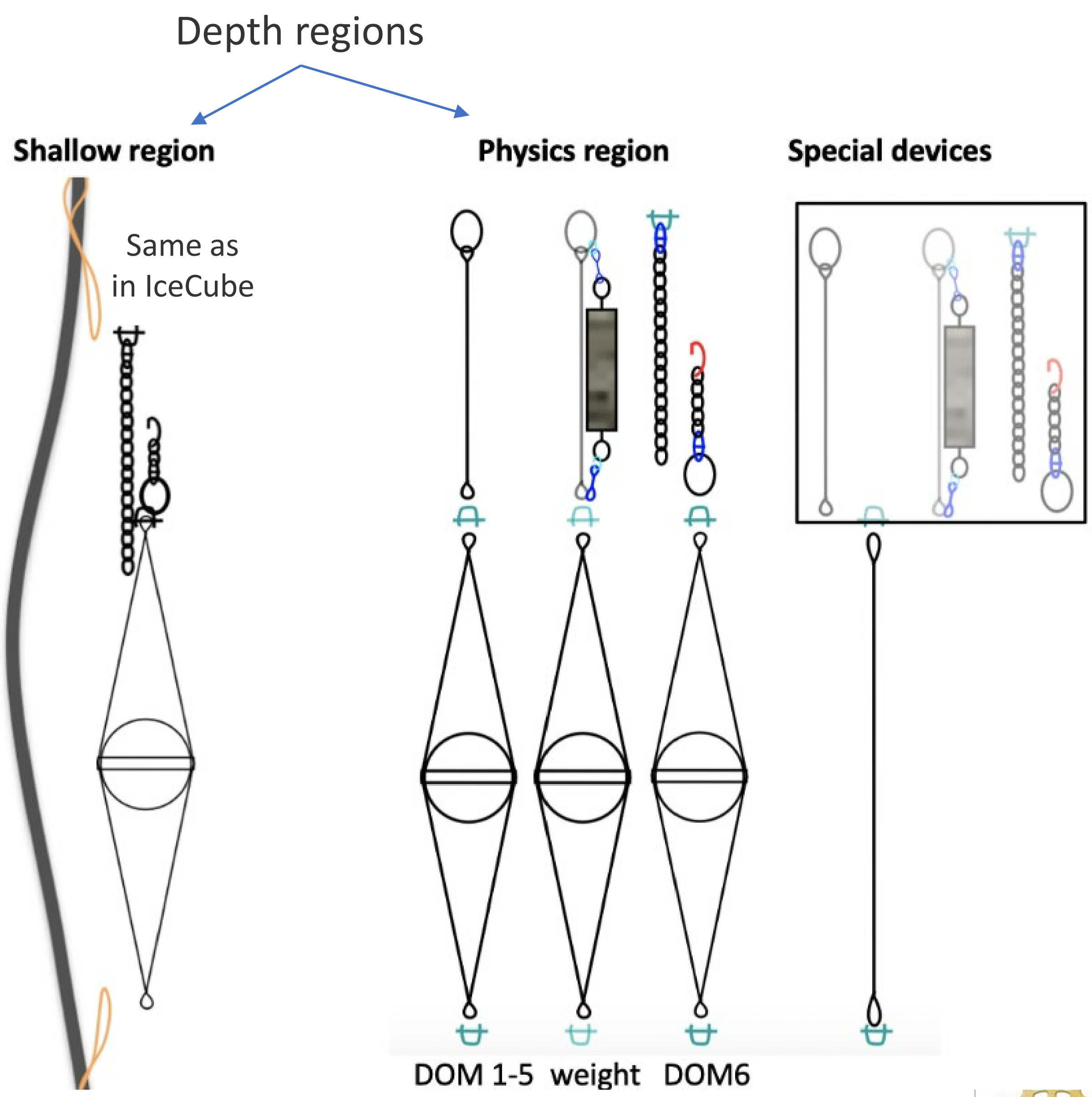
- Cables (1.4)
- Sensors (1.3)
- Calibration Devices (1.5)
- Hole (1.2): depth, type, lifetime diameter, driller support (personnel + equipment)
- Logistics and USAP Support
  - Cargo movement and timing
  - Population
  - On-Ice support and coordination

IceCube & Upgrade surface geometry

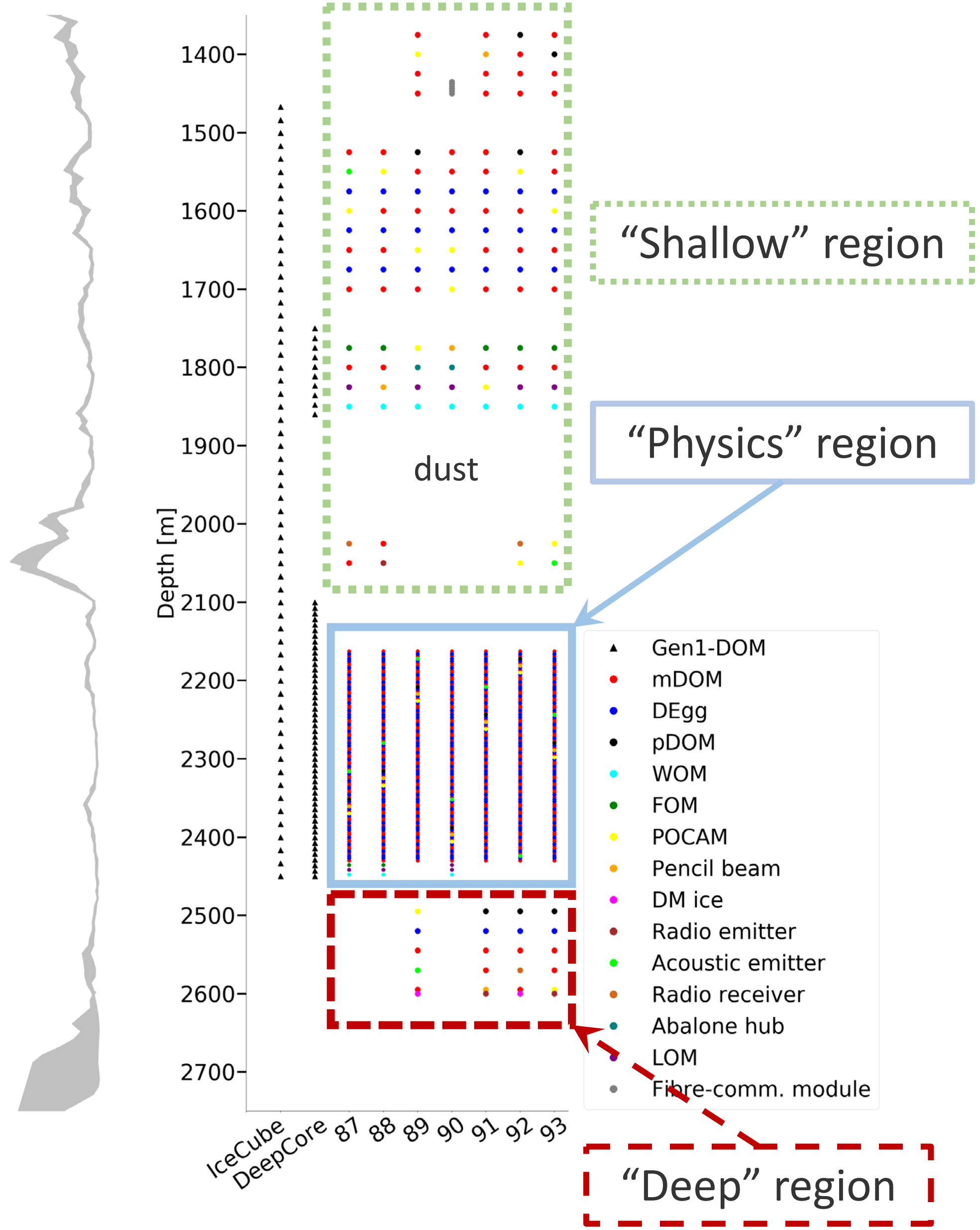


Upgrade String Design

- 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

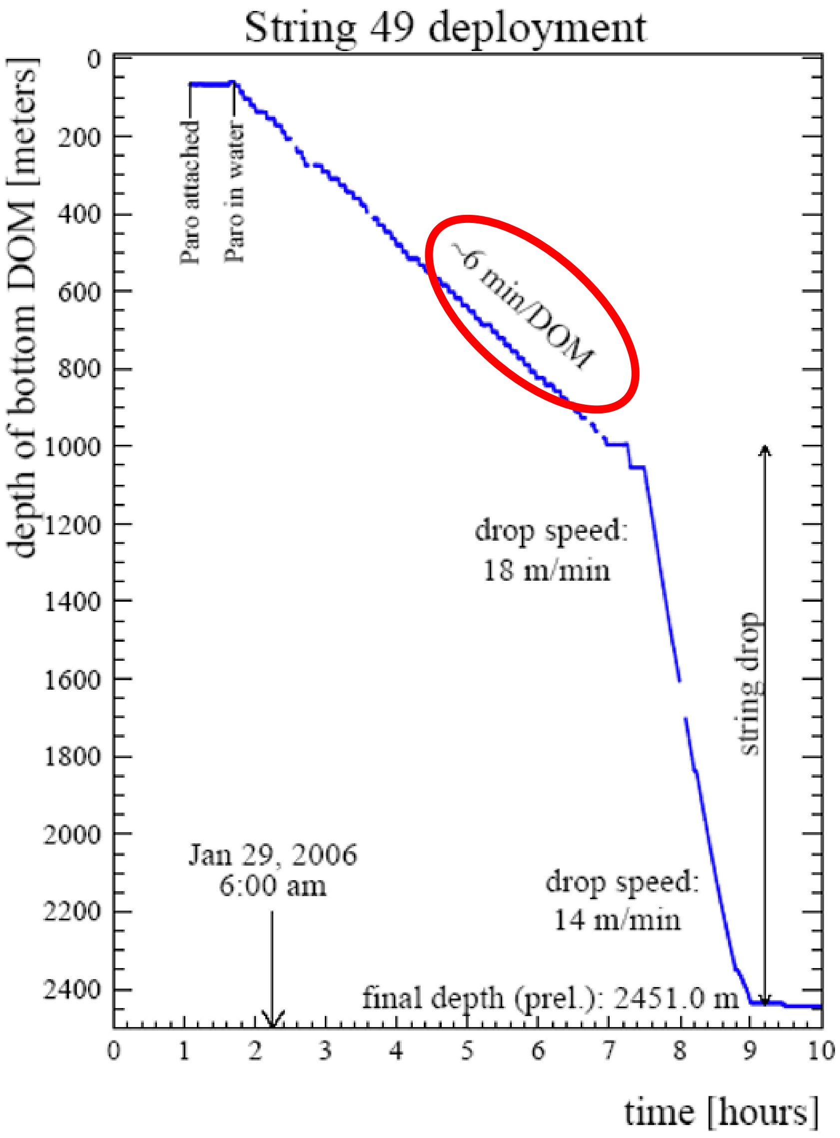


Type	String	87	88	89	90	91	92	93	Total
Optical modules	mDOM	59	57	57	53	60	58	58	402
679	D-Egg	39	41	40	38	40	39	40	277
Calibration devices	pDOM	1	1	2	1	2	4	3	14
61	POCAM	2	2	5	3	2	3	4	21
	Pencil Beam (PB)	1	2	1	2	3	1	1	11
	Acoustic Module (AM)	2	1	2	1	1	1	2	10
	Swedish Camera (SWE))	1	1	0	1	0	1	1	5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

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

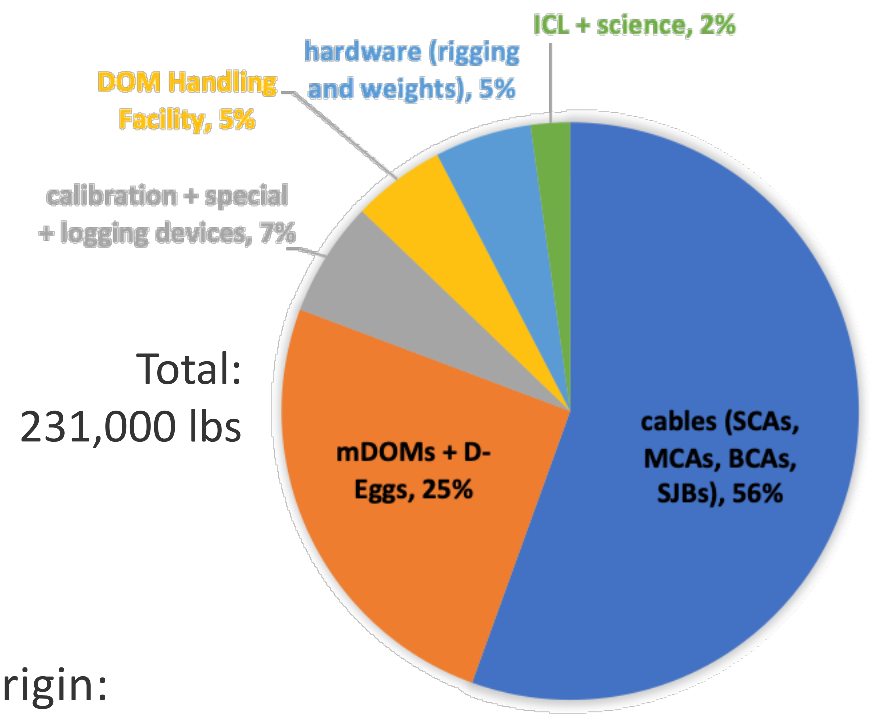
Load on each string is calculated specifically on the properties of various sensors.
Max load on sensors: 850 kg
Max load on cables: 1460 kg

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 hours/60*120 = 20 hours
- Assume 8 min/DOM to account for more complexity adds: 2 min *120 = 4 hours
- Total installation time: 24 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) [actual]
  - D-Eggs: 2 x 8 + 2 x 12 D-Eggs (=40) [actual]
  - Crates with special/calibr. devices and miscellaneous, breakout cables [estimated]

- **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

FS2 main tasks

- Surface cable installation
- Setup sensor testing chain & installation chain

FS2 Population	Personnel	Supporting WBS
CPT (electronics)	1	1.4
CPT (cables)	1	1.4
SPAT SME	1	1.6
Installation	1	1.2.10
Total (1.2.10 activities)	4	

FS3 main tasks

- ICL Comms/Power/Timing installation
- Sensor testing
- installation

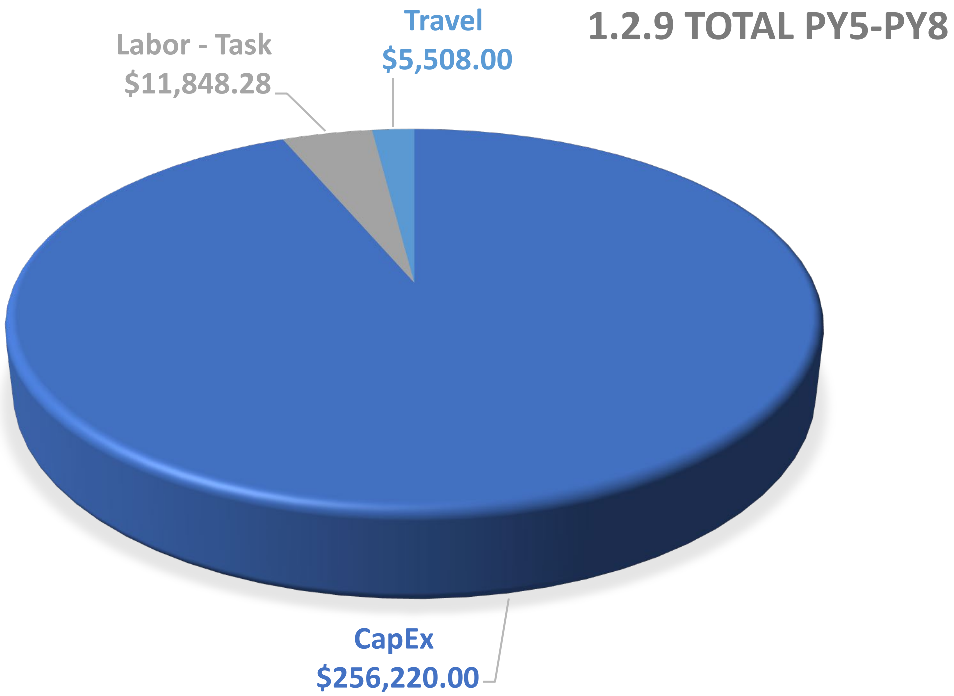
FS3 Population	Personnel	Supporting WBS
CPT (electronics)	1	1.4
CPT (cables) / Installation	1	1.4
ICECUBE Integration	1	1.6
SPAT SME	1	1.6
SPAT Helper	1	In-kind
Installation	9	1.2.10 (x1), in-kind (8)
Total (1.2.10 activities)	**14**	

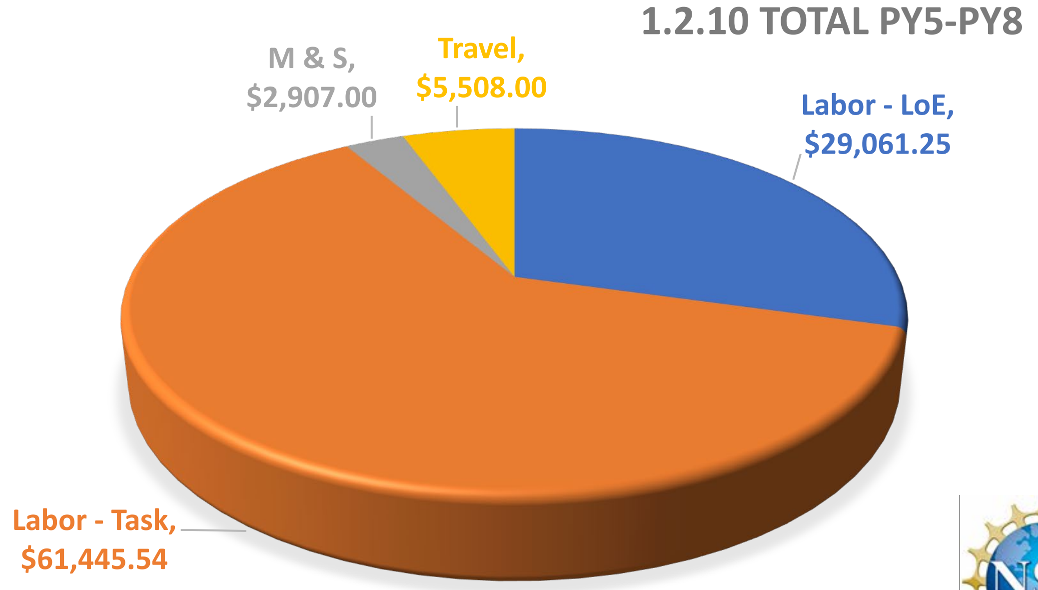
Milestones 1.2.9 & 1.2.10

- 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 Team Ready
  - Installation of 7 Strings
  - Lesson learned

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 firn 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.

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