Basis of Estimate

1. WBS ID	1.2.1	$2,381,686 total cost for this WBS

2. WBS Name Implementation Management & Systems Engineering

3. Estimated by Terry Benson, Delia Tosi, & Ian McEwen (University of Wisconsin)

4. WBS Dictionary Description

This WBS includes functional areas that directly support the seven string installation efforts at the South Pole. Primary components are Management/ Engineering/Logistics, Drill, and Installation. Northern hemisphere Enhanced Hot Water Drill (EHWD) refit activities included design, procurement, and construction of new drill systems, integration, verification, and testing of the drill system and subsystems as well as planning and implementation of drill field operations for refit activities and to accomplish required string borehole deliverables. Installation is responsible for sensor/device handling process development, South Pole Acceptance Testing activities, string hardware design and procurements, and surface cable/s optical sensor, calibration and special device string installation activities at the South Pole.

5. Assumptions and Related Documents

The estimates described in this document rely on the following assumptions, which are consistent with the Project's "Key Assumptions" document" (1) and the "Cost Estimating Plan" (2).

- The cost estimate technique classifications (A-L) follow the US Government Accountability Office (GAO) best practices. These are summarized in the Project's Key Assumptions document (1). The techniques are: A=Analogy; C=Engineering build-up; D=Expert opinion; E=Extrapolation from actuals; F=Parametric; L=Learning Curves.
- Contingency codes are assigned to each item: C1—C8. These reflect the estimated uncertainty in the estimate. The meanings of the contingency codes and the percentage of contingency in each case are described in the Key Assumptions document (1).

6. Scope

The scope of this BOE covers the following L4 areas:

1.2.1.1	Implementation Management & Controls	Includes project management for drill and installation systems.
1.2.1.2	Drill Management & System Engineering	EHWD Upgrade management; Plan, schedule, and budget development; Develops EHWD logistics and support requirements, works closely with 1.1's Polar Operations and the USAP Contractor. Facilitates design, production, and field season readiness reviews; Recruitment; Training; post-

		drill season close-out. Systems engineering, thermal modeling, fuel analyses, CAD support, procedures, post-drill season wrap up.
1.2.1.3	Installation Management & Systems Engineering	Installation management and coordination. Develop site plans. Plan & Coordinate String Installation Area. Work closely with 1.3 (DOM's) and 1.4 (CPT, especially Cables) to determine requirements, schedules, logistics, and constraints. Develop procurement lists of Installation related hardware and equipment. Develop detailed plans and procedures hazard analysis and safety plans for deep string installation. Assemble and lead a team of "Installers" during 2025/26 season to deploy 7 instrumented strings safely and successfully.
1.2.1.4	Implementation Quality and Safety	Drill & installation safety, quality assurance, documentation, post-drill season wrap up.
1.2.1.5	Implementation Travel	Travel for meetings and reviews, recruitment, and vendor visits.
1.2.1.6	Transportation & Logistics	Cargo crating and shipping from UW sites.

7. Materials, Supplies, Equipment, Travel

7.1. Equipment

No equipment is included.

7.2. Materials & Supplies

Procurements in 1.2.1 are limited to the Transportation & Logistics area, 1.2.1.6. Materials and Supplies (M&S) for 1.2.1.6 include:

- Shipment crating materials to support both Drill & Installation needs have been estimated using 2021 actuals, from current pricing posted on W.W. Grainger's website, and Subject Matter Expert (SME) input. PY5-PY8 drill and installation packaging materials total $18,926 in base cost.
- Shipping estimates are based on 2021 actuals and cover the shipping leg from PSL to Port Hueneme. PY5-PY8 drill and installation estimated shipping costs total $21,072 in base cost.

The drilling and installation M&S base costs are given in the table below.

1.2.1 MandS

Grid View | 2 Sheets | 9 Columns | 4 Filters | Group | Summarize | 1 Sort

WBS	Activity	12mo Subtotal PY5	12mo Subtotal PY6	12mo Subtotal PY7	12mo Subtotal PY8	Estimating Technique	Contingency
1.2.1.6.5.5	Ship (Installation): Science Equipment FS3 (Comsur)	$0	$0	$1,000	$0	E - Extrapolation f	C2
1.2.1.6.5.4	Ship (Installation): Science Equipment FS2 (SPAT, IME, Laser Rangers, Pressure Sensors) (Comsur)	$0	$1,000	$0	$0	E - Extrapolation f	C2
1.2.1.6.5.3	Ship (Installation): String Weights (Vessel)	$0	$520	$0	$0	E - Extrapolation f	C2
1.2.1.6.5.2	Ship (Installation): Installation Kits (Vessel)	$0	$2,052	$0	$0	E - Extrapolation f	C2
1.2.1.6.5.1	Ship (Installation): Sensor Handling Structure (Vessel)	$3,000	$0	$0	$0	E - Extrapolation f	C2
1.2.1.6.4.5	Crate (Installation): Science Equipment FS3 (Comsur)	$0	$0	$742	$0	D - Expert Opinion	C2
1.2.1.6.4.4	Crate (Installation): Science Equipment FS2 (SPAT, IME, Laser Rangers, Pressure Sensors)(Comsur)	$0	$742	$0	$0	D - Expert Opinion	C2
1.2.1.6.4.3	Crate (Installation): String Weights (Vessel)	$1,034	$0	$0	$0	D - Expert Opinion	C2
1.2.1.6.4.2	Crate (Installation): Installation Kits (Vessel)	$4,894	$0	$0	$0	D - Expert Opinion	C2
1.2.1.6.4.1	Crate (Installation): Sensor Handling Structure (Vessel)	$3,000	$0	$0	$0	D - Expert Opinion	C2
1.2.1.6.3.4	FS3 - Ship Resupply Container (Comsur)	$0	$0	$2,500	$0	E - Extrapolation f	C2
1.2.1.6.3.3	FS2 - Ship Control Systems Components Shipment	$0	$2,500	$0	$0	E - Extrapolation f	C2
1.2.1.6.3.2	FS1 - Ship Control Systems Components Shipment	$3,500	$0	$0	$0	E - Extrapolation f	C2
1.2.1.6.3.1	FS0 - Ship Control Systems Components Shipment	$4,000	$0	$0	$0	E - Extrapolation f	C2
1.2.1.6.3.1	FS0 - Ship Control Systems Components Shipment	$1,000	$0	$0	$0	E - Extrapolation f	C2
1.2.1.6.2.22	Crate Control Systems Components Shipment 2 - DN	$1,676	$0	$0	$0	C - Engineering Bu	C2
1.2.1.6.2.20	Load Container C (Main/Combo Cables, Bull Wheel,	$6,000	$0	$0	$0	D - Expert Opinion	C2
1.2.1.6.2.11	Crate Control Systems Components Shipment 1 - DNF (Vessel)	$838	$0	$0	$0	D - Expert Opinion	C2

7.3. Travel

- FY23 non-deployment travel, estimated at $12,600 using, standard University Rates for the Annual Collaboration Meeting (international) - 1x $3600; and a meeting with the USAP contractor in Denver (domestic): 5x $1800 = $9k Total
- FY24 non-deployment travel, estimated at $12,600 using, standard University Rates for the Annual Collaboration Meeting (international) - 1x $3600; and a meeting with the USAP contractor in Denver (domestic): 5x $1800 = $9k Total
- FY25 non-deployment travel, estimated at $12,600 using, standard University Rates for the Annual Collaboration Meeting (international) - 1x $3600; and a meeting with the USAP contractor in Denver (domestic): 5x $1800 = $9k Total

1.2.1 Travel

Grid View | 2 Sheets | 9 Columns | 4 Filters | Group | Summarize | 1 Sort

WBS	Activity	12mo Subtotal PY5	12mo Subtotal PY6	12mo Subtotal PY7	12mo Subtotal PY8	Estimating Technique	Contingency
1.2.1.5.5	2022-23 Travel (non-deployment)	$12,600	$0	$0	$0	E - Extrapolation from Actuals	C1
1.2.1.5.6	2023-24 Travel (non-deployment)	$0	$12,600	$0	$0	E - Extrapolation from Actuals	C1
1.2.1.5.7	2024-25 Travel (non-deployment)	$0	$0	$12,600	$0	E - Extrapolation from Actuals	C1

8. Labor

8.1. Labor Estimate

1.2.1 labor largely Level of Effort (LOE) to support management and engineering tasks. Task related labor, primarily in the Crating and Shipping area 1.2.1.6 has been estimated by subject matter experts with deep knowledge of the planned tasking and experience with previous efforts.

8.2. Summary of Labor Resources

1.2.1.1 covers the 1.2 L2 manager full time. Note that PY8 is prorated to 7 months (7/12)(1800) = 1050 hr.

1.2.1 Labor Hours

Grid View | 2 Sheets | 10 Columns | 4 Filters | Group | Summarize | 1 Sort

WBS	Activity	Resource ID	LPY5	LPY6	LPY7	LPY8	Estimating Technique	Contingency
1.2.1.1	EHWD Project Management and Controls (WIPAC_Implementation_Manager)	SE	1800	1800	1800	1050	D - Expert Opinion	C1

1.2.1.2 is Drill Systems Engineering. 1.2.1.2.5 captures PY5, 1.2.1.2.6 captures PY6, and so forth.

1.2.1 Labor Hours

Grid View | 2 Sheets | 10 Columns | 4 Filters | Group | Summarize | 1 Sort

WBS	Activity	Resource ID	LPY5	LPY6	LPY7	LPY8	Estimating Technique	Contingency
1.2.1.2.5.1	2022-23 Systems Engineering (Terry Benson)	EN-ME	900	0	0	0	D - Expert Opinion	C1
1.2.1.2.5.1	2022-23 Management	EN	1440	0	0	0	D - Expert Opinion	C1
1.2.1.2.5.1	2022-23 Systems Engineering Support	EN	459.6	0	0	0	D - Expert Opinion	C1
1.2.1.2.5.2	Drill Procedure Review	EN	280	0	0	0	D - Expert Opinion	C2
1.2.1.2.5.3	Drill Hole Modeling	EN-ME	80	0	0	0	D - Expert Opinion	C2
1.2.1.2.6.1	2023-24 Management & Systems Engineering	EN-ME	0	599.4	0	0	D - Expert Opinion	C1
1.2.1.2.6.1	2023-24 Management	EN	0	959.4	0	0	D - Expert Opinion	C1
1.2.1.2.6.1	2023-24 Systems Engineering Support	EN	0	368	0	0	D - Expert Opinion	C1
1.2.1.2.6.2	PY6 Season Debrief	EN	0	120	0	0	D - Expert Opinion	C2
1.2.1.2.6.3	Drill Procedure Review	EN	0	224	0	0	D - Expert Opinion	C2
1.2.1.2.6.5	Drill Hole Modeling	EN-ME	0	80	0	0	D - Expert Opinion	C2
1.2.1.2.7.1	2024-25 Management & Systems Engineering	EN-ME	0	0	599.4	0	D - Expert Opinion	C1
1.2.1.2.7.1	2024-25 Management	EN	0	0	959.4	0	D - Expert Opinion	C1
1.2.1.2.7.1	2024-25 Systems Engineering Support	EN	0	0	368	0	D - Expert Opinion	C1
1.2.1.2.7.2	PY7 Season Debrief	EN	0	0	120	0	D - Expert Opinion	C2
1.2.1.2.7.3	Drill Procedure Review	EN	0	0	224	0	D - Expert Opinion	C2
1.2.1.2.7.5	Drill Hole Modeling	EN	0	0	80	0	D - Expert Opinion	C2
1.2.1.2.7.6	Drill Readiness Review (PSL)	EN	0	0	192	0	D - Expert Opinion	C2
1.2.1.2.8.1	2025-26 Systems Engineering	EN-ME	0	0	0	270	D - Expert Opinion	C1
1.2.1.2.8.1	2025-26 Management	EN	0	0	0	360	D - Expert Opinion	C1
1.2.1.2.8.1	2025-26 Systems Engineering Support	EN	0	0	0	240	D - Expert Opinion	C1
1.2.1.2.8.2	PY8 Season Debrief	EN	0	0	0	120	D - Expert Opinion	C2

The basis for the 1.2.1.2 estimates are as follows:

Basis of Estimate

			PY5	PY6	PY7	PY8
1.2.1.2.5	**2022-23 Drill Management & Systems Engineering**		**Note: Full year, no field season**			
1.2.1.2.5.1	2022-23 Management & Systems Engineering	System Engineering	0.5 FTE x 1800hr/yr = 900 hr			
1.2.1.2.5.1	2022-23 Management & Systems Engineering	Drill Management	0.8 FTE x 1800hr/yr = 1440 hr			
1.2.1.2.5.1	2022-23 Management & Systems Engineering	Sys Engr Support: Team Meetings	weekly: (34wks)(1hr)(12people) = 408hr ASC coord, biweekly: (17wks)(3people) = 51hr Total = 408+51 = ~460hr			
1.2.1.2.5.2	Drill Procedure Review	Team Procedure Review	1hr session/wk x 35 wks/yr x 8people = 280hr/yr			
1.2.1.2.5.3	Drill Hole Modeling	Hole Modeling	80hr, engr estimate			
1.2.1.2.6	**2023-24 Drill Management & Systems Engineering**			**Note: Offseason only, assumed 8 months**		
1.2.1.2.6.1	2023-24 Management & Systems Engineering	System Engineering		0.5 FTE x (8/12)(1800hr/yr) = 600hr		
1.2.1.2.6.1	2023-24 Management & Systems Engineering	Drill Management		0.8 FTE x (8/12)(1800hr/yr) = 960hr		
1.2.1.2.6.1	2023-24 Management & Systems Engineering	Sys Engr Support: Team Meetings		weekly: (8mo)(4wk/mo)(10people) = 320hr ASC coord, biweekly: (16wks)(3people) = 48hr Total = 320+48 = 368hr		
1.2.1.2.6.2	PY6 Season Debrief	Season Debrief		hybrid, (30people)(4hr) = 120hr		
1.2.1.2.6.3	Drill Procedure Review	Team Procedure Review		1hr session/wk x 28 wks/yr x 8people = 224hr/yr		
1.2.1.2.6.5	Drill Hole Modeling	Hole Modeling		80hr, engr estimate		
1.2.1.2.7	**2024-25 Drill Management & Systems Engineering**				**Note: Offseason only, assumed 8 months**	
1.2.1.2.7.1	2024-25 Management & Systems Engineering	System Engineering			0.5 FTE x (8/12)(1800hr/yr) = 600hr	
1.2.1.2.7.1	2024-25 Management & Systems Engineering	Drill Management			0.8 FTE x (8/12)(1800hr/yr) = 960hr	
1.2.1.2.7.1	2024-25 Management & Systems Engineering	Sys Engr Support: Team Meetings			weekly: (8mo)(4wk/mo)(10people) = 320hr ASC coord, biweekly: (16wks)(3people) = 48hr Total = 320+48 = 368hr	
1.2.1.2.7.2	PY7 Season Debrief	Season Debrief			hybrid, (30people)(4hr) = 120hr	
1.2.1.2.7.3	Drill Procedure Review	Team Procedure Review			1hr session/wk x 28 wks/yr x 8people = 224hr/yr	
1.2.1.2.7.5	Drill Hole Modeling	Hole Modeling			80hr, engr estimate	
1.2.1.2.7.6	Drill Readiness Review (PSL)	FS3 Readiness Review			(2days)(8hr/day)(12people) =	
1.2.1.2.8	**2025-26 Drill Management & Systems Engineering**					**Note: Offseason only, assumed 3 months (Oct25, Feb26, Apr26)**
1.2.1.2.8.1	2025-26 Management & Systems Engineering	System Engineering				0.6 FTE x (3/12)(1800hr/yr) = 270hr
1.2.1.2.8.1	2025-26 Management & Systems Engineering	Drill Management				0.8 FTE x (3/12)(1800hr/yr) = 360hr
1.2.1.2.8.1	2025-26 Management & Systems Engineering	Sys Engr Support: Team Meetings				weekly: (2mo)(4wk/mo)(10people) = 80hr final documentation: 4 areas (sys, mech, elec, ops) x 40hr/ea = 160hr Total = 80+160 = 240hr
1.2.1.2.8.2	PY8 Season Debrief	Season Debrief				hybrid, (30people)(4hr) = 120hr

1.2.1.3 is Installation Management and Engineering. The Installation Manager position is broken into management/controls and installation engineering LOE tasks for each project year. This is 0.4 FTE for PY5 and 6, then tapers off. Engineering support is also included each year at a low level.

1.2.1 Labor Hours

Grid View | 2 Sheets | 10 Columns | 4 Filters | Group | Summarize | 1 Sort

WBS	Activity	Resource ID	LPY5	LPY6	LPY7	LPY8	Estimating Technique	Contingency
1.2.1.3.2.1	String Management and Controls (2022-2023)	SC	270	0	0	0	D - Expert Opinion	C1
1.2.1.3.2.2	Installation Engineering (2022-2023)	SC	450	0	0	0	D - Expert Opinion	C1
1.2.1.3.2.3	Installation Engineering Support (2022-2023)	EN	48	0	0	0	D - Expert Opinion	C2
1.2.1.3.3.1	String Management and Controls (2023-2024)	SC	0	180	0	0	D - Expert Opinion	C1
1.2.1.3.3.2	Installation Engineering (2023-2024)	SC	0	540	0	0	D - Expert Opinion	C1
1.2.1.3.3.3	Installation Engineering Support (2023-2024)	EN	0	48	0	0	D - Expert Opinion	C2
1.2.1.3.4.1	String Management and Controls (2024-2025)	SC	0	0	90	0	D - Expert Opinion	C1
1.2.1.3.4.2	Installation Engineering (2024-2025)	SC	0	0	450	0	D - Expert Opinion	C1
1.2.1.3.4.3	Installation Engineering Support (2024-2025)	EN	0	0	44	0	D - Expert Opinion	C2
1.2.1.3.5.1	String Management and Controls (2025-2026)	SC	0	0	0	18	D - Expert Opinion	C1
1.2.1.3.5.2	Installation Engineering (2025-2026)	SC	0	0	0	77	D - Expert Opinion	C1

Project and drill/installation quality/safety is captured in 1.1.3 Project Office Quality and Safety, and embedded within Implementation management and engineering (1.2.1.1, 1.2.1.2, 1.2.1.3). 1.2.1.4, however, specifically captures annual hazard analysis (HA) review. This is assumed to be (2 HAs/month)(1.5 hr/HA)(4 engr/HA) = 12 hr/mo = 144 hr/yr.

1.2.1 Labor Hours

Grid View | 2 Sheets | 10 Columns | 4 Filters | Group | Summarize | 1 Sort

WBS	Activity	Resource ID	LPY5	LPY6	LPY7	LPY8	Estimating Technique	Contingency
1.2.1.4.5	2022-23 Quality & Safety HA Review	EN	144	0	0	0	D - Expert Opinion	C2
1.2.1.4.6	2023-24 Quality & Safety HA Review	EN	0	144	0	0	D - Expert Opinion	C2
1.2.1.4.7	2025-25 Quality & Safety HA Review	EN	0	0	144	0	D - Expert Opinion	C2
1.2.1.4.8	2025-26 Quality & Safety HA Review	EN	0	0	0	24	D - Expert Opinion	C2

1.2.1.6 is crating and shipping tasks, estimated by expert opinion.

1.2.1 Labor Hours

Grid View | 2 Sheets | 10 Columns | 4 Filters | Group | Summarize | 1 Sort

WBS	Activity	Resource ID	LPY5	LPY6	LPY7	LPY8	Estimating Technique	Contingency
1.2.1.6.2.11	Crate Control Systems Components Shipment 1 - DNF (Vessel)	EN	16	0	0	0	D - Expert Opinion	C2
1.2.1.6.2.20	Load Container C (Main/Combo Cables, Bull Wheel,	TE	30	0	0	0	D - Expert Opinion	C2
1.2.1.6.2.22	Crate Control Systems Components Shipment 2 - DN	TE	24	0	0	0	D - Expert Opinion	C2
1.2.1.6.2.23	Crate Elect. Distribution System Components (ComSur)	EN	8	0	0	0	D - Expert Opinion	C2
1.2.1.6.2.24	Crate MDS Internal Hoses & Spares Resupply (FS2 I	TE	0	8	0	0	D - Expert Opinion	C2
1.2.1.6.2.25	Crate Drill Filtration Resupply (FS2 Resupply Contair	TE	0	8	0	0	D - Expert Opinion	C2
1.2.1.6.2.26	Crate FS2 SES Interconnect Resupply (FS2 Resuppl	TE	0	8	0	0	D - Expert Opinion	C2
1.2.1.6.2.28	Load FS2 Resupply Container (Comsur)	TE	0	16	0	0	D - Expert Opinion	C2
1.2.1.6.2.29	Crate Repair/Replacement Components Resupply (F	TE	0	8	0	0	D - Expert Opinion	C2
1.2.1.6.2.30	Crate Control Systems Components Shipment 3 - DN	TE	0	0	16	0	D - Expert Opinion	C2
1.2.1.6.4.2	Crate (Installation): Installation Kits (Vessel)	TE	32	0	0	0	D - Expert Opinion	C2
1.2.1.6.4.3	Crate (Installation): String Weights (Vessel)	TE	8	0	0	0	D - Expert Opinion	C2

9. References

[Ref-1] 1. **IceCube Upgrade Project.** *Key Assumptions for the IceCube Upgrade Project.*

[Ref-2] 2. —. *Cost Estimating Plan.*

Revision History

Date	Revised by	Summary of changes
2022-02-25	Delia Tosi	
2022-04-11	Terry Benson	Updated tables