Basis of Estimate

1. WBS ID 1.2.4

Total cost for this WBS: $1,110,838

2. WBS Name Computing and Control System - Off-ice

3. Estimated by Andrew Laundrie, Paul Wisniewski, & Terry Benson (University of Wisconsin)

4. WBS Dictionary Description

Includes development and verification of new drill control system software and hardware, network, sensors, e-stop, network and e-stop cabling and connectors, motor drives, and the Drill Control Center.

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 for PY5-8:

1.2.4.1	Architecture	Evaluate EHWD system and define IceCube Upgrade Drill requirements, system design.
1.2.4.2	Control System Hardware	Motor controllers and readouts, sensors, network controllers, indoor cables (sensor and network).
1.2.4.3	Control System Software	Motor controllers and readouts, data acquisition, system operator functions.
1.2.4.4	Motor Drives	Define functional and electrical requirements, specify and procure drives, programming and testing.

1.2.4.5	E-Stop System	Evaluate EHWD system and define IceCube Upgrade Drill requirements, system design and testing.
1.2.4.6	Drill Control Center	Computing system and electrical improvements.
1.2.4.7	Outdoor Cables	Assess existing cabling, design and procure, testing.
1.2.4.8	Controls Subsystems (PY5-PY8)	Includes control system design, procurement, assembly, and testing for MHPs, PHS & WT2, TOS & Reels, Drillheads, DCC, WT1, Fuel Day Tank, GenSets, HPP, and ARA Rodwell System in Project Years 5 through 8.

7. Equipment, Materials, Supplies, Travel

1.2.4 only contains equipment procurements, which are capitalized as part of the larger global control system. There is no M&S and no travel in 1.2.4.

7.1. Equipment

The Computing & Controls Systems materials are given in the tables below.

1.2.4.2 - 1.2.4.7

Basis of Estimate

1.2.4 CapEx

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

WBS	Activity	Subtype	12mo Subtotal PY5	12mo Subtotal PY6	12mo Subtotal PY8	12mo Subtotal PY7	Estimating Technique	Contingency
1.2.4.2.11.1	Network Controllers: CS HW Production Ignition Servers (3x: DCC, TOS1, TOS2)	CapEx	$4,671	$0	$0	$0	C - Engineering Buildup	C2
1.2.4.2.11.2	Network Controllers: CS HW Production Database Server (1x: DCC)	CapEx	$2,906	$0	$0	$0	C - Engineering Buildup	C2
1.2.4.2.11.3	Network Controllers: CS HW Production Peripherals (3x sets: DCC, TOS1, TOS2)	CapEx	$17,520	$0	$0	$0	C - Engineering Buildup	C2
1.2.4.2.11.4	Network Controllers: CS HW DCC Core Switch & Security Appliance	CapEx	$19,803	$0	$0	$0	C - Engineering Buildup	C2
1.2.4.2.11.5	Network Controllers: CS HW Production Main PLC - PLC (redundant), I/O, network, UPS, in a box (3x: DCC, TOS1, TOS2)	CapEx	$29,867	$0	$0	$0	C - Engineering Buildup	C2
1.2.4.2.13	Network Controllers: CS HW PY6 Resupply	CapEx	$0	$4,000	$0	$0	D - Expert Opinion	C4
1.2.4.2.14	Network Controllers: CS HW PY7 Resupply	CapEx	$0	$0	$0	$4,000	D - Expert Opinion	C4
1.2.4.2.2.5	Controls Hardware: Procure System Sensors (PY5)	CapEx	$27,776	$0	$0	$0	C - Engineering Buildup	C2
1.2.4.3.5	Controls Software: SCADA Monitoring Software - Server	CapEx	$2,297	$0	$0	$0	C - Engineering Buildup	C2
1.2.4.5.6	E-stop: Estop PY6 Resupply	CapEx	$0	$5,000	$0	$0	D - Expert Opinion	C4
1.2.4.5.7	E-stop: Estop PY7 Resupply	CapEx	$0	$0	$0	$5,000	D - Expert Opinion	C4
1.2.4.6.3	DCC: Update Workspace (desk, chairs), Procure Printer & Accessories	CapEx	$10,770	$0	$0	$0	C - Engineering Buildup	C2
1.2.4.7.4	Outdoor Cables: CS Cabling Resupply (PY6)	CapEx	$0	$5,000	$0	$0	D - Expert Opinion	C4
1.2.4.7.5	Outdoor Cables: CS Cabling Resupply (PY7)	CapEx	$0	$0	$0	$5,000	D - Expert Opinion	C4

1.2.4.8.1-1.2.4.8.2

1.2.4 CapEx

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

WBS	Activity	Subtype	12mo Subtotal PY5	12mo Subtotal PY6	12mo Subtotal PY8	12mo Subtotal PY7	Estimating Technique	Contingency
	Resupply (PY7)							
1.2.4.8.1.2.1	CS: Procure sample temperature display and digital thermostat, install in test bed heater, test	CapEx	$300	$0	$0	$0	D - Expert Opinion	C2
1.2.4.8.1.2.2	CS: Select and procure temperature display units for heater controls, conversion hardware	CapEx	$4,500	$0	$0	$0	C - Engineering Buildup	C2
1.2.4.8.1.2.4	CS: Select and procure digital thermostats for heater controls, conversion hardware	CapEx	$4,962	$0	$0	$0	C - Engineering Buildup	C2
1.2.4.8.1.3.3	CS: Assemble equipment to test flow meters (excitation coil and portable pulse generator)	CapEx	$759	$0	$0	$0	C - Engineering Buildup	C3
1.2.4.8.2.3.2	CS: Select and procure new power supplies for the network box, procure one RS-485 gateway	CapEx	$925	$0	$0	$0	C - Engineering Buildup	C2
1.2.4.8.2.3.3	CS: Redesign and rebuild PHS network box with new I/O, document as-built configuration	CapEx	$3,850	$0	$0	$0	C - Engineering Buildup	C3
1.2.4.8.2.4	CS PHS HW4: New estop slap switch and box for outdoor location	CapEx	$200	$0	$0	$0	D - Expert Opinion	C3

1.2.4.8.3

Basis of Estimate

1.2.4 CapEx

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

WBS	Activity	Subtype	12mo Subtotal PY5	12mo Subtotal PY6	12mo Subtotal PY8	12mo Subtotal PY7	Estimating Technique	Contingency
1.2.4.8.3.1.3	CS: Configure VFDs with accessories, connection pigtails, document	CapEx	$5,000	$0	$0	$0	D - Expert Opinion	C3
1.2.4.8.3.1.4	CS: Develop VFD mechanical and electrical installation strategies & document, procure materials	CapEx	$2,000	$0	$0	$0	D - Expert Opinion	C3
1.2.4.8.3.2.2	CS: Document changes to E-stop and Reel stop interfaces to motor drives, procure materials, implement	CapEx	$4,000	$0	$0	$0	D - Expert Opinion	C3
1.2.4.8.3.2.3	CS: Test refurbished E-stop panels with reel safety junction boxes, I/O boxes, network boxes, drives	CapEx	$250	$0	$0	$0	D - Expert Opinion	C3
1.2.4.8.3.2.6	CS: Design new E-stop controllers for TOS, build and test boxes	CapEx	$3,000	$0	$0	$0	D - Expert Opinion	C3
1.2.4.8.3.3.1	CS: Spec and procure new power supplies for TOS network boxes, procure DGH gateway, document changes	CapEx	$1,650	$0	$0	$0	C - Engineering Buildup	C2
1.2.4.8.3.3.2	CS: Document plans for TOS network box upgrades, specify and procure tools and materials	CapEx	$400	$0	$0	$0	D - Expert Opinion	C3
1.2.4.8.3.3.3	CS: Spec TOS nework switch location, spec cables to drives, I/O boxes, network box, DCC modem, PC, PLC, e-stop controller	CapEx	$1,000	$0	$0	$0	D - Expert Opinion	C3
1.2.4.8.3.3.4	CS: Design enclosures for TOS PLCs and attached I/O used for payout encoders, load cells; procure parts	CapEx	$2,000	$0	$0	$0	D - Expert Opinion	C3
1.2.4.8.3.3.5	CS: Construct enclosures for TOS PLCs and attached I/O , test	CapEx	$200	$0	$0	$0	D - Expert Opinion	C3
1.2.4.8.3.8	CS TOS HW9: Tower hoist reconnec	CapEx	$1,000	$0	$0	$0	D - Expert Opinion	C3

1.2.4.8.4-1.2.4.8.7

1.2.4 CapEx

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

WBS	Activity	Subtype	12mo Subtotal PY5	12mo Subtotal PY6	12mo Subtotal PY8	12mo Subtotal PY7	Estimating Technique	Contingency
1.2.4.8.4.1	CS HW Drillhead sofware/hardware production version	CapEx	$2,510	$0	$0	$0	C - Engineering Buildup	C2
1.2.4.8.5.1	CS: Design, construct and test master E-stop controller, produce documentation and user instructions	CapEx	$3,000	$0	$0	$0	D - Expert Opinion	C3
1.2.4.8.5.2	CS: Design and construct general-purpose I/O box for fuel sled, gather required component stock to install	CapEx	$3,850	$0	$0	$0	D - Expert Opinion	C3
1.2.4.8.5.3	Procure 20 kW three-phase heater fi	CapEx	$3,152	$0	$0	$0	C - Engineering Buildup	C2
1.2.4.8.5.4	CS: WT1 VT pump drives: procure, configure, rewire plan	CapEx	$5,083	$0	$0	$0	C - Engineering Buildup	C2
1.2.4.8.5.6	CS: WT1 VT pump drives: install plan and kit	CapEx	$1,500	$0	$0	$0	D - Expert Opinion	C3
1.2.4.8.6.1	CS: CS Gensets HW - identify, procure, assemble	CapEx	$0	$3,850	$0	$0	C - Engineering Buildup	C3
1.2.4.8.7.1.3	CS: Develop VFD mechanical and electrical installation strategies & document, procure materials	CapEx	$1,000	$0	$0	$0	D - Expert Opinion	C3
1.2.4.8.7.3.3	CS: Design and Construct PLC enclosure	CapEx	$7,050	$0	$0	$0	C - Engineering Buildup	C3
1.2.4.8.7.4.2	CS: Procure additional drives for charge pumps (4), AC and network pigtail materials	CapEx	$14,505	$0	$0	$0	C - Engineering Buildup	C2
1.2.4.8.7.4.3	CS: Connectorize four drives with power and network pigtails, test each in test bed	CapEx	$1,000	$0	$0	$0	D - Expert Opinion	C3
1.2.4.8.7.7.1	CS: Select and procure E-stop relays for pump VFD Enable signals	CapEx	$200	$0	$0	$0	D - Expert Opinion	C3

Total equipment cost is $226,306. 74% of the total equipment cost is based on engineering buildup from quotes or catalog pricing.

7.2. Materials & Supplies

No M&S included in this WBS

7.3. Travel

No travel included in this WBS

8. Labor

8.1. Labor Estimate

Labor includes design, specification, procurement, assembly/test, and shipping preparation. Labor is heavy in PY5 at 3.3 FTEs, then tapers off in PY6/7/8 (0.95/0.52/0.03 FTE respectively) - note that assumed FTE in PY6/7/8 is prorated for off-season work only, e.g. (8/12)(1800hr/yr) = 1200 hr/yr. Expertise is primarily electrical engineering and electrical technician.

The labor is broken out for each task in the tables below. All labor estimates are based on expert opinion.

8.2. Summary of Labor Resources

1.2.4.1-1.2.4.2

Basis of Estimate

1.2.4 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
1.2.4.1.10	Architecture: CS Drawings & Documentation (PY6)	EN-EE	0	32	0	0	D - Expert Opinion	C3
1.2.4.1.11	Architecture: CS Drawings & Documentation (PY7)	EN-EE	0	0	32	0	D - Expert Opinion	C3
1.2.4.1.12	Architecture: CS Drawings & Documentation (PY8)	EN-EE	0	0	0	32	D - Expert Opinion	C3
1.2.4.1.8	Architecture: Coordination with USAP IT (PY5) (station connectivity, internet, phone)	EN-EE	20	0	0	0	D - Expert Opinion	C3
1.2.4.1.9	Architecture: CS Drawings & Documentation (PY5)	EN-EE	32	0	0	0	D - Expert Opinion	C3
1.2.4.2.11.1	Network Controllers: CS HW Production Ignition Servers (3x: DCC, TOS1, TOS2)	EN-EE	10	0	0	0	D - Expert Opinion	C3
1.2.4.2.11.2	Network Controllers: CS HW Production Database Server (1x: DCC)	EN-EE	10	0	0	0	D - Expert Opinion	C3
1.2.4.2.11.3	Network Controllers: CS HW Production Peripherals (3x sets: DCC, TOS1, TOS2)	EN-EE	16	0	0	0	D - Expert Opinion	C3
1.2.4.2.11.4	Network Controllers: CS HW DCC Core Switch & Security Appliance	EN-EE	8	0	0	0	D - Expert Opinion	C3
1.2.4.2.11.5	Network Controllers: CS HW Production Main PLC - PLC (redundant), I/O, network, UPS, in a box (3x: DCC, TOS1, TOS2)	EN-EE	36	0	0	0	D - Expert Opinion	C3
1.2.4.2.13	Network Controllers: CS HW PY6 Resupply	EN-EE	0	80	0	0	D - Expert Opinion	C4
1.2.4.2.14	Network Controllers: CS HW PY7 Resupply	EN-EE	0	0	80	0	D - Expert Opinion	C4
1.2.4.2.2.5	Controls Hardware: Procure System Sensors (PY5)	EN-EE	32	0	0	0	D - Expert Opinion	C3

1.2.4.3.4-1.2.4.3.5

1.2.4 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
1.2.4.3.4	Controls Software: PLC & Software Development (w/sub-tasks)	EN-EE	60	60	0	0	D - Expert Opinion	C3
1.2.4.3.5	Controls Software: SCADA Monitoring Software Procurement - Server	EN-EE	20	0	0	0	D - Expert Opinion	C2

1.2.4.3.9

Basis of Estimate

1.2.4 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
1.2.4.3.9.1.1	Operator Screen MHP: Local-Panel MDS-specific HMI (PY5)	EN-EE	20	0	0	0	D - Expert Opinion	C3
1.2.4.3.9.1.2	Operator Screen MHP: Local-Panel MDS-specific HMI (PY6)	EN-EE	0	20	0	0	D - Expert Opinion	C3
1.2.4.3.9.1.3	Operator Screen MHP: DCC-based SCADA UI (PY5)	EN-EE	80	0	0	0	D - Expert Opinion	C3
1.2.4.3.9.1.4	Operator Screen MHP: DCC-based SCADA UI (PY6)	EN-EE	0	80	0	0	D - Expert Opinion	C3
1.2.4.3.9.2.1	Operator Screen Fuel System: Local-Panel MDS-specific HMI (PY5)	EN-EE	8	0	0	0	D - Expert Opinion	C3
1.2.4.3.9.2.2	Operator Screen Fuel System: Local-Panel MDS-specific HMI (PY6)	EN-EE	0	8	0	0	D - Expert Opinion	C3
1.2.4.3.9.2.3	Operator Screen Fuel System: DCC-based SCADA (PY5)	EN-EE	8	0	0	0	D - Expert Opinion	C3
1.2.4.3.9.2.4	Operator Screen Fuel System: DCC-based SCADA (PY6)	EN-EE	0	8	0	0	D - Expert Opinion	C3
1.2.4.3.9.3.1	Operator Screen Gensets: Local-Panel MDS-specific HMI (PY5)	EN-EE	8	0	0	0	D - Expert Opinion	C3
1.2.4.3.9.3.2	Operator Screen Gensets: Local-Panel MDS-specific HMI (PY6)	EN-EE	0	8	0	0	D - Expert Opinion	C3
1.2.4.3.9.3.3	Operator Screen Gensets: DCC-based SCADA (PY5)	EN-EE	12	0	0	0	D - Expert Opinion	C3
1.2.4.3.9.3.4	Operator Screen Gensets: DCC-based SCADA (PY6)	EN-EE	0	12	0	0	D - Expert Opinion	C3
1.2.4.3.9.4.3	Operator Screen Rodwell: DCC-based SCADA (PY5)	EN-EE	40	0	0	0	D - Expert Opinion	C3
1.2.4.3.9.4.4	Operator Screen Rodwell: DCC-based SCADA (PY6)	EN-EE	0	40	0	0	D - Expert Opinion	C3
1.2.4.3.9.5.1	Operator Screen HPP: Local-Panel MDS-specific HMI (PY5)	EN-EE	18	0	0	0	D - Expert Opinion	C3
1.2.4.3.9.5.2	Operator Screen HPP: Local-Panel MDS-specific HMI (PY6)	EN-EE	0	18	0	0	D - Expert Opinion	C3
1.2.4.3.9.5.3	Operator Screen HPP: DCC-based SCADA (PY5)	EN-EE	40	0	0	0	D - Expert Opinion	C3
1.2.4.3.9.5.4	Operator Screen HPP: DCC-based SCADA (PY6)	EN-EE	0	40	0	0	D - Expert Opinion	C3
1.2.4.3.9.6.1	Operator Screen PHS: Local-Panel MDS-specific HMI (PY5)	EN-EE	16	0	0	0	D - Expert Opinion	C3
1.2.4.3.9.6.2	Operator Screen PHS: Local-Panel MDS-specific HMI (PY6)	EN-EE	0	16	0	0	D - Expert Opinion	C3
1.2.4.3.9.6.3	Operator Screen PHS: DCC-based SCADA (PY5)	EN-EE	40	0	0	0	D - Expert Opinion	C3
1.2.4.3.9.6.4	Operator Screen PHS: DCC-based SCADA (PY6)	EN-EE	0	40	0	0	D - Expert Opinion	C3

1.2.4.3.10

Basis of Estimate

1.2.4 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
1.2.4.3.10.1	TOS Operator Screen: SCADA - DrillHead (PY5)	EN-EE	8	0	0	0	D - Expert Opinion	C3
1.2.4.3.10.10	TOS Operator Screen: SCADA - Drilling_Hose Level Wind (PY6)	EN-EE	0	12	0	0	D - Expert Opinion	C3
1.2.4.3.10.11	TOS Operator Screen: SCADA - Return Water Pump (PY5)	EN-EE	8	0	0	0	D - Expert Opinion	C3
1.2.4.3.10.12	TOS Operator Screen: SCADA - Return Water Pump (PY6)	EN-EE	0	8	0	0	D - Expert Opinion	C3
1.2.4.3.10.13	TOS Operator Screen: SCADA - Deployment - Cable (PY5)	EN-EE	8	0	0	0	D - Expert Opinion	C3
1.2.4.3.10.14	TOS Operator Screen: SCADA - Deployment - Cable (PY6)	EN-EE	0	8	0	0	D - Expert Opinion	C3
1.2.4.3.10.15	TOS Operator Screen: SCADA - Deployment Settings (PY5)	EN-EE	10	0	0	0	D - Expert Opinion	C3
1.2.4.3.10.16	TOS Operator Screen: SCADA - Deployment Settings (PY6)	EN-EE	0	10	0	0	D - Expert Opinion	C3
1.2.4.3.10.2	TOS Operator Screen: SCADA - DrillHead (PY6)	EN-EE	0	8	0	0	D - Expert Opinion	C3
1.2.4.3.10.3	TOS Operator Screen: SCADA - Drill_Settings (PY5)	EN-EE	8	0	0	0	D - Expert Opinion	C3
1.2.4.3.10.4	TOS Operator Screen: SCADA - Drill_Settings (PY6)	EN-EE	0	8	0	0	D - Expert Opinion	C3
1.2.4.3.10.5	TOS Operator Screen: SCADA - SCADA - Drilling_Drill Control (PY5)	EN-EE	12	0	0	0	D - Expert Opinion	C3
1.2.4.3.10.6	TOS Operator Screen: SCADA - Drilling_Drill Control (PY6)	EN-EE	0	12	0	0	D - Expert Opinion	C3
1.2.4.3.10.7	TOS Operator Screen: SCADA - SCADA - Drilling_Cable Level Wind (PY5)	EN-EE	12	0	0	0	D - Expert Opinion	C3
1.2.4.3.10.8	TOS Operator Screen: SCADA - Drilling_Cable Level Wind (PY6)	EN-EE	0	12	0	0	D - Expert Opinion	C3
1.2.4.3.10.9	TOS Operator Screen: SCADA - Drilling_Hose Level Wind (PY5)	EN-EE	12	0	0	0	D - Expert Opinion	C3

1.2.4.3.11-1.2.4.3.16

1.2.4 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
1.2.4.3.11.1	TOS Operator Screen: Build DCC dB schema (PY5)	EN-EE	80	0	0	0	D - Expert Opinion	C3
1.2.4.3.11.2	TOS Operator Screen: Build DCC dB schema (PY6)	EN-EE	0	80	0	0	D - Expert Opinion	C3
1.2.4.3.11.3	TOS Operator Screen: Build Drill dB schema (PY5)	EN-EE	40	0	0	0	D - Expert Opinion	C3
1.2.4.3.11.4	TOS Operator Screen: Build Drill dB schema (PY6)	EN-EE	0	40	0	0	D - Expert Opinion	C3
1.2.4.3.11.5	TOS Operator Screen: Build Deploy dB schema (PY5)	EN-EE	30	0	0	0	D - Expert Opinion	C3
1.2.4.3.11.6	TOS Operator Screen: Build Deploy dB schema (PY6)	EN-EE	0	30	0	0	D - Expert Opinion	C3
1.2.4.3.12	Controls Software: CS SW Standup Production Computing Hardware, Configure, Verify before Shipment (3x systems) (PY6)	EN-EE	0	140	0	0	D - Expert Opinion	C4
1.2.4.3.13	Controls Software: CS SW MDS-specific HMI Refinement (PY7)	EN-EE	0	0	80	0	D - Expert Opinion	C4
1.2.4.3.14	Controls Software: CS SW DCC-based SCADA Refinement (PY7)	EN-EE	0	0	120	0	D - Expert Opinion	C4
1.2.4.3.15	Controls Software: CS SW TOS-based SCADA Refinement (PY7)	EN-EE	0	0	120	0	D - Expert Opinion	C4
1.2.4.3.16	Controls Software: CS SW dB Refinement (PY7)	EN-EE	0	0	120	0	D - Expert Opinion	C4

1.2.4.4-1.2.4.7

1.2.4 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
1.2.4.4.4	Motor Drives: Programming and Testing at PSL (PSL_Engineer)	EN-EE	135	0	0	0	D - Expert Opinion	C3
1.2.4.5.6	E-stop: Estop PY6 Resupply	EN-EE	0	24	0	0	D - Expert Opinion	C4
1.2.4.5.6	E-stop: Estop PY6 Resupply	TE	0	24	0	0	D - Expert Opinion	C4
1.2.4.5.7	E-stop: Estop PY7 Resupply	EN-EE	0	0	24	0	D - Expert Opinion	C4
1.2.4.5.7	E-stop: Estop PY7 Resupply	TE	0	0	24	0	D - Expert Opinion	C4
1.2.4.6.3	DCC: Update Workspace (desk, chairs), Procure Printer & Accessories	EN-EE	32	0	0	0	C - Engineering Bu	C3
1.2.4.7.3	Outdoor Cables: Fabricate and Test SES & SES to TOS Cables - Signal	EN-EE	40	0	0	0	D - Expert Opinion	C3
1.2.4.7.4	Outdoor Cables: CS Cabling Resupply (PY6)	EN-EE	0	24	0	0	D - Expert Opinion	C4
1.2.4.7.5	Outdoor Cables: CS Cabling Resupply (PY7)	EN-EE	0	0	24	0	D - Expert Opinion	C4

1.2.4.8.1

Basis of Estimate

1.2.4 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
1.2.4.8.1.2.1	CS: Procure sample temperature display and digital thermostat, install in test bed heater, test	EN	8	0	0	0	D - Expert Opinion	C3
1.2.4.8.1.2.2	CS: Select and procure temperature display units for heater controls, conversion hardware	EN	8	0	0	0	D - Expert Opinion	C3
1.2.4.8.1.2.3	CS: Replace temperature display units, remove RTD DGHs, transfer net connections, test	EN	24	0	0	0	D - Expert Opinion	C3
1.2.4.8.1.2.3	CS: Replace temperature display units, remove RTD DGHs, transfer net connections, test	TE	100	0	0	0	D - Expert Opinion	C3
1.2.4.8.1.2.4	CS: Select and procure digital thermostats for heater controls, conversion hardware	EN	8	0	0	0	D - Expert Opinion	C3
1.2.4.8.1.2.5	CS: Write thermostat field replacement procedure	EN	24	0	0	0	D - Expert Opinion	C3
1.2.4.8.1.3.1	CS: Write rewiring and test instructions for MHP E-stop boxes (fixes switch contact selections made in Gen 1)	EN	24	0	0	0	D - Expert Opinion	C3
1.2.4.8.1.3.2	CS: Write test procedures for dry heater tests	EN	32	0	0	0	D - Expert Opinion	C3
1.2.4.8.1.3.3	CS: Assemble equipment to test flow meters (excitation coil and portable pulse generator)	EN	24	0	0	0	D - Expert Opinion	C3
1.2.4.8.1.3.4	CS: Write flow meter test procedure and assemble test kit	EN	24	0	0	0	D - Expert Opinion	C3
1.2.4.8.1.5.1	CS: Develop heater-based sensor readout; (heater temp/flow manifold pressures	EN	120	0	0	0	D - Expert Opinion	C3
1.2.4.8.1.5.2	CS: Develop environmental sensor readout; (bldg temps, smoke, e-stop)	EN	36	0	0	0	D - Expert Opinion	C3
1.2.4.8.1.5.3	CS: Develop heater control; (ON/OFF, Thermostat setpoint)	EN	40	0	0	0	D - Expert Opinion	C3
1.2.4.8.1.5.7	CS: Implement interlocks	EN	20	0	0	0	D - Expert Opinion	C3
1.2.4.8.1.5.8	CS: Document Subsystem	EN	20	0	0	0	D - Expert Opinion	C1

1.2.4.8.2

Basis of Estimate

1.2.4 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
1.2.4.8.2.1.3	CS: Develop VFD installation strategy & document, procure materials	TE	16	0	0	0	D - Expert Opinion	C3
1.2.4.8.2.3.2	CS: Select and procure new power supplies for the network box, procure one RS-485 gateway	EN	16	0	0	0	D - Expert Opinion	C3
1.2.4.8.2.3.3	CS: Redesign and rebuild PHS network box with new I/O, document as-built configuration	EN	144	0	0	0	D - Expert Opinion	C3
1.2.4.8.2.3.3	CS: Redesign and rebuild PHS network box with new I/O, document as-built configuration	TE	40	0	0	0	D - Expert Opinion	C3
1.2.4.8.2.3.4	CS: Indicate where approximately 20 sensor and network cables terminate in PHS and document config. plans	EN	108	0	0	0	D - Expert Opinion	C3
1.2.4.8.2.3.5	CS: Configure heater-mounted DGH modules, develop and document DGH installation and test plans	EN	24	0	0	0	D - Expert Opinion	C3
1.2.4.8.2.3.5	CS: Configure heater-mounted DGH modules, develop and document DGH installation and test plans	TE	16	0	0	0	D - Expert Opinion	C3
1.2.4.8.2.4	CS PHS HW4: New estop slap switch and box for outdoor location	EN	8	0	0	0	D - Expert Opinion	C3
1.2.4.8.2.5	CS PHS HW5: Develop heater test procedures, configure test tools, document test plans	EN	36	0	0	0	D - Expert Opinion	C3
1.2.4.8.2.7.1	CS: Develop and document test plans for all PHS system components	EN	36	0	0	0	D - Expert Opinion	C3
1.2.4.8.2.7.2	CS: Develop and document test plans for all PHS system components	EN	36	0	0	0	D - Expert Opinion	C3
1.2.4.8.2.8.1	CS: Develop heater-based sensor readout; (heater temp/flow manifold pressures)	EN	24	0	0	0	D - Expert Opinion	C3
1.2.4.8.2.8.10	CS: Implement interlocks	EN	20	0	0	0	D - Expert Opinion	C3
1.2.4.8.2.8.11	CS: Implement interlocks	EN	40	0	0	0	D - Expert Opinion	C3
1.2.4.8.2.8.2	CS: Develop environmental sensor readout; (bldg temps, smoke, e-stop)	EN	16	0	0	0	D - Expert Opinion	C3
1.2.4.8.2.8.3	CS: Develop water tank sensors readout	EN	24	0	0	0	D - Expert Opinion	C3
1.2.4.8.2.8.4	CS: Develop heater control; (ON/OFF, Thermostat setpoint)	EN	16	0	0	0	D - Expert Opinion	C3
1.2.4.8.2.8.5	CS: Develop AB drive/pump control; (variable speed velocity drives)	EN	40	0	0	0	D - Expert Opinion	C3

1.2.4.8.3.1

1.2.4 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
1.2.4.8.3.1.3	CS: Configure VFDs with accessories, connection pigtails, document	EN	24	0	0	0	D - Expert Opinion	C3
1.2.4.8.3.1.3	CS: Configure VFDs with accessories, connection pigtails, document	TE	40	0	0	0	D - Expert Opinion	C3
1.2.4.8.3.1.4	CS: Develop VFD mechanical and electrical installation strategies & document, procure materials	EN	40	0	0	0	D - Expert Opinion	C3
1.2.4.8.3.1.4	CS: Develop VFD mechanical and electrical installation strategies & document, procure materials	TE	80	0	0	0	D - Expert Opinion	C3
1.2.4.8.3.1.5	CS: SW configuration and autotuning, make plan - MDCR/LW, DSHR/LW, RWHR, RWCR, Tower Hoist	EN	80	0	0	0	D - Expert Opinion	C3

1.2.4.8.3.2-1.2.4.8.3.9

Basis of Estimate

1.2.4 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
1.2.4.8.3.2.2	CS: Document changes to E-stop and Reel stop interfaces to motor drives, procure materials, implement	EN	120	0	0	0	D - Expert Opinion	C3
1.2.4.8.3.2.2	CS: Document changes to E-stop and Reel stop interfaces to motor drives, procure materials, implement	TE	40	0	0	0	D - Expert Opinion	C3
1.2.4.8.3.2.3	CS: Test refurbished E-stop panels with reel safety junction boxes, I/O boxes, network boxes, drives	EN	200	0	0	0	D - Expert Opinion	C3
1.2.4.8.3.2.3	CS: Test refurbished E-stop panels with reel safety junction boxes, I/O boxes, network boxes, drives	TE	80	0	0	0	D - Expert Opinion	C3
1.2.4.8.3.2.6	CS: Design new E-stop controllers for TOS, build and test boxes	EN	120	0	0	0	D - Expert Opinion	C3
1.2.4.8.3.2.6	CS: Design new E-stop controllers for TOS, build and test boxes	TE	80	0	0	0	D - Expert Opinion	C3
1.2.4.8.3.3.1	CS: Spec and procure new power supplies for TOS network boxes, procure DGH gateway, document changes	EN	24	0	0	0	D - Expert Opinion	C3
1.2.4.8.3.3.2	CS: Document plans for TOS network box upgrades, specify and procure tools and materials	EN	24	0	0	0	D - Expert Opinion	C3
1.2.4.8.3.3.2	CS: Document plans for TOS network box upgrades, specify and procure tools and materials	TE	16	0	0	0	D - Expert Opinion	C3
1.2.4.8.3.3.3	CS: Spec TOS nework switch location, spec cables to drives, I/O boxes, network box, DCC modem, PC, PLC, e-stop controller	EN	60	0	0	0	D - Expert Opinion	C3
1.2.4.8.3.3.3	CS: Spec TOS nework switch location, spec cables to drives, I/O boxes, network box, DCC modem, PC, PLC, e-stop controller	TE	32	0	0	0	D - Expert Opinion	C3
1.2.4.8.3.3.4	CS: Design enclosures for TOS PLCs and attached I/O used for payout encoders, load cells; procure parts	EN	80	0	0	0	D - Expert Opinion	C3
1.2.4.8.3.3.5	CS: Construct enclosures for TOS PLCs and attached I/O , test	EN	60	0	0	0	D - Expert Opinion	C3
1.2.4.8.3.3.5	CS: Construct enclosures for TOS PLCs and attached I/O , test	TE	72	0	0	0	D - Expert Opinion	C3
1.2.4.8.3.5.1	CS: Develop and document on-ice test plans for E-stop, Reel-Stop, and Fault Detection hardware	EN	40	0	0	0	D - Expert Opinion	C3
1.2.4.8.3.5.2	CS: Develop and document on-ice test plans for integrated hardware	EN	120	0	0	0	D - Expert Opinion	C3
1.2.4.8.3.6.2	CS: Test load cells and payout encoders with PLC, verify functionality required for payout control, load sharing	EN	200	0	0	0	D - Expert Opinion	C3
1.2.4.8.3.8	CS TOS HW9: Tower hoist reconnect materials TOS:	EN	40	0	0	0	D - Expert Opinion	C3
1.2.4.8.3.9	CS TOS HW10: Review deployment plans and HW, ir	EN	120	0	0	0	D - Expert Opinion	C3

1.2.4.8.3.10

1.2.4 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
1.2.4.8.3.10.1	CS: Develop general control/monitoring software	EN	120	0	0	0	D - Expert Opinion	C3
1.2.4.8.3.10.2	CS: Develop reel control software(MCR/LW, DSHR/LW, RWHR, RWCR, Tower Winch)	EN	80	0	0	0	D - Expert Opinion	C3
1.2.4.8.3.10.3	CS: Develop tension-sharing algorithm software (MCR/LW, DSHR/LW)	EN	120	0	0	0	D - Expert Opinion	C3
1.2.4.8.3.10.4	CS: Develop drillhead data monitoring interface)	EN	24	0	0	0	D - Expert Opinion	C3
1.2.4.8.3.10.8	CS: Implement interlocks	EN	40	0	0	0	D - Expert Opinion	C3
1.2.4.8.3.10.9	CS: Document Subsystem	EN	40	0	0	0	D - Expert Opinion	C3

1.2.4.8.4-1.2.4.8.6

1.2.4 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
1.2.4.8.4.1	CS HW Drillhead sofware/hardware production version	EN	60	0	0	0	D - Expert Opinion	C3
1.2.4.8.4.2.1	CS: Port C-Lang ingest process to rPI platform & test	EN	32	0	0	0	D - Expert Opinion	C3
1.2.4.8.4.2.2	CS: Integrate rPI platform into PLC infrastructure	EN	40	0	0	0	D - Expert Opinion	C3
1.2.4.8.4.2.3	CS: Document Subsystem	EN	40	0	0	0	D - Expert Opinion	C3
1.2.4.8.5.1	CS: Design, construct and test master E-stop controller, produce documentation and user instructions	EN	160	0	0	0	D - Expert Opinion	C3
1.2.4.8.5.1	CS: Design, construct and test master E-stop controller, produce documentation and user instructions	TE	40	0	0	0	D - Expert Opinion	C3
1.2.4.8.5.2	CS: Design and construct general-purpose I/O box for fuel sled, gather required component stock to install	EN	80	0	0	0	D - Expert Opinion	C3
1.2.4.8.5.3	CS: Procure 20 kW three-phase heater for DCC and 208V breakers	TE	16	0	0	0	D - Expert Opinion	C3
1.2.4.8.5.4	CS: WT1 VT pump drives: procure, configure, rewire plan	EN	16	0	0	0	D - Expert Opinion	C3
1.2.4.8.5.5	CS: WT1 VT pump drives: final configure	EN	60	0	0	0	D - Expert Opinion	C3
1.2.4.8.5.6	CS: WT1 VT pump drives: install plan and kit	EN	60	0	0	0	D - Expert Opinion	C3
1.2.4.8.5.7.1	CS: Develop fuel system sensor readout ; (multi-level tank status, control relay status)	EN	36	0	0	0	D - Expert Opinion	C3
1.2.4.8.5.7.2	CS: Configure/document Point I/O Block	EN	16	0	0	0	D - Expert Opinion	C3
1.2.4.8.5.7.3	CS: Document Subsystem	EN	36	0	0	0	D - Expert Opinion	C3
1.2.4.8.5.7.4	CS: Implement interlocks	EN	20	0	0	0	D - Expert Opinion	C3
1.2.4.8.6.1	CS: CS Gensets HW - identify, procure, assemble	EN	0	40	0	0	D - Expert Opinion	C3
1.2.4.8.6.1	CS: CS Gensets HW - identify, procure, assemble	TE	0	40	0	0	D - Expert Opinion	C3
1.2.4.8.6.2.1	CS: Develop sensor readout; (bldg temps, fuel temps, supply/return water temps)	EN	0	40	0	0	D - Expert Opinion	C3
1.2.4.8.6.2.2	CS: Develop sensor readout; (engine jacket temps, exhaust temps, drip pan status)	EN	0	40	0	0	D - Expert Opinion	C3
1.2.4.8.6.2.3	CS: Configure/document network switch	EN	0	8	0	0	D - Expert Opinion	C3
1.2.4.8.6.2.4	CS: Configure/document RTA gateway to M-DGH interface	EN	0	10	0	0	D - Expert Opinion	C3
1.2.4.8.6.2.5	CS: Configure/document M-DGHs	EN	0	20	0	0	D - Expert Opinion	C3
1.2.4.8.6.2.6	CS: Document Subsystem	EN	0	40	0	0	D - Expert Opinion	C3

1.2.4.8.7

1.2.4 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
1.2.4.8.7.1.3	CS: Develop VFD mechanical and electrical installation strategies & document, procure materials	EN	72	0	0	0	D - Expert Opinion	C3
1.2.4.8.7.10.1	CS: Develop water path sensor readout; (pressure, temp, flow)	EN	40	0	0	0	D - Expert Opinion	C3
1.2.4.8.7.10.10	CS: Document Subsystem	EN	40	0	0	0	D - Expert Opinion	C3
1.2.4.8.7.10.2	CS: Develop environmental sensor readout; (bldg temps, smoke, e-stop)	EN	40	0	0	0	D - Expert Opinion	C3
1.2.4.8.7.10.9	CS: Implement interlocks	EN	20	0	0	0	D - Expert Opinion	C3
1.2.4.8.7.2.1	CS: Define requirements and procedures for reading signals applied to HPP motor drives	EN	16	0	0	0	D - Expert Opinion	C3
1.2.4.8.7.2.2	CS: Define method of verifying sensor readout accuracy (reading vs stimulus)	EN	16	0	0	0	D - Expert Opinion	C3
1.2.4.8.7.2.3	CS: Develop and document test procedures for on-ice personnel	EN	16	0	0	0	D - Expert Opinion	C3
1.2.4.8.7.3.1	CS: Define core HPP PLC functions and requirements, define needed I/O connections	EN	40	0	0	0	D - Expert Opinion	C3
1.2.4.8.7.3.2	CS: Select PLC, Enclosure, Power supplies, I/O expansion cards, power distribution, connectors and cables	EN	40	0	0	0	D - Expert Opinion	C3
1.2.4.8.7.3.3	CS: Design and Construct PLC enclosure	EN	32	0	0	0	D - Expert Opinion	C3
1.2.4.8.7.3.3	CS: Design and Construct PLC enclosure	TE	40	0	0	0	D - Expert Opinion	C3
1.2.4.8.7.3.4	CS: Test HPP PLC enclosure with HPP Network box	EN	24	0	0	0	D - Expert Opinion	C3
1.2.4.8.7.4.2	CS: Procure additional drives for charge pumps (4), AC and network pigtail materials	EN	16	0	0	0	D - Expert Opinion	C3
1.2.4.8.7.4.3	CS: Connectorize four drives with power and network pigtails, test each in test bed	EN	24	0	0	0	D - Expert Opinion	C3
1.2.4.8.7.4.3	CS: Connectorize four drives with power and network pigtails, test each in test bed	TE	40	0	0	0	D - Expert Opinion	C3
1.2.4.8.7.7.1	CS: Select and procure E-stop relays for pump VFD Enable signals	EN	8	0	0	0	D - Expert Opinion	C3
1.2.4.8.7.7.2	CS: Develop and document rewiring instructions for HPP E-stop box	EN	16	0	0	0	D - Expert Opinion	C3
1.2.4.8.7.9.1	CS: Develop and document test plans for all HPP system components	EN	36	0	0	0	D - Expert Opinion	C3
1.2.4.8.7.9.2	CS: Review Gen-1 docs, identify where sensor connections terminated, plan for field integration and	EN	32	0	0	0	D - Expert Opinion	C3

1.2.4.8.8

1.2.4 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
	test							
1.2.4.8.8.2.1	CS: Develop ARA-drill sensor readout; (heater flows, head press, tank level)	EN	80	0	0	0	D - Expert Opinion	C3
1.2.4.8.8.2.2	CS: Develop AB drive/pump control; (variable speed velocity drives)	EN	40	0	0	0	D - Expert Opinion	C3
1.2.4.8.8.2.3	CS: Configure/document Point I/O Block	EN	16	0	0	0	D - Expert Opinion	C3
1.2.4.8.8.2.4	CS: Configure/document network switch	EN	8	0	0	0	D - Expert Opinion	C3
1.2.4.8.8.2.5	CS: Configure/document RTA gateway to M-DGH interface	EN	16	0	0	0	D - Expert Opinion	C3
1.2.4.8.8.2.6	CS: Configure/document M-DGHs	EN	20	0	0	0	D - Expert Opinion	C3
1.2.4.8.8.2.7	CS: Implement interlocks	EN	20	0	0	0	D - Expert Opinion	C3
1.2.4.8.8.2.8	CS: Document Subsystem	EN	40	0	0	0	D - Expert Opinion	C3

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
2022-03-04	Barb Birrittella	Initialized document
2022-04-09	Terry Benson	Updated tables