Basis of Estimate

1. WBS ID	1.3.3	$150,870.05 total burdened cost for this WBS

2. WBS Name	PDOM

3. Estimated by	Perry Sandstrom (WIPAC)

4. WBS Dictionary Description

This element is responsible for upgrading 20 spare IceCube Gen1 DOMs with PDOM readout electronics, HV systems, calibration devices, and penetrators. This includes software and firmware to integrate it into the IceCube Upgrade data acquisition system, acceptance tests, and procedures and tools for safe transport and deployment. Deliverables are 20 deployment-ready refurbished IceCube DOMs delivered to Port Hueneme that meet the high-level design requirements of the IceCube Upgrade.

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).
- Invoice for PDOM Mainboard prototype production run (3)
- Purchase order for penetrator cable assemblies (4)

6. Scope

The scope of this BOE covers the production of printed circuit assemblies, the procurement of penetrator cable assemblies, and the labor to refurbish (20) IceCube DOMs to Upgrade PDOMs as well as the final acceptance testing and shipping of the PDOMs.

7. Materials, Supplies, Equipment, Travel

7.1. Procurement of Materials, Supplies, Equipment

- (27) PDOM Mainboard printed circuit assemblies to be produced by a contract manufacturer: $1,585/board. The same cost per board as for the prototype production run (Ref. (3)) is assumed. We expect no significant cost reduction due to the low quantity.
- PDOM Calibration Board printed circuit assemblies to be produced by a contract manufacturer: $650/board estimated by the lead engineer based on current design status
- PDOM High-Voltage Supply printed circuit assemblies to be produced by a contract manufacturer: $350/board estimated by the lead engineer based on current design status
- (35) Penetrator Cable Assemblies (PCAs) to be procured from MSU who coordinated the development and production: $610/PCA
  The PCAs have already been procured by MSU and the purchase order (Ref. (4)) is the basis for the cost estimate.
  The quantity (35) includes (10) PCAs for prototype PDOMs that have been built in PY3 and PY4.
- Materials and lab supplies for IceCube DOM refurbishment: $300/DOM
- Materials and lab supplies to run PDOM final acceptance testing in one of the existing dark freezer labs: $5,000
- Materials to pack the PDOMs for shipping, including replacement of shipping boxes, pallets, and tie-down equipment: $1,000
- Shipping of (10) design verification PDOMs to the Northern Test System (NTS) at MSU for system integration testing: $1,000
- Shipping of (3) PDOMs, incl. spares, for String 87+88 to Pt. Hueneme: $500
- Shipping of (13) PDOMs, incl. spares, for Strings 89-93 to Pt. Hueneme: $1,000

7.2. Summary of Materials, Supplies, and Equipment Resources

WBS	M&S/Equipment Activity	Type of Equipment	FY23	FY24	FY25	FY26	Institution	GAO Estimation Technique	Base Year of Estimate	Unit Cost ($)	Qty	Direct Cost	Contingency Code
1.3.3.1	(27) Rev3 PDOM Mainboards		$42,795	-	-		UW	E	FY22	$1,585	27	$42,795	C2
1.3.3.1	PDOM Calibration Boards		$17,550	-	-		UW	D	FY22	$650	27	$17,550	C3
1.3.3.2	PDOM HV subsystems		$9,450	-	-		UW	D	FY22	$350	27	$9,450	C3
1.3.3.4	(35) Penetrator Cable Assemblies		$21,350	-	-		UW	E	FY22	$610	35	$21,350	C1
1.3.3.4	M&S for DOM refurbishment		$6,000	-	-		UW	D	FY22	$300	20	$6,000	C3
1.3.3.4	M&S for final acceptance testing		$5,000	-	-		UW	D	FY22	$5,000	1	$5,000	C3

1.3.3.4	Packing material for shipping to South Pole		$1,000	-	-		UW	D	FY22	$1,000	1	$1,000	C3
1.3.3.4	Shipping of (3) PDOMs		$500	-	-		UW	D	FY22	$500	1	$500	C3
1.3.3.4	Shipping of (13) PDOMs		-	$1,000	-		UW	D	FY22	$1,000	1	$1,000	C3

7.3. Travel

- (1) domestic trip to visit the contract manufacturer for the PDOM Mainboard to coordinate the production and for quality control

WBS	Travel Activity	FY23	FY24	FY25	FY26	Institution	GAO Estimation Technique	Base Year of Estimate	Contingency Code
1.3.3.1	Visit to mainboard manufacturer	$1,800	-	-		UW	E	FY22	C1

8. Labor

8.1. Labor Estimate

- Labor of technicians at PSL to refurbish an IceCube DOM to a PDOM based on experience from integration of IceCube DOMs: 12h/DOM
- Labor of a scientist to develop, oversee, and analyze the results of the final acceptance testing based on experience from testing of IceCube DOMs: 130h
- Labor of technicians at PSL to pack the PDOMs for shipping to South Pole based on experience form integration of IceCube DOMs: 40h
- The labor of the PDOM lead engineer, P. Sandstrom, is covered in WBS 1.1

8.2. Summary of Labor Resources

WBS	Labor Activity	FY23	FY24	FY25	FY26	Institution	GAO Estimation Technique	Resource Type	Contingency Code
1.3.3.4	DOM refurbishment	240				PSL	A	TE	C3
1.3.3.4	Final Acceptance Testing	130				UW	A	SC	C3
1.3.3.4	Packing of DOMs	40				PSL	A	TE	C3

9. References

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

[Ref-2] 2. —. *Cost Estimating Plan.*

[Ref-3] 3. **MicroFab.** *Invoice for PDOM Mainboard prototype production run.* BOE-1-3-3_invoice_MB.pdf.

[Ref-4] 4. **Hydro Group Systems Inc.** *Purchase order for penetrator cable assemblies.* BOE-1-3-3_PO_PCA.pdf.

Revision History

Date	Revised by	Summary of changes
2022-01-27	Timo Karg	First version created
2022-02-25	Timo Karg	v1 for review
2022-03-07	Timo Karg	Removed FY22
2022-03-23	V. O'Dell	Did some cleanup, used fully burdened cost