IceCube Upgrade: Cost and Schedule
IceCube Upgrade NSF Rebaselining Review
April 26-28, 2022

Vivian O'Dell
University of Wisconsin

From the November Logistics Review…

					Last update 4/07/2022
ID	Recommendation	Responsible	Status	Estimated Date for closing	Response
LR1	Project team should perform their own schedule analysis using the 10 Best Practices for a high-quality and reliable schedule discussed in the GAO Schedule Assessment Guide	Vivian O'Dell / Jim Lowe	closed	03/01/22	Schedule cleanup performed to implement GAO best practice.
LR2	Produce graphic that shows all planning tools being used and how they feed and/or link with each other. Additionally, identify who is the single point of contact and/or manager for	Vivian O'Dell / Jim Lowe	closed	04/07/22	Produced document that has all of this information
LR7	Planning should identity the schedule float that exists between the earliest and latest dates when deliverables must be ready to enter the USAP logistics system. Add a float column with conditional formatting (red, yellow, green; based on number of days) in the cargo spreadsheet.	Vivian O'Dell /Ian McEwen/Delia Tosi	closed	04/01/22	Float calculations are now included in the Cargo Master as Shipment Float & South Pole Float. Total time between Shipment and need by date at South Pole is calculated additionally.
LR13	The risk register should include both technical risks and programmatic risks. An analysis of the risk register should include looking for pairs of risks that are correlated (i.e., if Risk A happens, then the probability of Risk B increases).	Vivian O'Dell/Farshid Feyzi/Mike Duvernois/Mike Zernick	closed	03/07/21	Risk Register includes both technical and programmatic risks. Risk workshop conducted with all L2s in January. Correlated risks have been identified and analyzed
NSFLR3	Develop the software toolset to meet the requirements of an integrated master schedule including linkages and dependencies	Jim Lowe	closed	03/10/22	Have made a new bottom up estimate of cost and schedule, including dependencies and linkages.
NSFLR4	Provide better visualization such as float associated with tasks and cargo	Jim Lowe, Ian McEwen, Delia Tosi	In progress	03/10/22	Cargo Master as Shipment Float & South Pole Float. Total time between Shipment and need by date at South Pole is

6 / 17 (35%) of the recommendations referred to cost / schedule / risk methodologies

I will talk about cost & schedule, MikeD will talk about risk

Basically…

We need to explain our tools better

We need to use our tools better

We need to standardize tools and best practices

Explaining tools: documentation

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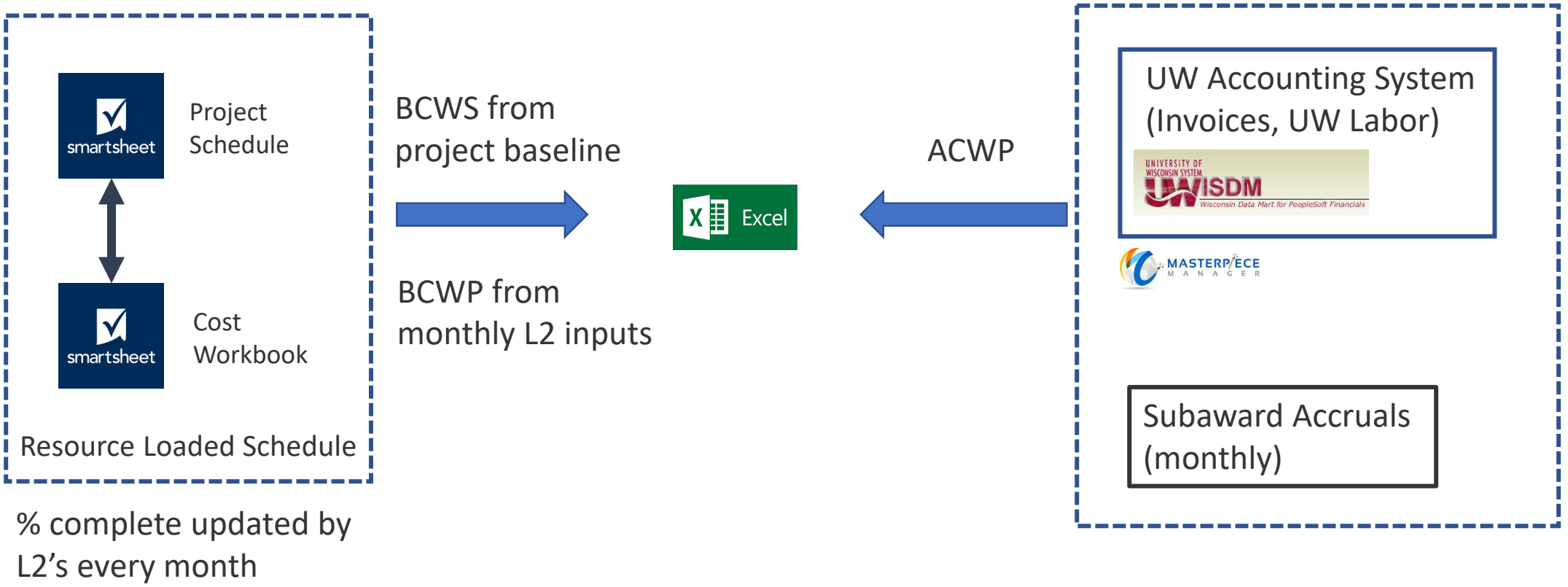
Overview of tools/EVMS

Charge Question S2, L1 [LR2]



Project Management Tools Used by the IceCube Upgrade Project

Using Smartsheets as Resource Loaded Scheduling tool

- Pros
  - Lightweight / Cloud based / Platform independent
  - Easy to navigate for novices
  - Allows all CAMS to collaborate both in putting the schedule together and in inputting % completes
  - Keeps history of changes by cell, and who changed it
  - Supports critical path / Project Management Baseline
- Cons
  - The schedule + costworkbook is a little clunky
  - Require manual intervention in both the schedule and the cost workbook when rescheduling tasks
- Upshot
  - Clunky, but works. CAMS are used to using it.
  - Was a good choice for the original 5 year project

Smartsheets as RLS tool

Here I've tried to boil down core requirements for the RLS toolset to meet GAO scheduling guidelines

	Critical Requirements	
S.1	support task dependencies (i.e. predecessor / successor dependencies) and task durations.	Yes
S.2	support milestones (i.e. zero duration tasks)	Yes
S.3	support critical path analysis.	Yes*
S.4	support resource loading (personnel / equipment)	Yes
S.5	support named / critical resources. Flag when these resources are overcommitted.	Yes*
E.1	allow task statusing	Yes
E.2	support calculation of schedule & cost variances against a project baseline cost and schedule	Yes
E.3	support spending and resource profiles by funding source	Yes
G.1	mechanism for CAMS to update task status and actual costs while maintaining the project baseline.	Yes
G.2	user-friendly views / outputs in order to monitor how the project is doing in terms of cost and schedule.	Yes
G.3	backed up regularly.	Yes (cloud based)

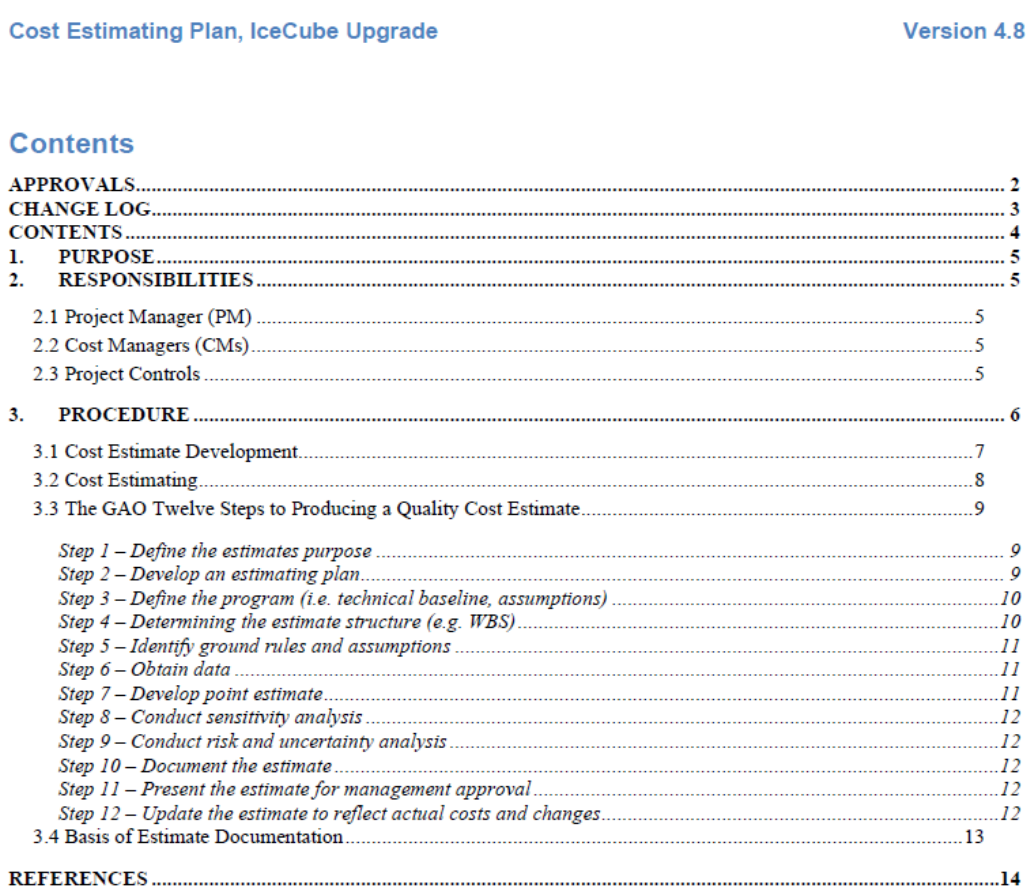
Table 2 List requirements and smartsheets capabilities. Items marked with * require some manual intervention.

Using our tools better

- Since December, we have been reviewing and reworking our project schedule
  - Working with Project Controls Jim Lowe, who helped the project set up the smart sheet system in the beginning
  - Going through the schedule, and implementing the GAO schedule best practices
- Complete bottom up estimate of cost and schedule for work to go
  - All costs estimated according to our Cost Estimating Plan and Key Assumptions Document.
  - New bases of estimates for all project costs
- The cost workbook has been updated for new schedule, costs, contingencies
- Much more detail is now contained in both the schedule and in the cost workbook
- This includes an overhaul of the smartsheet scheduling tool and how we were using it

Standardizing tools, best practices

- Cost Estimating Plan, Key Assumptions document



Cost Estimating Plan, IceCube Upgrade Version 4.8

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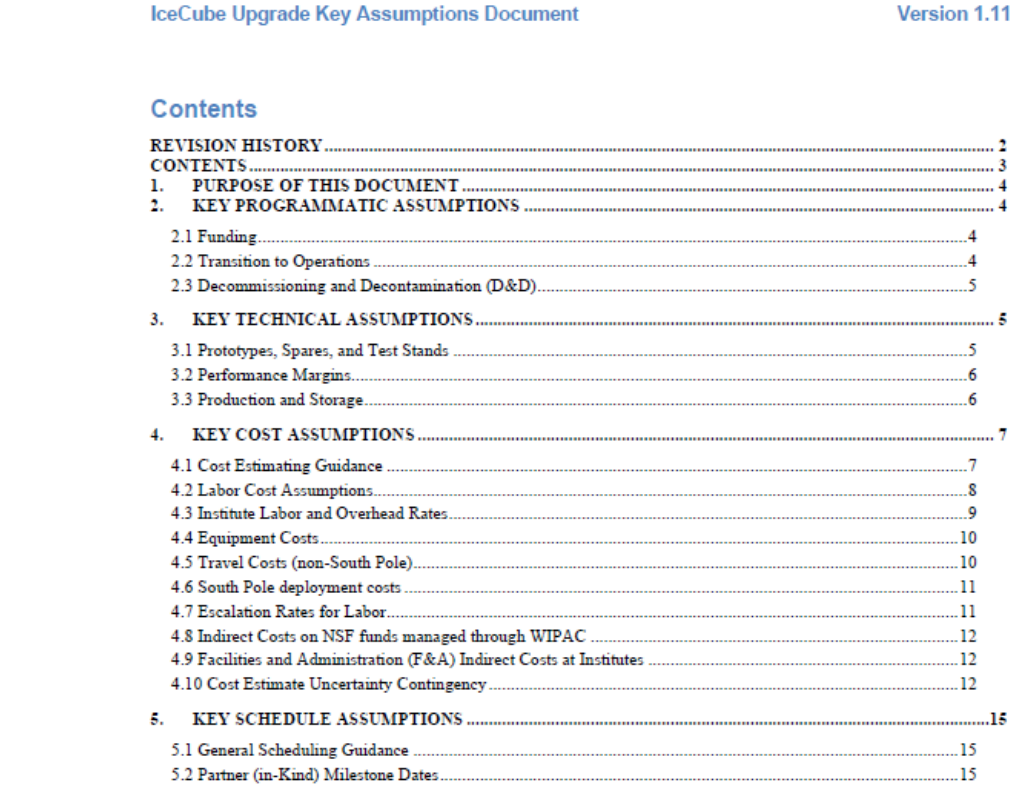

IceCube Upgrade Key Assumptions Document Version 1.11

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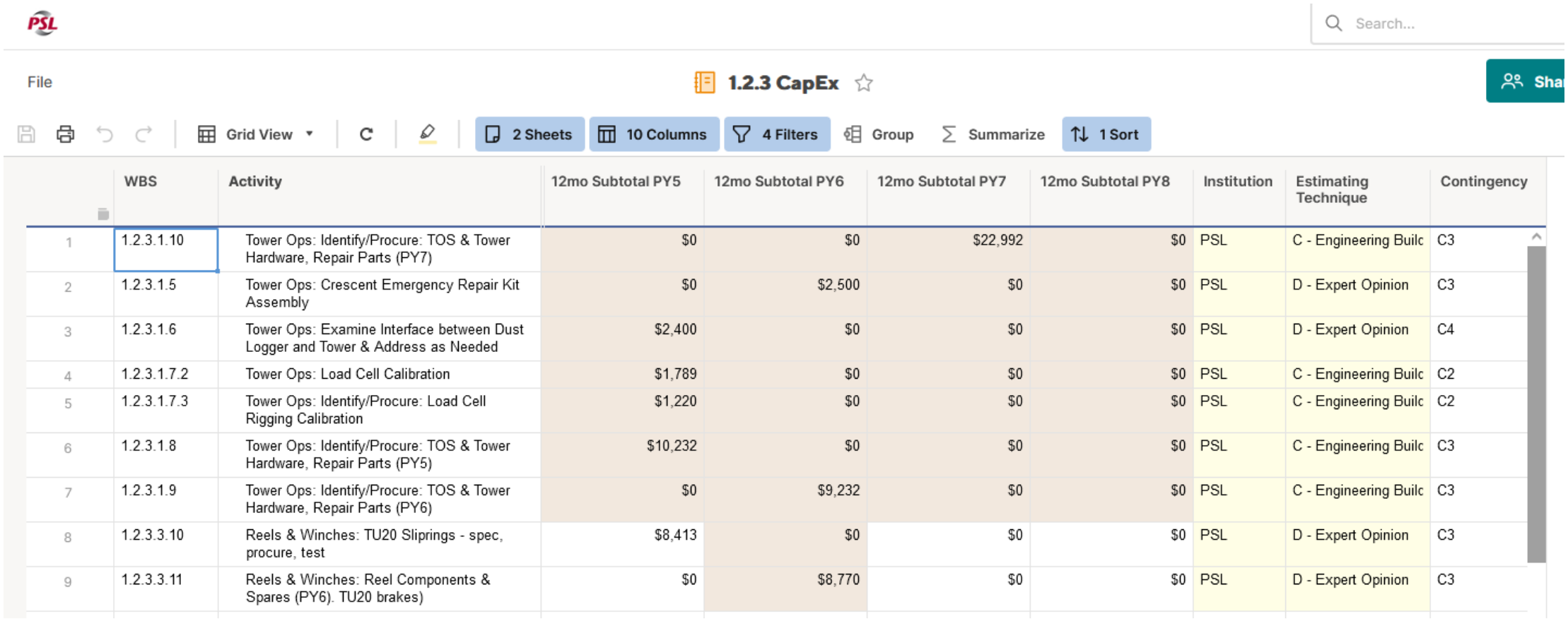
Key Assumptions for the IceCube Upgrade Project

Cost Estimating Plan for the IceCube Upgrade Project

Contingency Table from Key Assumptions Document

Code	Type of Estimate	Contingency % range	Description
C1	Level of Effort Tasks	3%-15%	**Labor:** Support type activities that must be done to support other work activities or the entire project office, where estimated effort is based on the activities it is supporting.
			M&S/Equipment items such as travel, software purchases and upgrades, computers, etc. estimated to support LOE efforts and other work activities.
C2	Advanced	5%-20%	**Labor** based on experience with documented identical or nearly identical work. Development of activities, resource requirements, and schedule constraints are highly mature. Technical requirements are very straightforward to achieve.
			M&S/Equipment items for which there is a catalog price or recent vendor quote based on a completed or nearly completed design or an existing design with little or no modifications and for which the costs are documented.
C3	Preliminary	10%-30%	**Labor**: Based on direct experience with similar work. Development of activities, resource requirements, and schedule constraints are defined at a preliminary (beyond conceptual) design level. Technical requirements are achievable and with some precedent.
			M&S/Equipment items that can be readily estimated from a reasonably detailed but not completed design; items adapted from existing designs but with moderate modifications, which have documented costs from past projects. A recent vendor survey (e.g. budgetary quote, vendor RFI response) based on a preliminary design belongs here.
C4	Conceptual	20%-50%	**Labor** based on expert judgment using some experience as a reference. Development of activities, resource requirements, and schedule constraints are defined at a conceptual level. Technical requirements are moderately challenging.
			M&S/Equipment items with a documented conceptual level of design; items adapted from existing designs which have documented costs from past projects, but with extensive modifications.
C5	Pre-conceptual	40%-60%	**Labor** based only on expert judgment without similar experience. Development of activities, resource requirements, and schedule constraints are defined at a pre-conceptual level. Technical requirements are moderately challenging.
			M&S/Equipment items that do not have a documented conceptual design, but do have documented costs from past projects. Use of this estimate type for M&S/Equipment indicates little confidence in the estimate. Should be minimized when completing the final estimate.
C6	Rough Estimate	60%-80%	**Labor** based only on expert judgment without similar experience. Development of activities, resource requirements, and schedule constraints is largely incomplete. Technical requirements are challenging.
			M&S/Equipment items that do not have a documented conceptual design, and have no documented costs from past projects. Use of this code for M&S/Equipment should be minimized when completing the final estimate.

Example of Estimates in Cost Workbook



PSL

Search...

File

1.2.3 CapEx

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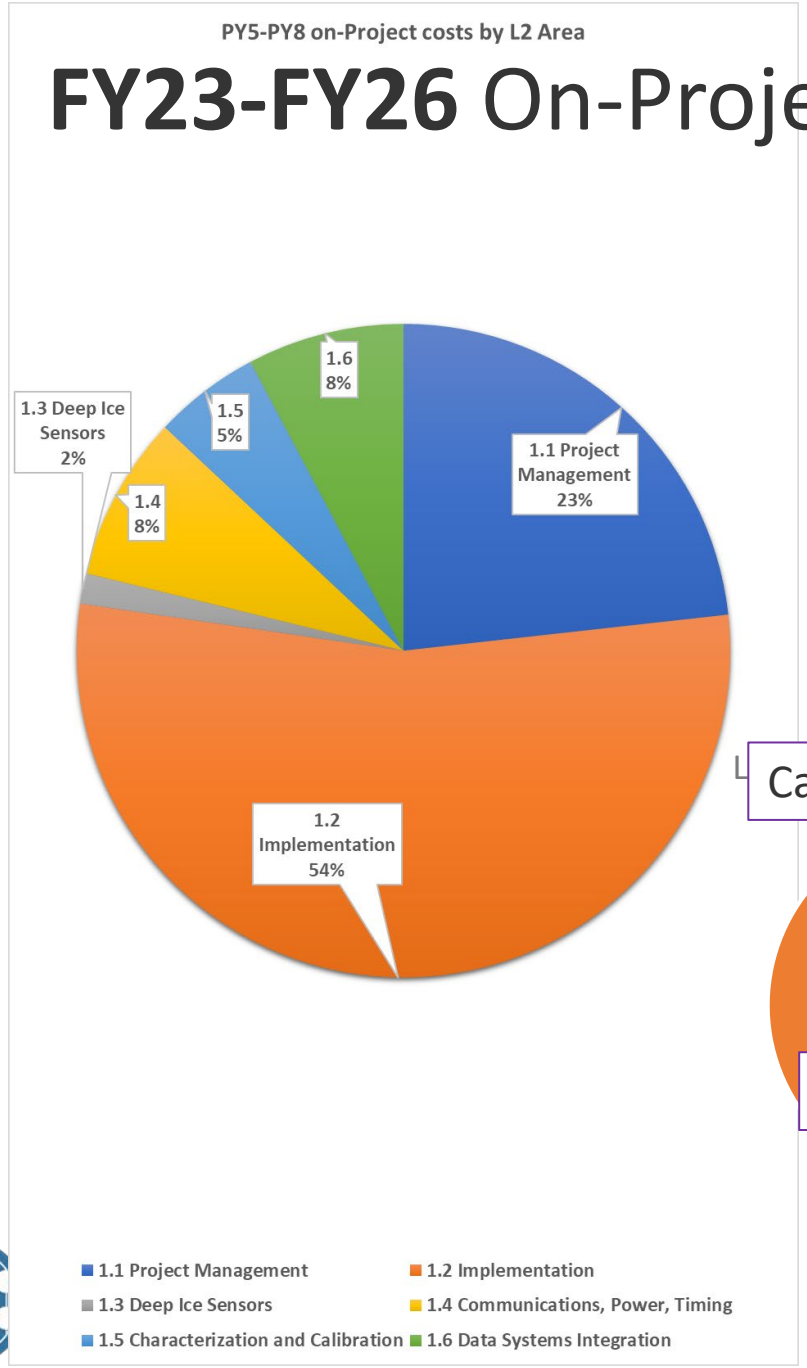
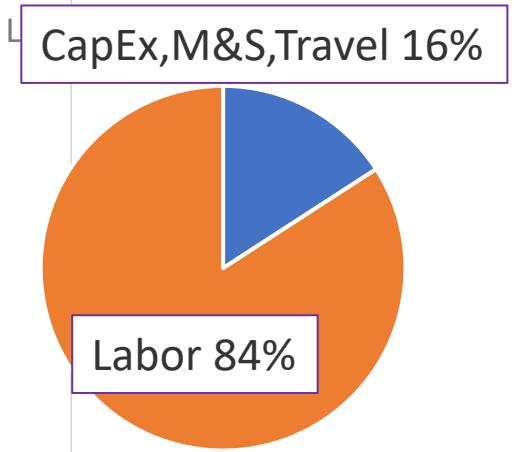
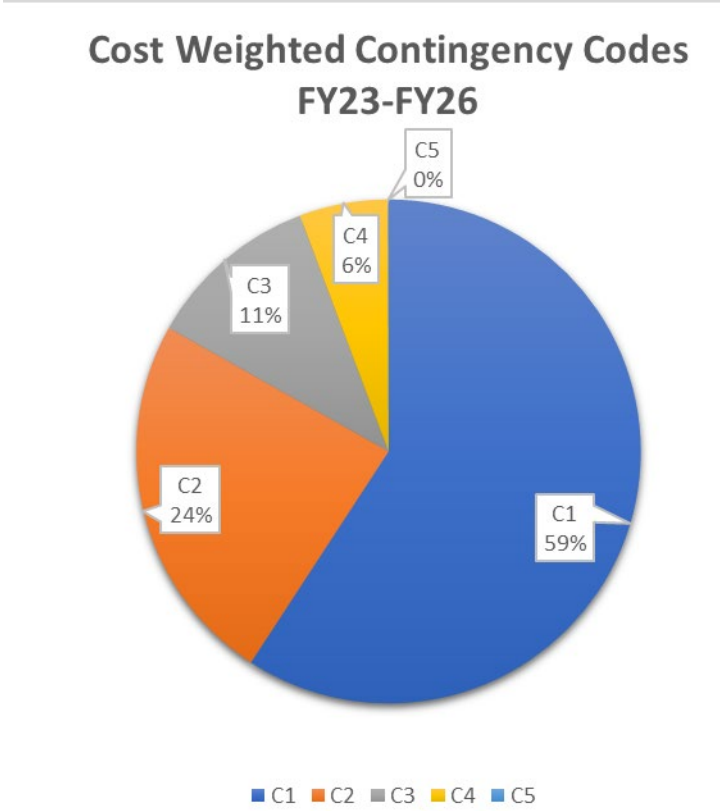
Grid View | 2 Sheets | 10 Columns | 4 Filters | Group | Summarize | 1 Sort

	WBS	Activity	12mo Subtotal PY5	12mo Subtotal PY6	12mo Subtotal PY7	12mo Subtotal PY8	Institution	Estimating Technique	Contingency
1	1.2.3.1.10	Tower Ops: Identify/Procure: TOS & Tower Hardware, Repair Parts (PY7)	$0	$0	$22,992	$0	PSL	C - Engineering Builc	C3
2	1.2.3.1.5	Tower Ops: Crescent Emergency Repair Kit Assembly	$0	$2,500	$0	$0	PSL	D - Expert Opinion	C3
3	1.2.3.1.6	Tower Ops: Examine Interface between Dust Logger and Tower & Address as Needed	$2,400	$0	$0	$0	PSL	D - Expert Opinion	C4
4	1.2.3.1.7.2	Tower Ops: Load Cell Calibration	$1,789	$0	$0	$0	PSL	C - Engineering Builc	C2
5	1.2.3.1.7.3	Tower Ops: Identify/Procure: Load Cell Rigging Calibration	$1,220	$0	$0	$0	PSL	C - Engineering Builc	C2
6	1.2.3.1.8	Tower Ops: Identify/Procure: TOS & Tower Hardware, Repair Parts (PY5)	$10,232	$0	$0	$0	PSL	C - Engineering Builc	C3
7	1.2.3.1.9	Tower Ops: Identify/Procure: TOS & Tower Hardware, Repair Parts (PY6)	$0	$9,232	$0	$0	PSL	C - Engineering Builc	C3
8	1.2.3.3.10	Reels & Winches: TU20 Sliprings - spec, procure, test	$8,413	$0	$0	$0	PSL	D - Expert Opinion	C3
9	1.2.3.3.11	Reels & Winches: Reel Components & Spares (PY6). TU20 brakes)	$0	$8,770	$0	$0	PSL	D - Expert Opinion	C3

FY23-FY26 On-Project Estimates

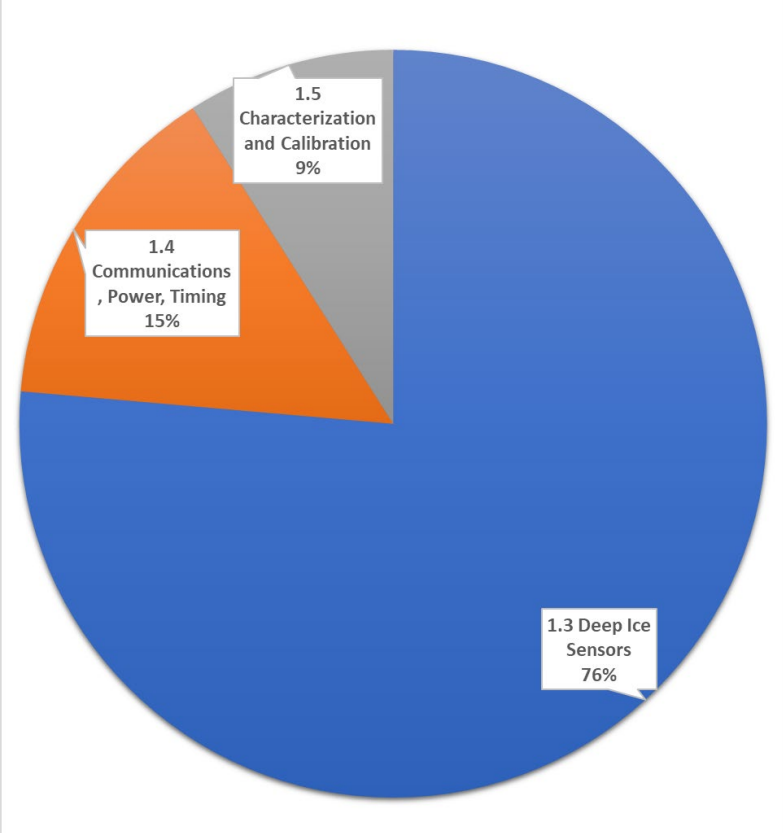




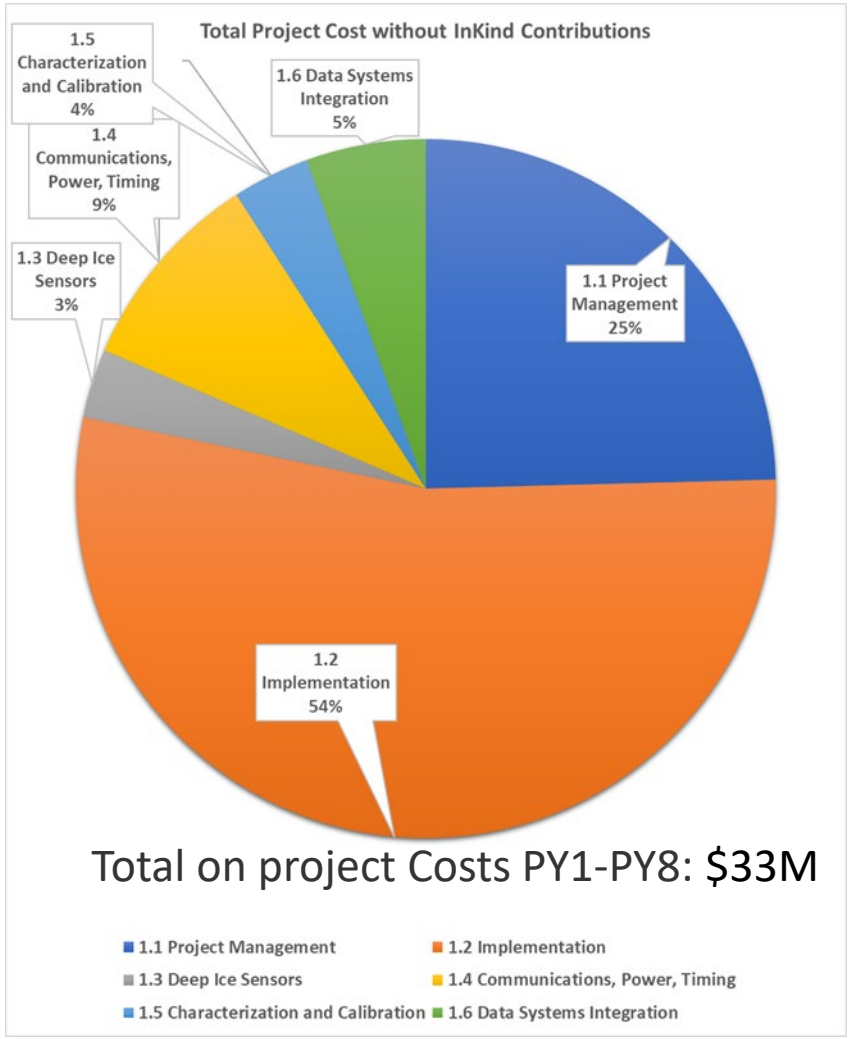


Cost Weighted Estimate Uncertainty (i.e. overall cost estimate maturity)

Total Project Costs (excluding discrete Risks)

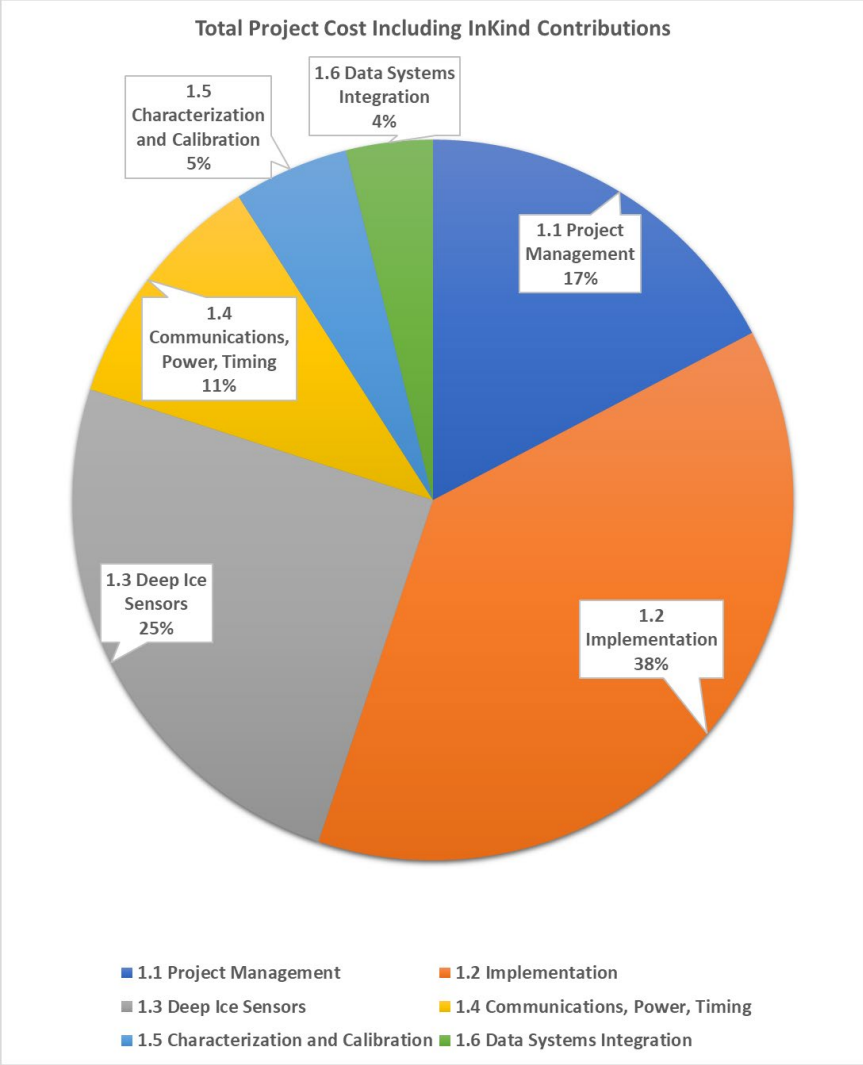


Total in-Kind contribution $14M



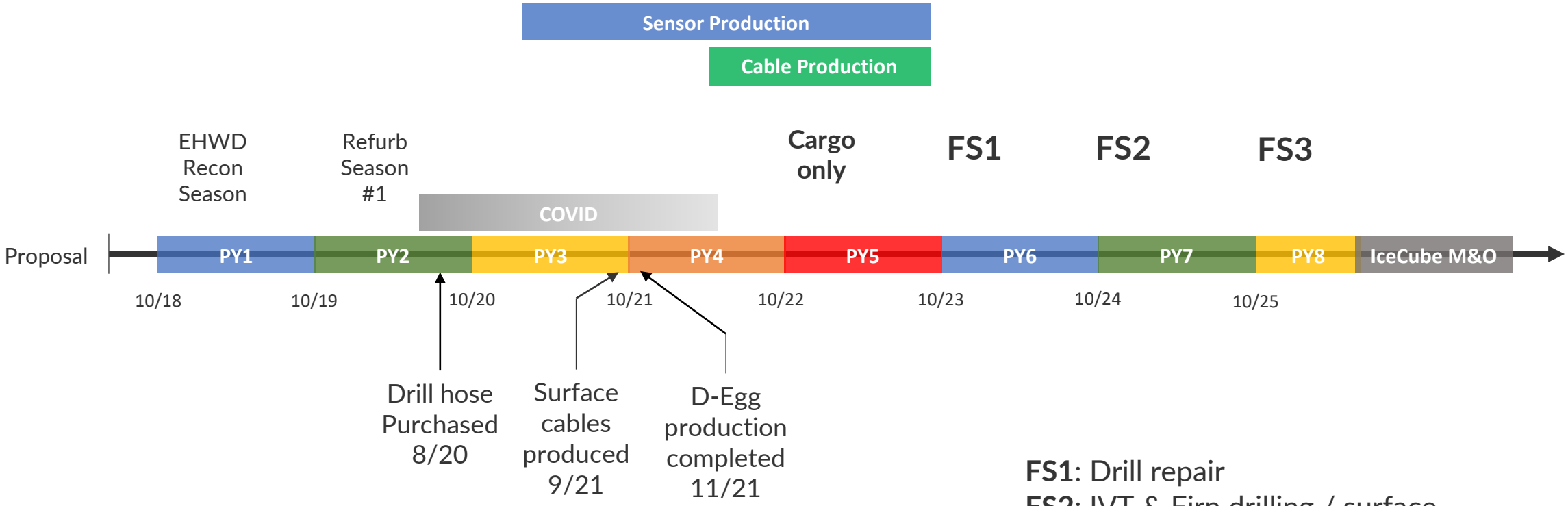
Total on project Costs PY1-PY8: $33M

Overall Total Project Costs with InKind



- Overall project costs, including in Kind, excluding discrete risks (an additional $1.8M) but including estimate uncertainties: $48M
- Project Office is ~17% of the total

Schedule



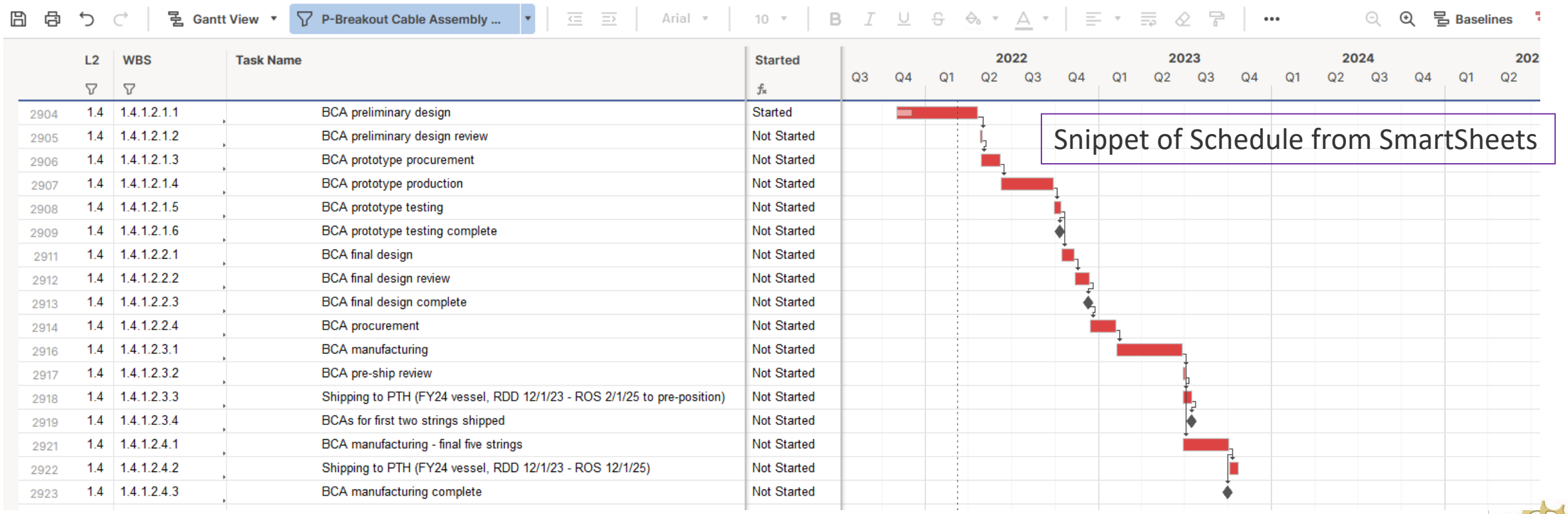
FS1: Drill repair
FS2: IVT & Firn drilling / surface
FS3: Deep drilling & installation

Schedule Methodology

- A complete bottom-up schedule estimate was done
- In-Kind and on-project activities are included in the schedule
  - In general In-Kind activities are not resource loaded
  - However, In-Kind activities are linked to on project activities where appropriate
- Task durations and order were estimated by SMEs without additional schedule contingency
- Tasks are logically linked; traceable
- Have a comprehensive set of milestones

Full Schedule

- Developed in smartsheets; 3563 activities in total
- Activities logically linked



	L2	WBS	Task Name	Started
2904	1.4	1.4.1.2.1.1	BCA preliminary design	Started
2905	1.4	1.4.1.2.1.2	BCA preliminary design review	Not Started
2906	1.4	1.4.1.2.1.3	BCA prototype procurement	Not Started
2907	1.4	1.4.1.2.1.4	BCA prototype production	Not Started
2908	1.4	1.4.1.2.1.5	BCA prototype testing	Not Started
2909	1.4	1.4.1.2.1.6	BCA prototype testing complete	Not Started
2911	1.4	1.4.1.2.2.1	BCA final design	Not Started
2912	1.4	1.4.1.2.2.2	BCA final design review	Not Started
2913	1.4	1.4.1.2.2.3	BCA final design complete	Not Started
2914	1.4	1.4.1.2.2.4	BCA procurement	Not Started
2916	1.4	1.4.1.2.3.1	BCA manufacturing	Not Started
2917	1.4	1.4.1.2.3.2	BCA pre-ship review	Not Started
2918	1.4	1.4.1.2.3.3	Shipping to PTH (FY24 vessel, RDD 12/1/23 - ROS 2/1/25 to pre-position)	Not Started
2919	1.4	1.4.1.2.3.4	BCAs for first two strings shipped	Not Started
2921	1.4	1.4.1.2.4.1	BCA manufacturing - final five strings	Not Started
2922	1.4	1.4.1.2.4.2	Shipping to PTH (FY24 vessel, RDD 12/1/23 - ROS 12/1/25)	Not Started
2923	1.4	1.4.1.2.4.3	BCA manufacturing complete	Not Started

Snippet of Schedule from SmartSheets

Resource loading in separate smartsheet

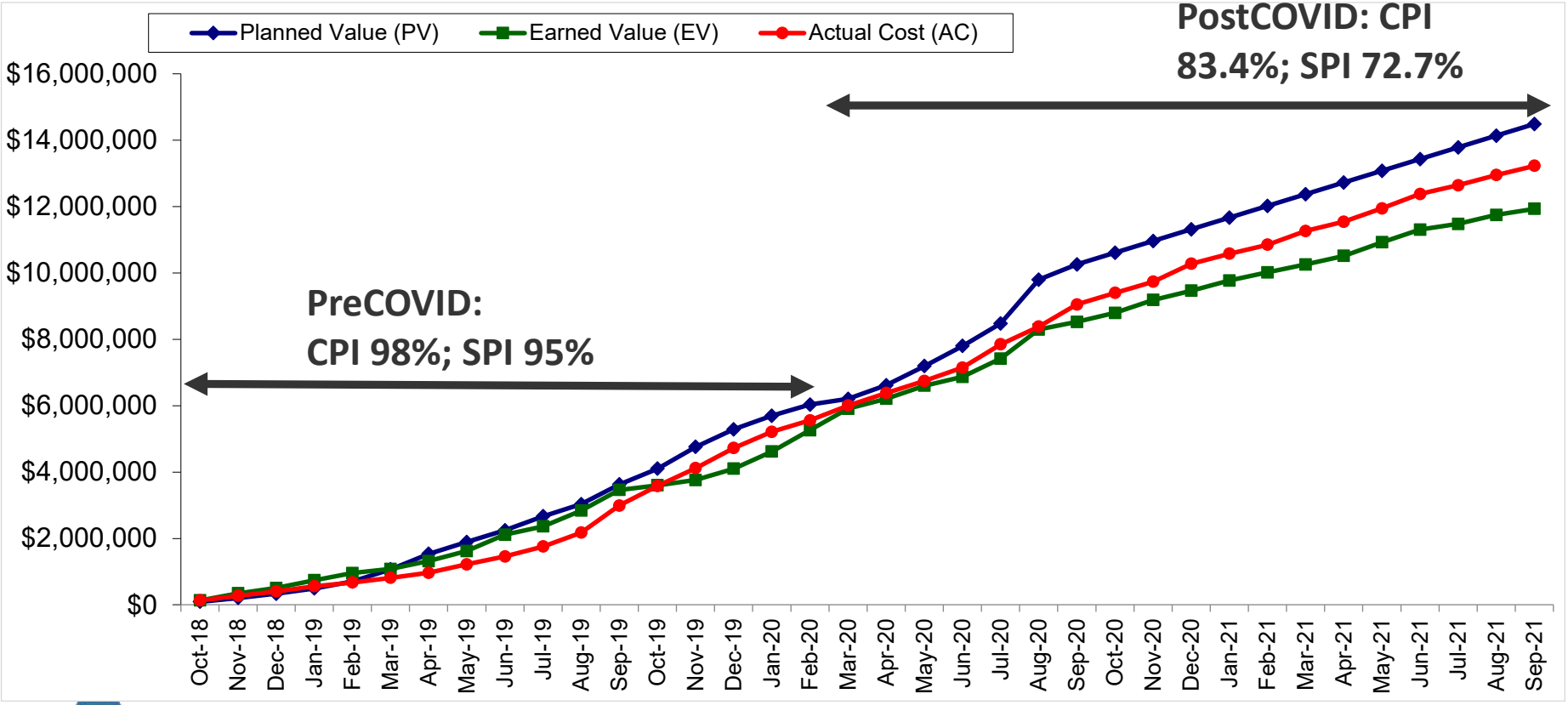
- "Cost workbook" smartsheet – linked to the schedule smartsheet
- Connects to schedule smartsheet via WBS assignment

Rebaseline Cost Workbook PY4-PY8 w/o 1.2

L2	WBS	P/C	Ins...	Schedule Task Name	10-2022	11-2022	12-2022	01-2023	02-2023	03-2023	04-2023	05-2023	06-2023
1.4	1.4.1.1.1.2.3.4	C	MSU	Fibron prototype main cable communications testing									
1.4	1.4.1.1.1.2.4	C	MSU	Hexatronic main cable final design review / decision									
1.4	1.4.1.1.1.2.4	C	MSU	Hexatronic main cable final design review / decision									
1.4	1.4.1.1.1.2.4	C	MSU	Hexatronic main cable final design review / decision									
1.4	1.4.1.1.1.3.1	C	MSU	Main cable procurement									
1.4	1.4.1.1.1.3.2.1	C	MSU	Fabrication	16	16	16						
1.4	1.4.1.1.1.3.2.2	C	MSU	Acceptance testing				32					
1.4	1.4.1.1.1.3.2.2	C	MSU	Acceptance testing				32					
1.4	1.4.1.1.1.3.2.4	C	MSU	First article shipping to breakout installation facility				16	16				
1.4	1.4.1.1.1.3.3	C	MSU	Production readiness review					56				
1.4	1.4.1.1.1.3.3	C	MSU	Production readiness review					56				
1.4	1.4.1.1.1.3.4	C	MSU	Production of final six main cables					16	16	16		
1.4	1.4.1.1.1.3.6	C	MSU	Production main cable shipping to breakout installation facility							8	8	16

Earned Value

- For EV, CAMs are estimating % complete of each activity every month
- For AC, we get cost reports from UW, Universities; PV comes from the PMB



Project Year 1-3 for 5 year baseline

At the end of PY3,
EV=11,933,881
PV=14,489,330
AC=13,227,660

SPI = EV/PV = 82.4%
CPI = EV/AC = 90.2%

Conclusions

- We have gone through a complete bottom up estimate of cost, schedule, risk for the project to go (PY5-PY8)
  - Using common methods and assumptions (Cost Estimating Plan, Key Assumptions Document)
- Our project tools are standardized: all managers are using smartsheet schedule and resource sheets
- We have standard Basis of Estimates, typically at L3, for the on-project cost elements
- Our new cost and schedule is conservative; gives us confidence we can complete the project on budget and on schedule
- We have appropriate tools for supporting EVMS and to use it as a management tool

BACKUPS

Milestones

Primary	2022				2023				2024				2025				2026			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
mDOM Final Design Review	◆																			
Control Systems - 60% Design Review Complete	◆																			
Delivery of Camera mDOM to DESY Completed	◆																			
SCAs shipped to PTH		◆																		
Main cable final design review complete		◆																		
78 + 18 spares D-Eggs for Strings 87-88 ready to ship to CHC		◆																		
MMB Rev3 delivered		◆																		
mDOM Production Readiness Review (in Germany)		◆																		
FS1 Field Season Readiness Review																				
PDOM Final Design Review		◆																		
POCAM Design complete, Final Design Review		◆																		
Sweden Camera Final Design Review		◆																		
mDOM Production Readiness Review (in US at MSU)			◆																	
Acoustic Design complete, Final Design Review			◆																	
All components for mDOM Mainboard production available			◆																	
Delivery of Camera mDOM to MSU Completed			◆																	
Breakout final design review complete			◆																	
2 + 2 spare PDOMs for Strings 87-88 ready to ship to Pt. Hueneme			◆																	
12 + 4 spare PDOMs for Strings 89-93 ready to ship to Pt. Hueneme			◆																	
Production readiness review complete			◆																	
Pencil Beam Final Design Review			◆																	
Main Cable Production Complete			◆																	
197 + 11 spare D-Eggs for Strings 89-93 ready to ship to CHC			◆																	
128 mDOMs for Strings 87-88 ready to ship to CHC			◆																	
FieldHub design complete			◆																	
POCAM ready to ship			◆																	
PencilBeam Batch 1 Ready to Ship			◆																	
96 mDOMs for Strings 89-93 ready to ship to CHC			◆																	
Sweden Camera Ready to Ship			◆																	
Acoustic Modules Ready to Ship			◆																	
FS2 Field Season Readiness Review																				
200 mDOMs for Strings 89-93 ready to ship to Pt. Hueneme			◆																	
MCAs shipped to PTH			◆																	
BCA manufacturing complete			◆																	
FieldHub production complete			◆																	
SES Initial Setup Complete				◆																
Review ExpControl/Special devices operations plan for new calibration devices									◆											
Review SPAT testing plans for Pole																				
PencilBeam Batch 2 Ready to Ship									◆											
Dust Logger and IDP Winch - Ready to Ship									◆											
FS3 Field Season Readiness Review																				
9 Holes Drilled, Covered and Flagged													◆							
FieldHubs installed in ICL													◆							
Wet-Test Operations Complete													◆							
Storage and Retrograde Complete													◆							
Retrograde (USAP)													◆							
Drill Readiness Review (PSL)																				
TOS1/Tower2 Site Ready for Drilling																◆				
TOS1/Tower1 Site Ready for Drilling																◆				

11 L1 Milestones
80 L2 Milestones (shown)
604 Internal Milestones

IceCube Upgrade All L2 Milestones

Primary	2022				2023				2024				2025				2026			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
EHWD System Ready for Drilling																	◆			
DAQ software ready for deployment including support for all new OMs																	◆			
Hole 1 Drilling Complete, Turn Over to Installation Team																	◆			
Install String 87 / Hole 1 Complete																				
Hole 2 Drilling Complete, Turn Over to Installation Team																	◆			
Install String 88 / Hole 2 Complete																				
Hole 3 Drilling Complete, Turn Over to Installation Team																	◆			
Install String 89 / Hole 3 Complete																				
Hole 4 Drilling Complete, Turn Over to Installation Team																	◆			
Install String 90 / Hole 4 Complete																				
Hole 5 Drilling Complete, Turn Over to Installation Team																	◆			
Install String 91 / Hole 5 Complete																				
Hole 6 Drilling Complete, Turn Over to Installation Team																	◆			
Dust Logging Complete																				
Install String 92 / Hole 6 Complete																				
Hole 7 Drilling Complete, Turn Over to Installation Team																	◆			
Install String 93 / Hole 7 Complete																				
Drilling & Installation Complete																	◆			
Drill and Safety Lessons Learned Complete																	◆			
Installation and Safety Lessons Learned Complete																	◆			
SPS computing system for Upgrade complete at pole																	◆			
DAQ software ready for deployment including support for all new Calibration devices																	◆			
ExpControl ready for deployment including support for all new Calibration devices																	◆			
Deliver commissioned OMs to detector operations team for integration																	◆			
Delivery of Preliminary Timing and Geometry Calibration																	◆			
Preliminary Delivery of Dust Logger Data																	◆			
Detector complete and handed off to M&O																	◆			
Deliver commissioned calibration devices to detector operations team for integration																	◆			
Final Drill Completion Report																	◆			
Final String Installation Completion Report																	◆			

Total Project Cost

	PY4	PY5	PY6	PY7	PY8	Total
Rebaseline estimate (w/o contingency)		$ 4,769,325	$ 3,774,471	$ 3,799,270	$ 2,383,917	$ 14,726,983
Anticipated actual cost PY1 thru PY4	$ 17,426,108					$ 17,426,108
Total rebaseline (w/o contingency)						$ 32,153,091
Cost uncertainty		$ 683,102	$ 487,010	$ 419,023	$ 259,733	$ 1,848,869
Risks MC(80%)		$ 620,414	$ 620,414	$ 620,414		$ 1,861,241
Total contingency to go						$ 3,710,110
Total with contingency						$ 35,863,201
Contingency on cost to go						25.2%

	PY1	PY2	PY3	PY4	PY5	Total
Baseline estimate (w/o contingency)	$ 4,069,958	$ 5,130,418	$ 3,638,071	$ 3,604,047	$ 3,685,017	$ 20,127,511
Contingency	$ 664,979	$ 575,002	$ 362,238	$ 464,748	$ 788,853	$ 2,855,811
Total cost with contingency						**$ 22,983,322**
Overall Contingency						14.2%

Original Project Baseline Costs

GAO Ten Best Practices for Project Schedules (GAO-16-89G)

1. **Capturing all activities** needed to achieve the project's scope (WBS)
2. **Sequencing all activities** activities must be logically sequenced and linked. Date constraints should be minimized and justified.
3. **Assigning resources to all activities**
4. **Establishing the duration of all activities**
5. **Verifying that the schedule can be traced horizontally and vertically**
6. **Confirming that the critical path is valid**
7. **Ensuring reasonable total float**
8. **Conducting a schedule risk analysis**
9. **Updating the schedule using actual progress and logic**
10. **Maintaining a baseline schedule**

Requirements for a mid-scale project

- **EVMS Requirements** Define control accounts at a level that suits management needs
- **Change Control** Major changes to the project plan should be implemented with change control and incorporated into the performance measurement baseline through the established change control process.
- **Risk Assessment** The project is responsible for doing a comprehensive risk assessment and maintaining a risk register. A risk Monte Carlo is not needed for a mid-scale project.

Total On-Project Costs PY5-PY8 (FY23-FY26)

- Total Cost = Point Estimate + Contingency Estimate Uncertainty Contingency + Discrete Risk Contingency

L2 Area	Point Estimate	Estimate Uncertainty Contingency	% Total
1.1 Project Management	$3,534,132	$318,072	23.2%
1.2 Implementation	$7,906,611	$1,055,429	54.1%
1.3 Deep Ice Sensor Modules	$218,668	$30,415	1.5%
1.4 Communications, Power, Timing	$1,147,559	$206,913	8.2%
1.5 Characterization and Calibration	$801,145	$72,103	5.3%
1.6 Data Systems Integration	$1,118,868	$165,937	7.8%
Sub Total	**$14,726,983**	**$1,848,869**	**$16,575,851**
Discrete Risks		**$1,861,241**	**$18,437,093**
Total Contingency		**$3,710,110**	**25.2%**

Bottom Line: Estimate for FY23-FY26 = $18,437,092 which includes a 25.2% contingency

Cost and Contingency Methodology

- Used a standard set of assumptions for all cost elements
  - Key Assumptions Document, Cost Estimating Plan
- Estimate techniques based on GAO 20-195G (Cost Estimating and Assessment Guide)
  - A=Analogy; C=Engineering build-up; D=Expert opinion; E=Extrapolation from actuals; F=Parametric; L=Learning Curves.
- Estimate Uncertainty based on the maturity of the estimate (coded C1-C6 in the KA document)
  - Estimate Uncertainty codes are assigned at each activity level
- Standard BOE documentation
- Contingency for discrete risk events is done separately (see talk by MikeD)
- Total Contingency is the sum of the Estimate Uncertainty + Risk

Cost Estimating Plan for the IceCube Upgrade Project

Key Assumptions for the IceCube Upgrade Project