

IceCube Upgrade: Upgrade Project Status
IceCube Upgrade NSF Rebaselining Review
April 26-28, 2022

Vivian O'Dell
University of Wisconsin

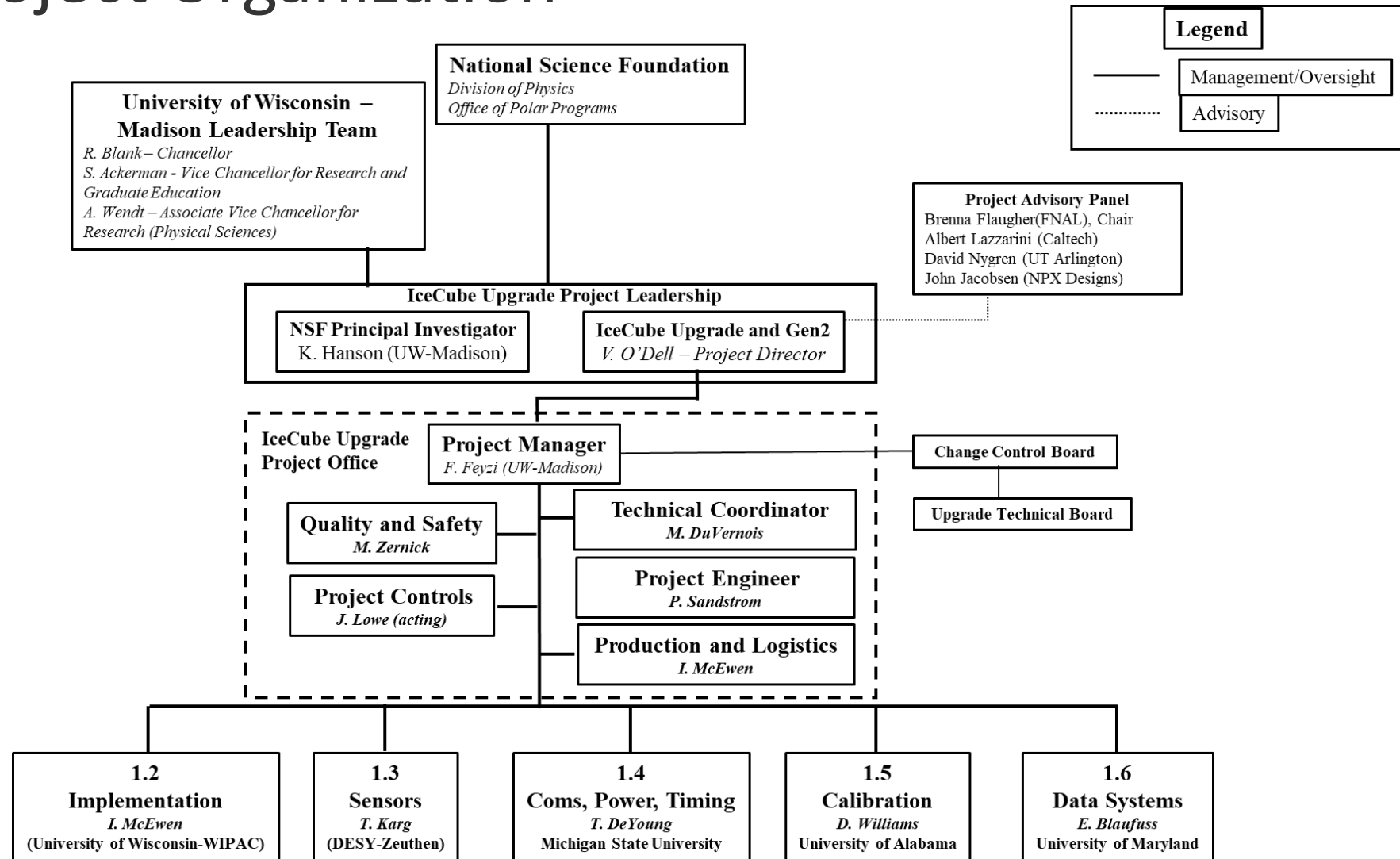


Brief Bio

Vivian O'Dell, Ph.D. in Particle Physics (Brown University, 1987)

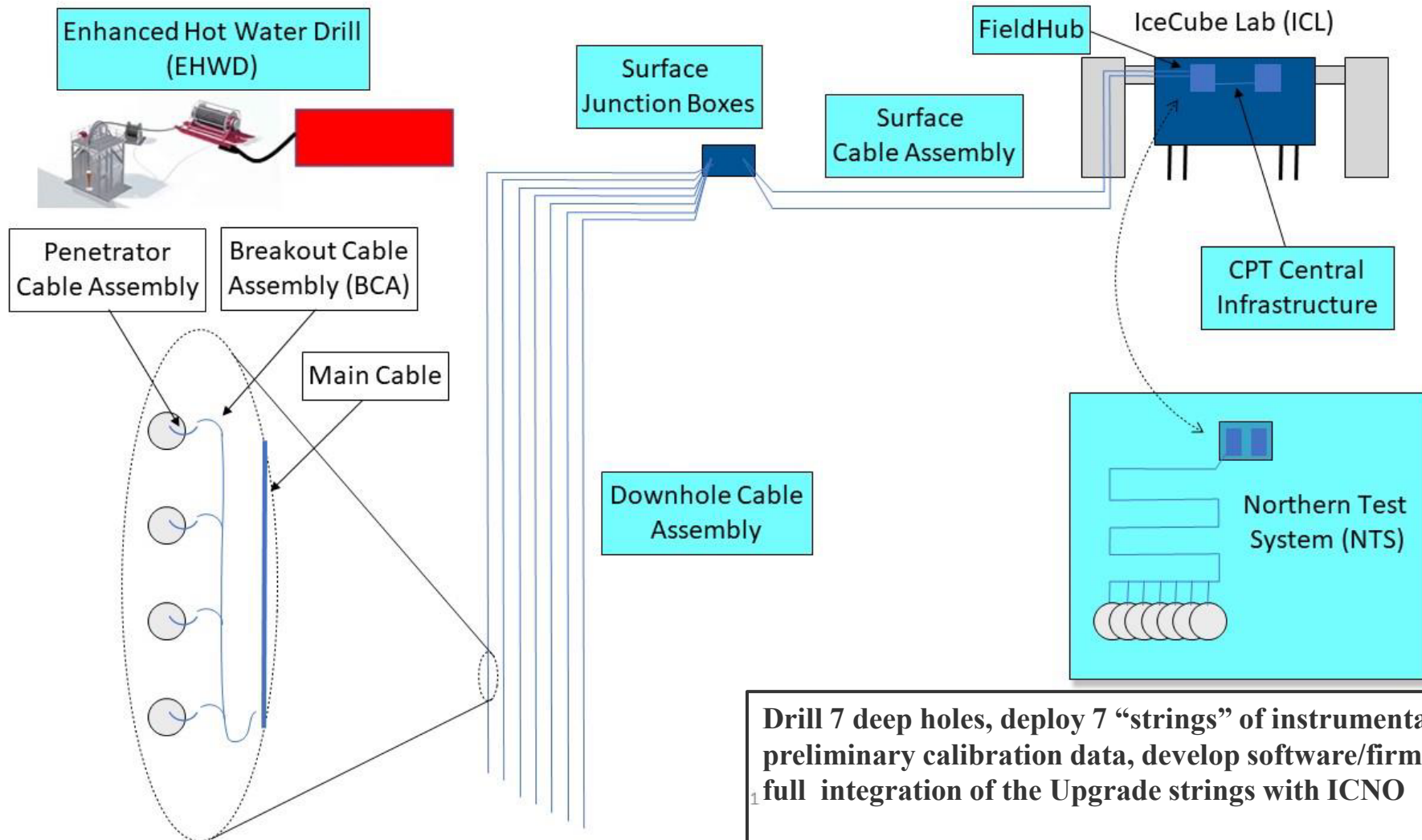
- Fermilab Scientist (1993-present [on LOA])
- KTeV, D0, CMS, Mu2e; HERA, UA1
- Project Director IceCube Upgrade / Gen2 (WIPAC)
 - Project Director for IceCube-Gen2 since January 2021
 - Project Director for IceCube Upgrade since January 2022
- Previous Project Management Experience
 - U.S. CMS HL-LHC Upgrade Project Manager (2015-2019)
 - (combined DOE 413.3b / NSF MREFC project)
 - U.S. CMS Detector Operations Manager (2014) and Deputy Operations Manager (2011-2013)
 - U.S. CMS Level 2 Project Manager for the Data Acquisition from 2002 – completion of construction project. Continued as leader of the U.S. CMS effort in DAQ in the Operations Program
 - Project Manager for the D0 Run IIb Upgrade (DOE 413.3b project)
- Certified PMP

Project Organization



Project Scope

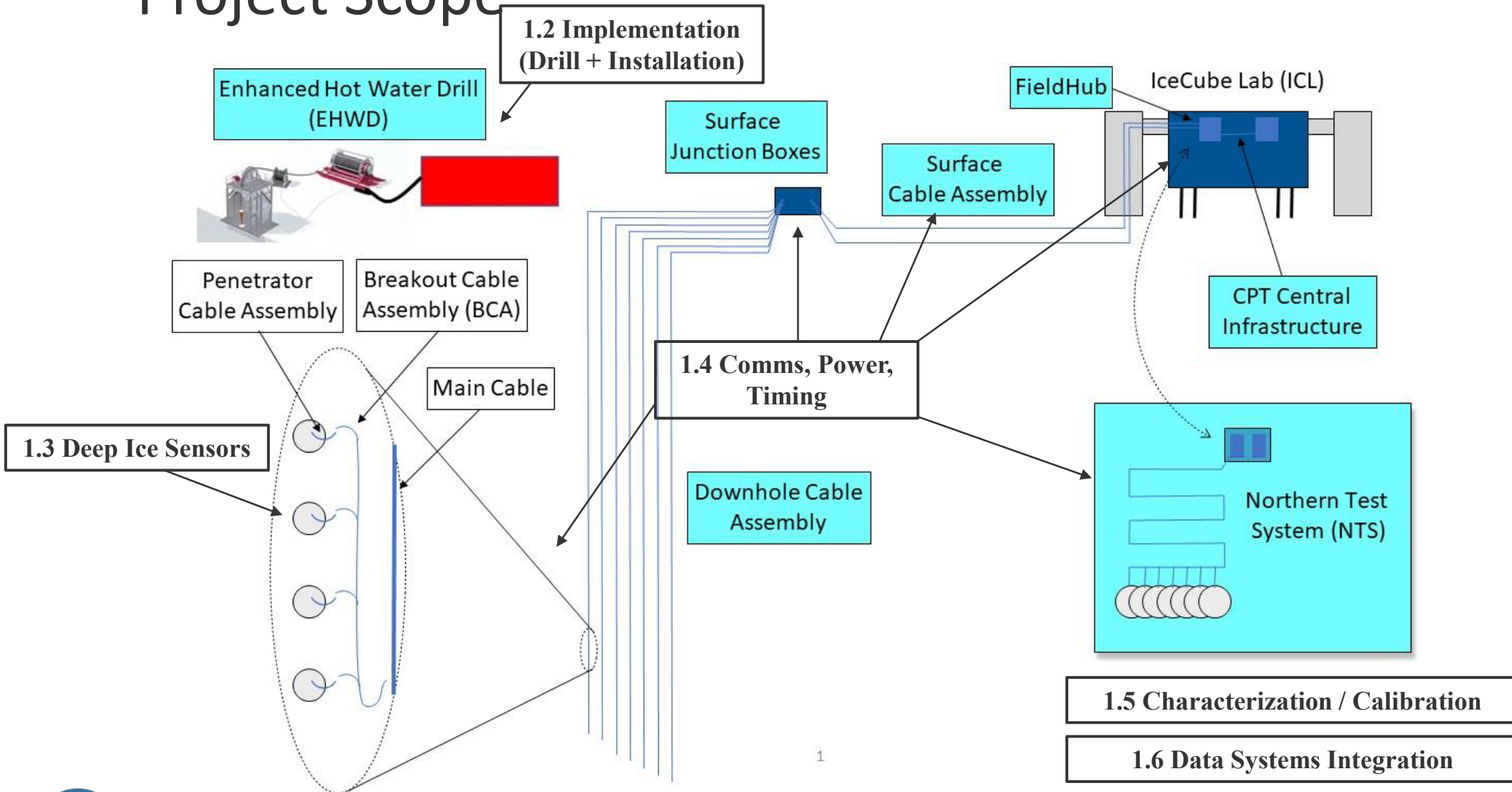
Project Scope



Drill 7 deep holes, deploy 7 “strings” of instrumentation, deliver preliminary calibration data, develop software/firmware for the full integration of the Upgrade strings with ICNO

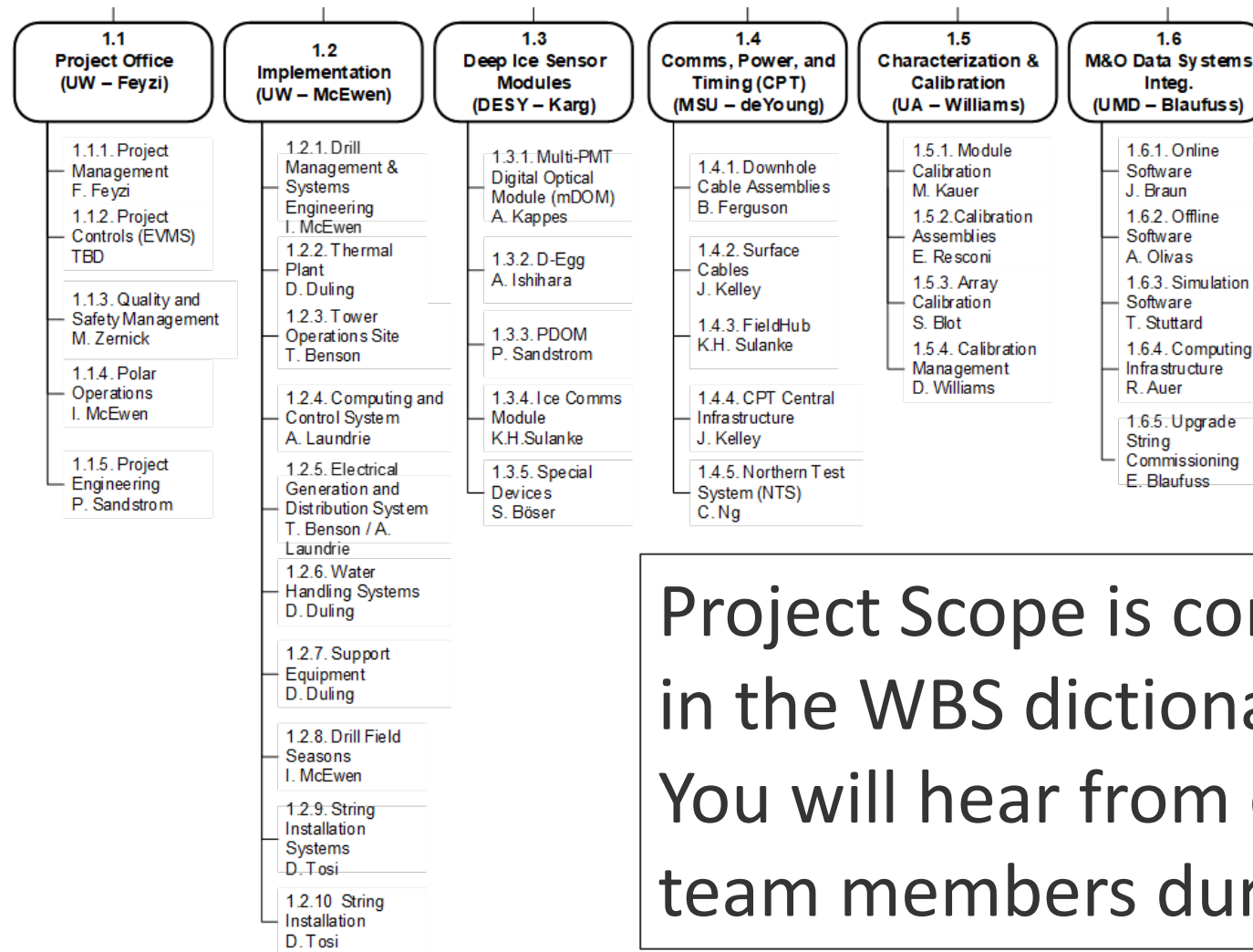
Upgrade detector is then handed off to the ongoing Maintenance and Operations program.

Project Scope



1

Project Definition / WBS



Project Scope is completely defined in the WBS dictionary
 You will hear from each of the L2 team members during this plenary

Project Scoping Options

- Descoping options
 - Much of the hardware for the project is either already bought or in-kind contributions – not a lot of cost savings available.
 - We have studied drilling/instrumenting 5 out of the 7 holes and varying hole parameters
 - This saves schedule in the critical last on-ice season
 - This option would likely be decided shortly before or during the last Field Season, as the schedule unfolds
- Upscoping options
 - We have identified a suite of upscoping options totaling about \$800k that can be exercised late in the project, as we retire final risks
 - These options are to support IceCube Upgrade data handling and computing needs

Project Cost

Original Project Cost

	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	\$ 362,229	\$ 464,748	\$ 788,853	\$ 2,855,811
Total cost with contingency						\$ 22,983,322
Overall Contingency						14.2%
<i>In-Kind Contributions*</i>						\$14,158,420
Total NSF Project + In-Kind						\$37,141,742

* In-Kind contributions covers deep-ice sensors (1.3), main cable assemblies(1.4), some special devices. This represents a considerable investment by our collaboration, especially Germany, Japan, MSU

Original Project was for 5 years (FY19-23): now cannot complete until FY26, i.e. the 5 year project has become a 7.6 year project.

Project was following the 5 year plan until March, 2020

Covid impacts:

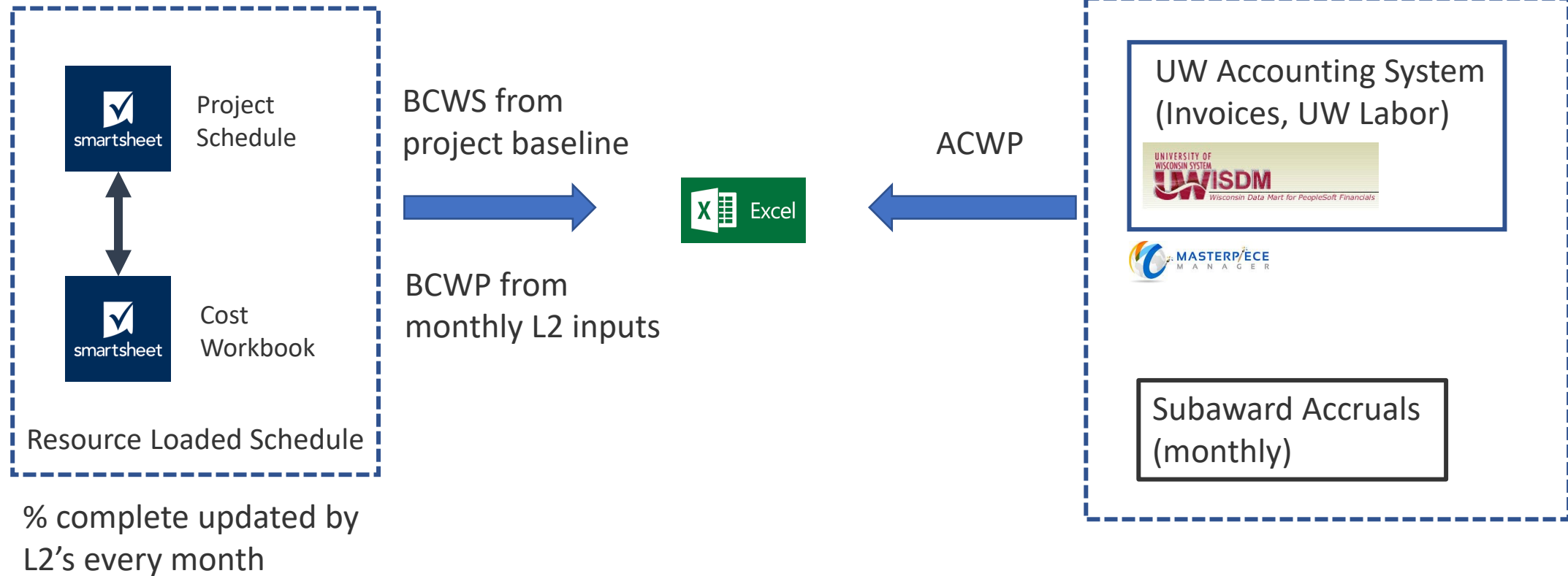
- Loss of efficiency within the project – hands on work delayed
- 3 on-ice field seasons cancelled – needed to complete drill repair work at SP
- Antarctic logistics chain jammed up – could not move Upgrade cargo in FY20/21

Replanning the project

- Logistics capacity for getting equipment and people to the South Pole for future seasons was confirmed by NSF at the end of January
 - Since then we have had regular meetings between IceCube management, NSF, and the Antarctic Contractor
- Given this information, the project did a complete replan of the cost and schedule for work to go
 - Costs and schedule were entered into the Project's Resource Loaded Schedule and Costbook as estimated by the SME's (i.e. L2/L3/L4 managers and other SME's)
- Project is using the Smart Sheet system to maintain the Project Cost, Schedule and Baseline
 - Have been using this system successfully to calculate EV and track progress and milestones

[NSF AIL Logistics Document \(ICU Planning Capacities\)](#)

Overview of tools/EVMS



Project Management Tools Used by the IceCube Upgrade Project

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 later slides)
- 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](#)

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

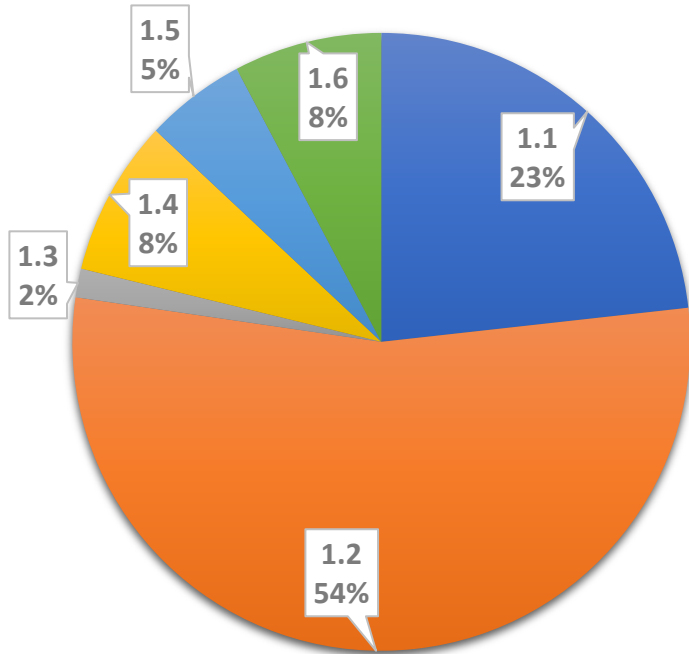
- Total Cost = Point Estimate + Estimate Uncertainty Contingency + Discrete Risk Contingency

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%

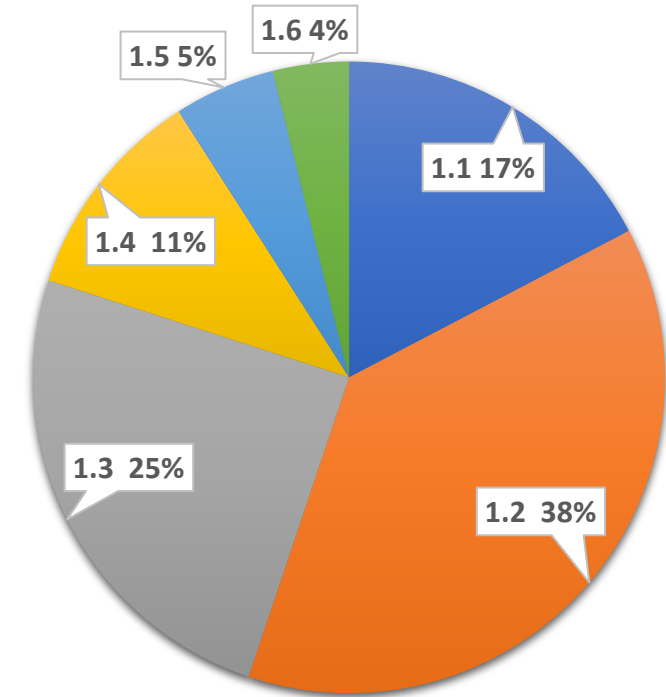
Bottom Line: Estimate for FY23-FY26 = \$18,437,092 which includes a 25.2% contingency

Cost Breakdowns by L2

On Project Costs to Go
(FY23-FY26) (\$18.4M)



Total Costs: Spent + Cost to Go + InKind Contributions (\$49.8M)



Cost Breakdown by WBS L2

- 1.1 Project Management
- 1.2 Implementation
- 1.3 Deep Ice Sensors
- 1.4 Communications, Power, Timing
- 1.5 Characterization and Calibration
- 1.6 Data Systems Integration

Risks

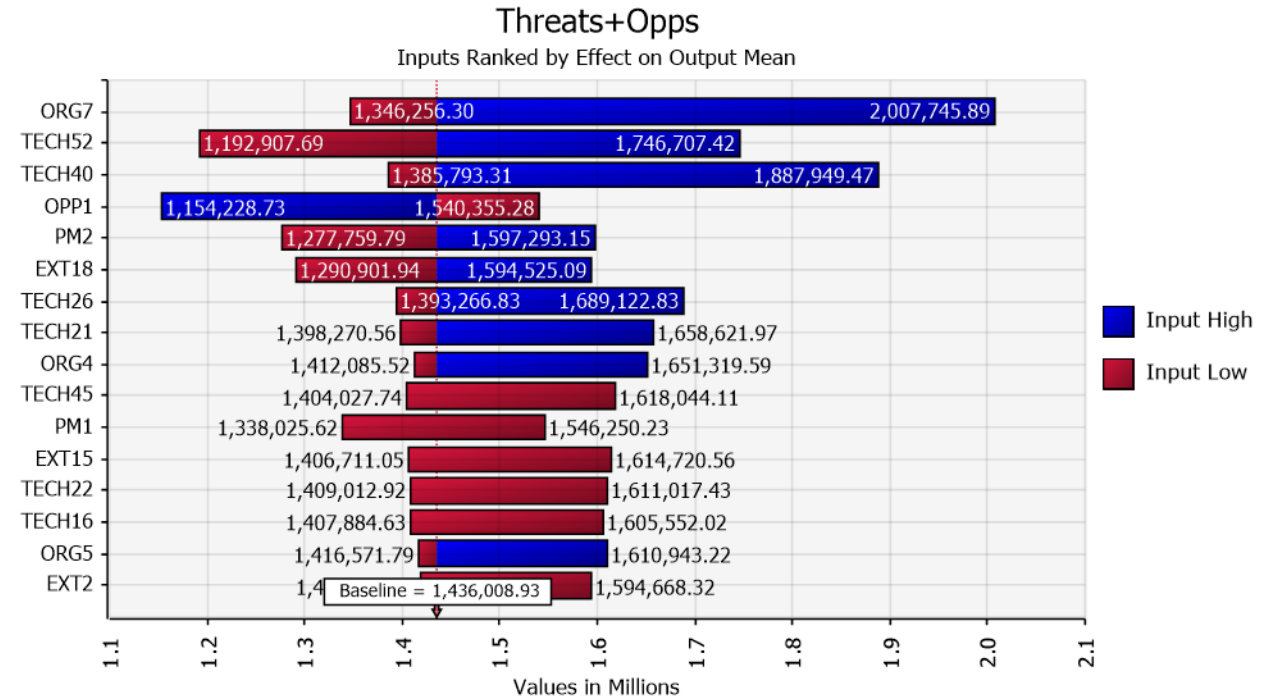
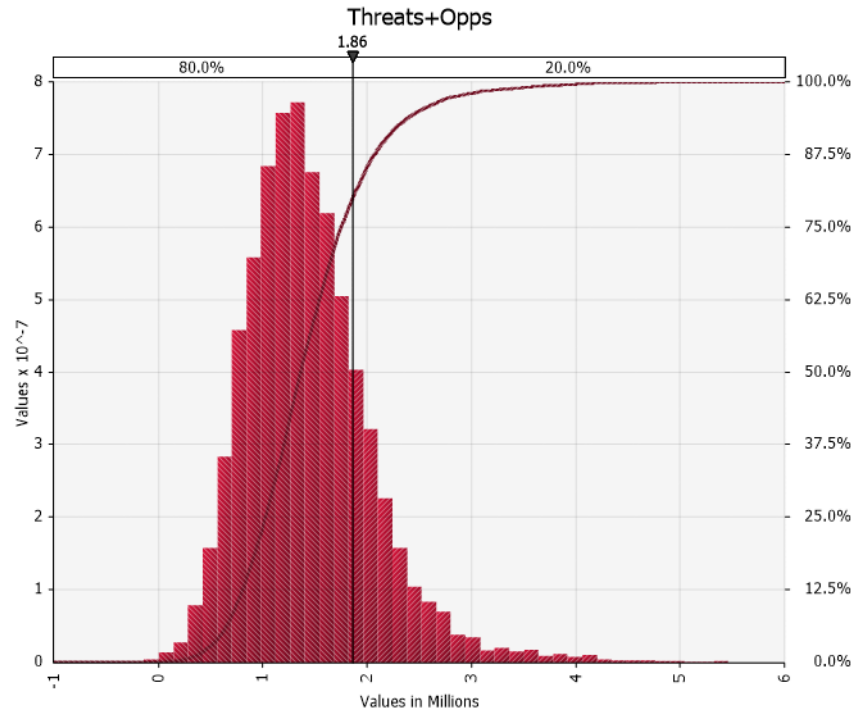
- Held a risk workshop January 25
 - Full day, Project Office + L2's + SME's
- Discussed, reviewed and refined risks
- Risk register updated
- Total active risks: 77 Threats, 1 Opportunity

WBS L2	Active Threats	Retired Threats
1.1	10	7
1.2	35	4
1.3	10	6
1.4	15	1
1.5	2	2
1.6	5	3
Total	77	23

WBS ID	Description / Title	Risk Category	Risk Type	Pre-Mitigated Risk Evaluation										Current Risk	Risk Register	Post-Mitigated Risk Evaluation							Comments / Notes	Risk Cost Exposure	Risk Schedule Exposure	Risk Schedule Exposure	Risk Schedule Exposure	Risk Schedule Exposure	Risk Schedule Exposure																																																																										
				High	Medium	Low	Very Low	Very High	High	Medium	Low	Very Low	Very High			High	Medium	Low	Very Low	Very High	High	Medium								Low	Very Low	Very High																																																																							
1.1	1.1.1	1.1.1.1	1.1.1.1.1	1.1.1.1.1.1	1.1.1.1.1.2	1.1.1.1.1.3	1.1.1.1.1.4	1.1.1.1.1.5	1.1.1.1.1.6	1.1.1.1.1.7	1.1.1.1.1.8	1.1.1.1.1.9	1.1.1.1.1.10	1.1.1.1.1.11	1.1.1.1.1.12	1.1.1.1.1.13	1.1.1.1.1.14	1.1.1.1.1.15	1.1.1.1.1.16	1.1.1.1.1.17	1.1.1.1.1.18	1.1.1.1.1.19	1.1.1.1.1.20	1.1.1.1.1.21	1.1.1.1.1.22	1.1.1.1.1.23	1.1.1.1.1.24	1.1.1.1.1.25	1.1.1.1.1.26	1.1.1.1.1.27	1.1.1.1.1.28	1.1.1.1.1.29	1.1.1.1.1.30	1.1.1.1.1.31	1.1.1.1.1.32	1.1.1.1.1.33	1.1.1.1.1.34	1.1.1.1.1.35	1.1.1.1.1.36	1.1.1.1.1.37	1.1.1.1.1.38	1.1.1.1.1.39	1.1.1.1.1.40	1.1.1.1.1.41	1.1.1.1.1.42	1.1.1.1.1.43	1.1.1.1.1.44	1.1.1.1.1.45	1.1.1.1.1.46	1.1.1.1.1.47	1.1.1.1.1.48	1.1.1.1.1.49	1.1.1.1.1.50	1.1.1.1.1.51	1.1.1.1.1.52	1.1.1.1.1.53	1.1.1.1.1.54	1.1.1.1.1.55	1.1.1.1.1.56	1.1.1.1.1.57	1.1.1.1.1.58	1.1.1.1.1.59	1.1.1.1.1.60	1.1.1.1.1.61	1.1.1.1.1.62	1.1.1.1.1.63	1.1.1.1.1.64	1.1.1.1.1.65	1.1.1.1.1.66	1.1.1.1.1.67	1.1.1.1.1.68	1.1.1.1.1.69	1.1.1.1.1.70	1.1.1.1.1.71	1.1.1.1.1.72	1.1.1.1.1.73	1.1.1.1.1.74	1.1.1.1.1.75	1.1.1.1.1.76	1.1.1.1.1.77	1.1.1.1.1.78	1.1.1.1.1.79	1.1.1.1.1.80	1.1.1.1.1.81	1.1.1.1.1.82	1.1.1.1.1.83	1.1.1.1.1.84	1.1.1.1.1.85	1.1.1.1.1.86	1.1.1.1.1.87	1.1.1.1.1.88	1.1.1.1.1.89	1.1.1.1.1.90	1.1.1.1.1.91	1.1.1.1.1.92	1.1.1.1.1.93	1.1.1.1.1.94	1.1.1.1.1.95	1.1.1.1.1.96	1.1.1.1.1.97	1.1.1.1.1.98	1.1.1.1.1.99	1.1.1.1.1.100



Risk Monte Carlo (@risk)



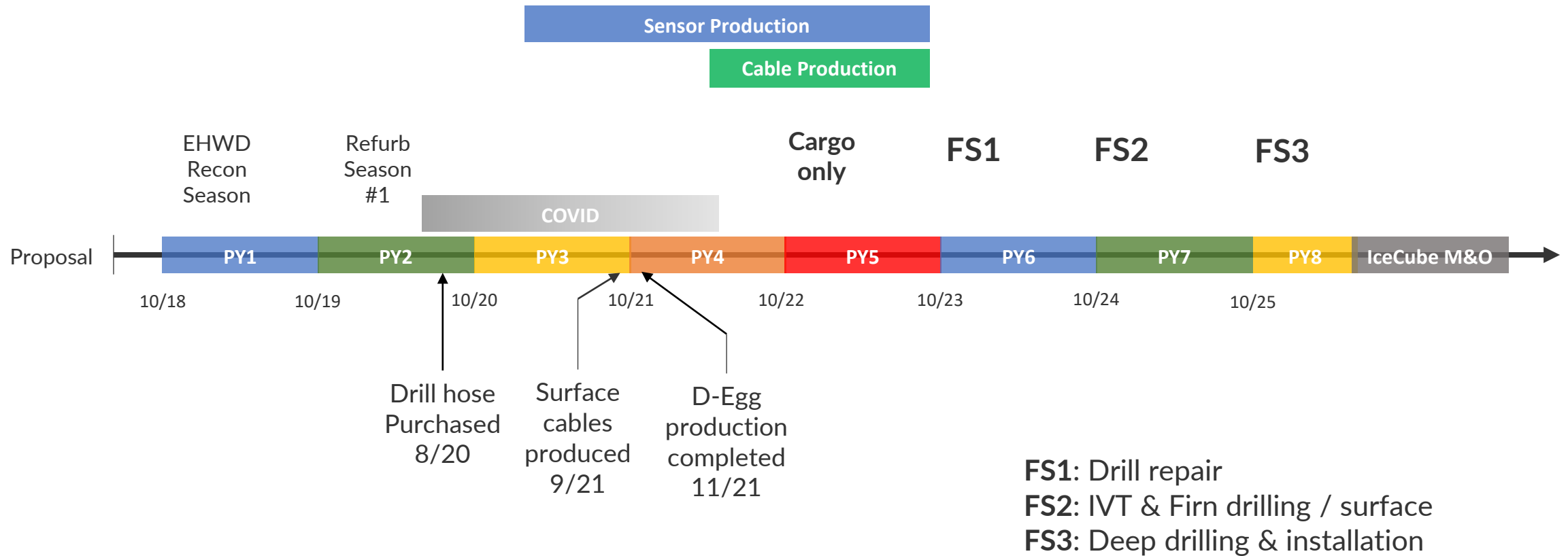
	Confidence Level		
	70%	80%	90%
All Threats + Opportunities	\$1,663,149	\$1,861,241	\$2,170,439

Top Risks (Threats and Opportunities)

Tag	Description
ORG7	Driller talent acquisition and retention. Cost impact estimated by increasing pay per driller per season
TECH52	Breakout Cable Costs – the cables are an in-kind contribution, but may exceed the amount of in-kind funding available. Risk exposure is estimated by initial bids from companies who have not yet seen the prototype cable.
TECH40	Main Cable Costs. These costs are estimated by costs incurred if the main cable prototype does not pass mechanical testing, and we have to switch main cable vendors. This risk will be either realized or retired in the next couple of months.
OPP1	Contributed drillers. All drillers are costed on project. This risk represents the opportunity that the collaboration contributes drillers, as has happened in the past. The savings is estimated by 50k / driller / season and up to 10 contributed drillers over the 3 field seasons.
PM2	Risk of losing key personnel. This cost is estimated by a 20% increase in salaries on 10% of key personnel from PY5-PY8
EXT18	Unavailable parts for mDOM main board means the board has to be redesigned. Design work is in-kind, however firmware and software changes could be significant. The on-project risk exposure is estimated at 1.5 software engineer FTEs.

Schedule

High Level Schedule

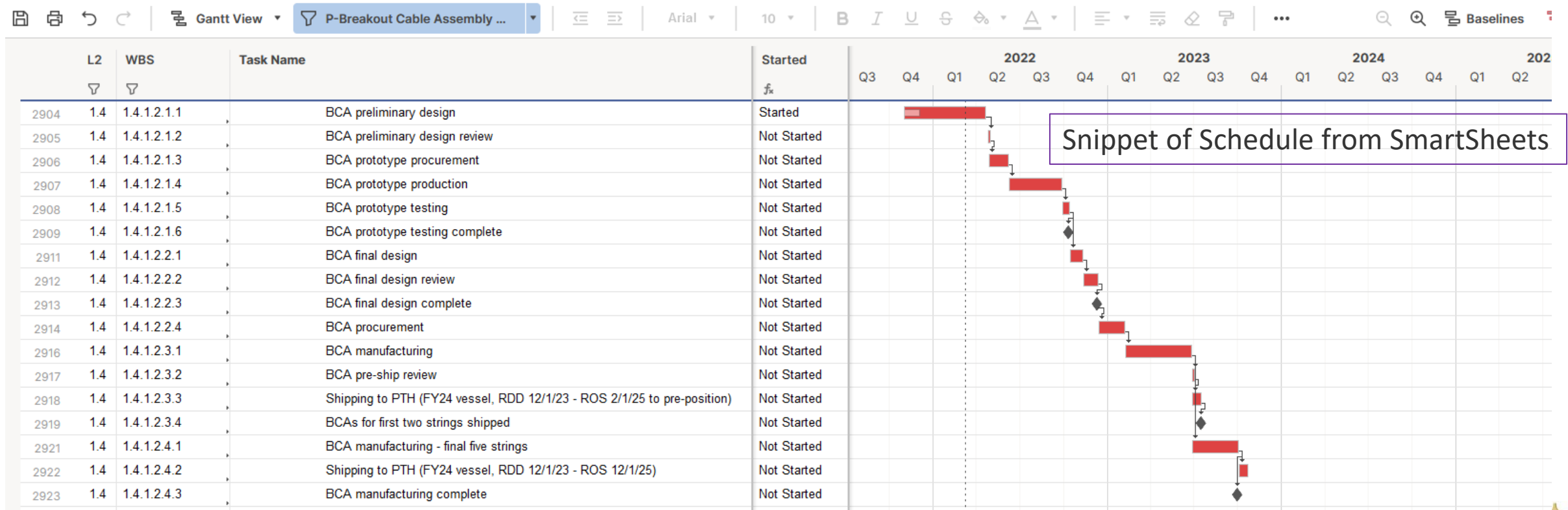


Schedule Methodology

- A complete bottom-up schedule estimate was done
- In-Kind and on-project activities are included in the schedule
 - 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



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

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

IceCube Upgrade Full 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																				



Critical Path

- Project Critical Path is defined with respect to getting items into the USAP cargo stream ***in time for delivery before the start of the relevant Field Season and in-line with the overall logistics plan/capacity.***
- Float is the time between items “ready to ship” and “required to ship” which depends on overall logistics planning
- All of this must be watched carefully by our logistics team, who interfaces regularly with USAP / ASC to ensure cargo is shipped and transported on time
- All of this information is captured in the “Cargo Master Spreadsheet” as this is the interface preferred by the NSF AIL/Antarctic Contractor
- “Ready to ship” dates are verified / updated monthly along with the EV data collected across the project
- Items with little float are watched carefully, and alternative shipping times / methods discussed with the logistics team well in advance

Master Cargo Spreadsheet

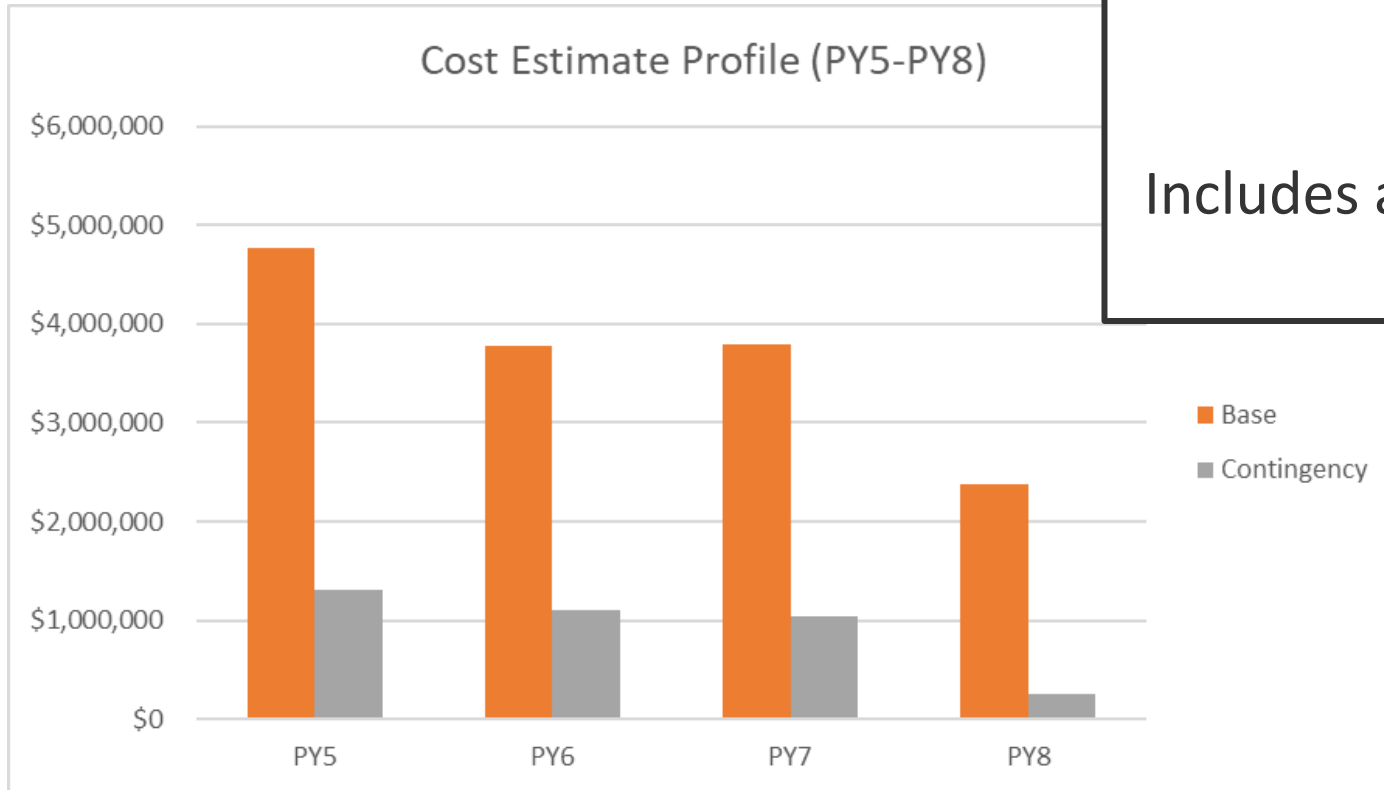
Item description	SHIPMENT FLOAT: Time between completion and shipping to USAP site	FLOAT AT NPX (delivery to required) [days]	Total Time Between Shipment and Latest Arrival Date at NPX [days]
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
Gen 1 - housed in 20' container	In McMurdo	334	-
Gen 2 - housed in 20' container	In McMurdo	0	-
Gen 3 - housed in 20' container	In McMurdo	334	-
Gen Discharge Hoods (bermed)	In McMurdo	376	-
Firn Drill	In McMurdo	348	-
Weight stack and crates	In McMurdo	1096	-
Fuel Tower	In McMurdo	369	-
HPU 2	In McMurdo	350	-
8' Refit Container	In McMurdo	348	728
20' Refit Container A	In McMurdo	317	728
20' Refit Container B	In McMurdo	348	773
ARA Trailer	In McMurdo	371	765
Return Water Cable Reel (RWCR)	In McMurdo	367	792
Main Cable Reel (MCR)	In McMurdo	367	778

Snippet of Master Cargo Spreadsheet

Cost+Schedule = Cost Profile

Total on-project cost for FY23-FY26 is \$18.4 M

Includes an overall contingency of 25.2%



	PY5	PY6	PY7	PY8	Total (PY5-PY8)
Base	\$4,769,325	\$3,774,471	\$3,799,270	\$2,383,917	\$14,726,983
Contingency	\$1,303,516	\$1,107,424	\$1,039,437	\$259,733	\$3,710,110
Total	\$6,072,841	\$4,881,895	\$4,838,707	\$2,643,650	\$18,437,093
% Contingency	27.3%	29.3%	27.4%	10.9%	25.2%

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	\$ 362,299	\$ 464,748	\$ 788,853	\$ 2,855,811
Total cost with contingency						\$ 22,983,322
Overall Contingency						14.2%

Original Project Baseline Costs

Conclusions

- Our project was originally a 5 year, \$23M project(+ \$14M in-kind contributions)
 - We are now in year 4 of the project
 - Due to COVID impacts, both within the project and external to the project, we will need 7.6 years to complete
- We have done a complete bottom-up estimate, taking stock of where we are now in the project, the work to go, and external realities
 - We used common methods and assumptions (Cost Estimating Plan, Key Assumptions Document)
 - Bottom line is that we estimate a total project cost from PY5-PY8 of \$18,437,092 including 25.2% contingency
- We have a solid plan, cost, schedule, and an experienced team to execute the project
- We are eagerly looking forward to installing and commissioning the detector!

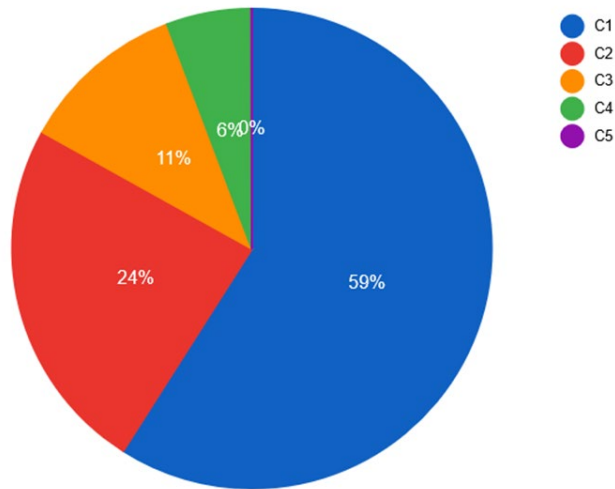
BACKUPS

Critical Path

- 1.2 Drill: Drill Control System
 - Just had a review, see more details in Terry's talk
- 1.3 mDOMs
 - And more specifically parts for the mDOM mainboard (FPGAs)
- 1.4 CPT
 - Main cable assemblies; main cables + breakout cables

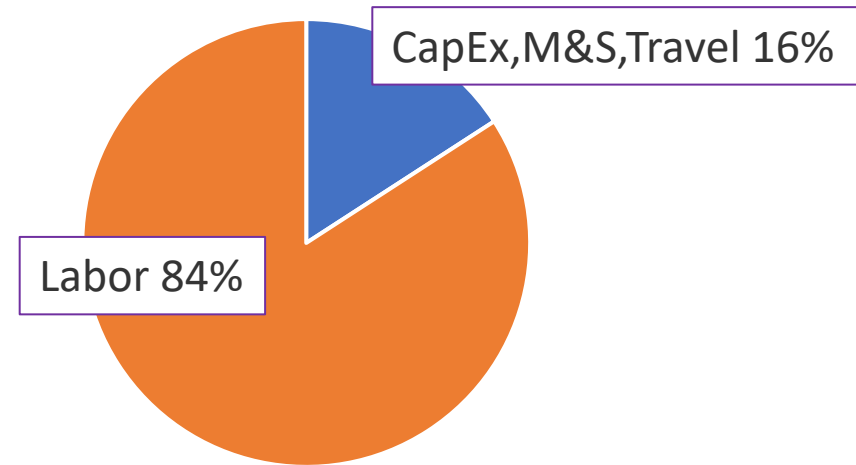
FY23-FY26 On-Project Cost Estimates

Cost Weighted Estimate Uncertainty Assignment



Cost Weighted Estimate Uncertainty

Labor vs. CapEx, M&S, Travel



Labor / Materials, Capital Equipment, Travel