

## IceCube Upgrade PY3 Plan

**Draft**

**rev5**

**September 21, 2020**

### Introduction

The following sections describe the IceCube Upgrade project year 3 (PY3) plan starting in October 2020 and ending in September 2021. The stand-alone PY3 plan, as presented here, was necessitated as a result of the COVID-19 pandemic which caused delays in nearly all technical areas. The effects of the pandemic will continue in PY3 at the current level for an unknown period. As a result the plan is presented as a technical and financial plan without a detail schedule of when tasks will be completed.

The overall aim of the plan is to make as much technical progress as possible towards the original installation schedule of seven strings in the 2022-2023 season. Any other potential back up plans are not presented at this time due to uncertainty in the future. Financial plans are also focused on the PY3 to stay within funded project budget without any predication for the future years.

While there have been many delays in technical areas, the progress in the second half of PY2 has been excellent despite the pandemic. The technical staff and infrastructure at collaborating institutions have been functioning very effectively and should continue to do so in PY3. As a result the outlook for completing the project on schedule remains positive. The project office and technical leaders are committed to the original schedule and will continue all possible efforts to achieve it.

### WBS 1.1: Project Office

The project office will remain the same in PY3 and will work in remote fashion, as has been the case since the beginning of the pandemic. The staff in the project office have been able to meet the needs of the project and interact effectively with level 2 managers, the National Science Foundation and the Integrated Project Team.

### Level 1 and 2 Milestones

The following tables show the status of level 1 and 2 milestones at the beginning of the pandemic and at the beginning of PY3. More details of the status and plans for PY3 are included for each WBS level 2 in individual sections.

ID	Milestones	Target Dates	Status February 2020	Status October 2020
1	NSF Upgrade readiness review	Mar 2019	Done on time	
1	Deploy drill team (8) for recon and fire/life safety upgrades	Nov 2019	Done on time	

1	D-Egg final design and production readiness review exit	Nov 2019	FDR done Feb 2020 PR in May 2020	PR in October 2020
1	Start of D-Egg production	Dec 2019	Feb 2020 start pre-production	50 D-Eggs assembled, full production of remainder will start October 2020
1	mDOM final design review exit	Apr 2020	July 2020	Delayed due to Covid-19, expected November 2020
1	Upgrade string design complete	May 2020	Pending definition	Completed June 2020
1	South Pole 2020 shipment complete	Oct 2020		Drill hose delivered to USAP resupply vessel, expected in McMurdo in Jan 2020, drill cable reel and drill control parts delayed to October 2021
1	Start of mDOM production	Jan 2021	Preproduction start Oct 2020	Start early 2021
1	Standalone calibration devices final design review exit (There is preliminary but no final – 1.5.2.2.1)	Jul 2021		TBD
1	South Pole readiness review	Aug 2021		TBD
1	South Pole 2021 shipment complete	Oct 2021		May be delayed by one year
1	EHWD wet test and commissioning and firm drilling complete	Jan 2022		May be delayed by one year
1	Special devices readiness review	Feb 2022		TBD
1	CPT infrastructure systems commissioned in ICL	Feb 2022		TBD
1	Drill readiness review - PSL	Apr 2022		May be delayed by one year

1	South Pole readiness review	Sep 2022		May be delayed by one year
1	South Pole 2022 shipment complete	Oct 2022		May be delayed by one year
1	Online software ready for deployment in 2022/23 season	Nov 2022 (01/16/23 1.6.1.1.1.9)		TBD
1	SJBs and ICL ready for Upgrade string commissioning	Dec 2022	Will be ready Feb 2022	May be delayed by one year
1	On-Ice drilling readiness assessment and start of drilling (1.2.8.6.6.13)	Dec 2022		May start later in season
1	7 Upgrade strings commissioned	Jan 2023	March 2023	May be delayed by one year
1	Decommission, retro and store drill equipment	Feb 2023		May be delayed by one year
1	Upgrade project completion report	Sep 2023		May be delayed by one year

<b>ID</b>	<b>Milestones</b>	<b>Target Dates</b>	<b>Status February 2020</b>	<b>Status October 2020</b>
<b><i>Project Office</i></b>				
1.1	Start EV reporting	Mar 2019	Done	
1.1	NSF Upgrade readiness review	Mar 2019	Done	
1.1	Quarterly risk registry update	Mar Jun Sep Dec	Ongoing	Ongoing
1.1	Instrumentation and online systems pre-ship review	Sep 2021	Was intended for traverse, not needed until Sept 2022	May be delayed by one year
1.1	Upgrade project completion report	Sep 2023		May be delayed by one year
<b><i>Enhanced Hot-Water Drill</i></b>				
1.2	Generator 1 overhaul complete	Sep 2019	Done	
1.2	Procure main drill hose	Nov 2019	Ahead of schedule	Complete August 2020

1.2	Deploy drill team (8) for recon and fire/life safety	Nov 2019	Done	
1.2	Procure drill cables (1.2.3.5.9 shipment)	Mar 2020	Start Mar 2020	Contract issued September 2020
1.2	Fuel day tank rebuild complete	Oct 2020		Deferred until next available field season
1.2	Winches and reels complete	Oct 2020		Delayed, ship Oct 2021
1.2	Deploy drill team (8) to start replacement/repairs	Nov 2020		Cancelled
1.2	Complete drill head rebuild	Nov 2020		Complete August 2020
1.2	Deploy drill team (15) for commission, wet test, firm drilling	Nov 2021		TBD
1.2	EHWD wet test and commissioning	Jan 2022		Completion may be delayed by one year
1.2	Drill all 7 firm holes	Jan 2022		May be delayed by one year
1.2	Drill readiness review	Apr 2022		May be condensed
1.2	Deploy drill team (30) for drilling and installation	Nov 2022		TBD, may need additional staff
1.2	Drilling start	Dec 2022		May start late in season
1.2	Drilling/installation ends	Jan 2023		May be delayed by one year
1.2	Decommission and store drill	Feb 2023		May be delayed by one year
1.2	Final drill completion report	May 2023		May be delayed by one year
<b><i>Deep Ice Sensor Modules</i></b>				
1.3	Ice comms module and DOMs interface defined	Feb 2019	Done on time	

1.3	Decision on mDOM baseline PMT model	Feb 2019	Done April 2019	
1.3	D-Egg production test complete	Feb 2019	Done March 2019	
1.3	Start of mass production of ice comms modules (NOT a milestone, 1.3.4.12.1)	Oct 2019	Started Nov 2019	Ongoing
1.3	D-Egg final design review and production readiness review	Nov 2019	See above	See above
1.3	Start of D-Egg mass production (bundled with 1.3.2.8.6)	Dec 2019	See above	See above
1.3	mDOM final design review	Apr 2020	See above	See above
1.3	mDOM production readiness review	Jul 2020		See above
1.3	Start of refurbishment of IceCube DOMs	Aug 2020	Delayed due to reduced number, start Feb 2021	Planned in PY3
1.3	Start of mDOM mass production	Jan 2021	See above	See above
1.3	Special devices mission review	Jan 2021	May 2020	Completed May 2020
1.3	All DOMs ready to ship to Pt. Hueneme (Production ready, 1.3.1.10.1.2.23)	Sep 2021	First 2 strings Sep 2021, next 5 Sep 2022	TBD
1.3	Special devices deployment readiness review	Jan 2022		TBD
<b><i>Communications Power and Timing</i></b>				
1.4	Penetrators shipped to DOM assembly facilities (not a milestone, bundled into 1.4.1.3.5)	Sep 2019	Prototypes Dec 2019, Prod. Mar 2020	Shipments ongoing since April 2020
1.4	First-run main cable delivered for evaluation	Dec 2019	Feb 2021 Moved from traverse to airlift	Summer 2021
1.4	NTS dark facility ready for operations	Dec 2019	March 2020	Delayed due to COVID-19, current estimate Fall 2020
1.4	FAT driver units (early FieldHubs) for DOM production testing (1.4.3.1.1.5)	Dec 2019	Done on time	

1.4	Main cable assembly production complete	Oct 2020	Sep 2021 Replanned for air shipment	Production complete in PY4
1.4	Breakout cable assembly production complete	Oct 2021		TBD
1.4	FieldHub final design review	Dec 2021		Expected on time
1.4	CPT infrastructure systems commissioned in ICL	Feb 2022		See above
1.4	FieldHub production complete	Oct 2022		Expected on time
<b><i>Calibration and Characterization</i></b>				
1.5	Module production calibration review	Aug 2019		
1.5	Onboard device PDR, determine scope of non-flasher devices	Apr 2019	Done on time	
1.5	Final design reviews for onboard devices	Sep 2019	Done on time	
1.5	Onboard devices ready for integration into DOMs	Nov 2019	Done Jan 2020	
1.5	Preliminary design reviews for standalone devices	Nov 2019	Broken into individual devices, started on Oct 2019	Each was completed individually; last one was acoustics Summer 2020, except for Pencil Beam, expect Fall 2020
1.5	Final design review for standalone devices	Jul 2021		Expect this on time
1.5	Standalone devices delivered (shipping to SP)	Sep 2022		Expect this on time
1.5	Delivery of timing, geometry calibration	Mar 2023		Expect this on time
<b><i>Data Systems and M&amp;O Integration</i></b>				

1.6	Provide design verification simulation samples	Feb 2019	Done on time	
1.6	DAQ/experiment control/OM software interfaces defined	Jun 2019	Done Oct 2019	
1.6	NTS Upgrade computing infrastructure ready	Oct 2019	Done on time	
1.6	Provide software development tool support for Upgrade	Aug 2019	Done on time	
1.6	Minimal DAQ/experiment control ready for OM testing	Oct 2019	Done Jan 2020	
1.6	Testing DAQ/experiment control ready for FAT testing	Jan 2020	May 2020	Planned September 2020 ahead of D-Egg FAT
1.6	Core software (IceTray) upgraded to support new sensors	Jul 2020	Oct 2020	Planned for Oct – Nov 2020
1.6	Provide full as-designed simulation samples	Jan 2021		Expect on time
1.6	Online software ready for deployment in 2022/23 season	Nov 2022		Expect on time
1.6	SPS Upgrade computing infrastructure ready for use	Jan 2023		Expect on time
1.6	Provide full as-built simulation samples	Jul 2023		Expect on time

## Financial Plan

The following table shows the estimated cost for PY3 replan due to COVID-19, the original PY3 plan and the difference between them. As can be seen the estimated costs for labor, capital equipment and materials and supplies are expected to be higher due to delayed work.

It must be noted that the estimated cost are based on best estimates at this time assuming present conditions continue. Actual costs and variances will be analyzed and reported on a monthly basis.

This plan shows a possible shortfall in PY3 as compared to original project plan. The possible shortfall is being analyzed for how it may fit within overall project scope and performance baseline.

WBS	Replan PY3 due to COVID	PY3 original plan	Difference (Replan- original)
<b>1.1</b>	<b>\$ 1,282,773</b>	<b>\$ 1,307,190</b>	<b>\$ (24,417)</b>
Labor	\$ 1,200,614	\$ 1,216,746	\$ (16,132)
M & S	\$ 22,795	\$ 1,530	\$ 21,265
Travel	\$ 59,364	\$ 88,914	\$ (29,550)
<b>1.2</b>	<b>\$ 3,197,911</b>	<b>\$ 1,872,423</b>	<b>\$ 1,325,488</b>
CapEx	\$ 1,335,355	\$ 223,194	\$ 1,112,161
Labor	\$ 1,642,424	\$ 1,485,642	\$ 156,782
M & S	\$ 160,157	\$ 74,075	\$ 86,082
Travel	\$ 59,976	\$ 89,512	\$ (29,536)
<b>1.3</b>	<b>\$ 426,165</b>	<b>\$ 156,211</b>	<b>\$ 269,954</b>
CapEx	\$ 80,250	\$ 44,500	\$ 35,750
Labor	\$ 295,174	\$ 69,632	\$ 225,542
M & S	\$ 50,740	\$ 13,923	\$ 36,817
Travel	\$ -	\$ 28,156	\$ (28,156)
<b>1.4</b>	<b>\$ 855,164</b>	<b>\$ 658,543</b>	<b>\$ 196,621</b>
CapEx	\$ 407,890	\$ 336,701	\$ 71,189
Labor	\$ 366,853	\$ 255,313	\$ 111,540
M & S	\$ 33,063	\$ 22,105	\$ 10,958
Travel	\$ 47,358	\$ 44,424	\$ 2,934
<b>1.5</b>	<b>\$ 97,001</b>	<b>\$ 30,162</b>	<b>\$ 66,839</b>
CapEx	\$ 37,000		\$ 37,000
Labor	\$ 37,877	\$ 11,050	\$ 26,827
M & S	\$ 4,470	\$ 4,470	\$ -
Travel	\$ 17,654	\$ 14,642	\$ 3,012
<b>1.6</b>	<b>\$ 255,541</b>	<b>\$ 149,155</b>	<b>\$ 106,386</b>
CapEx	\$ 10,000		\$ 10,000
Labor	\$ 224,401	\$ 130,771	\$ 93,630
M & S	\$ 2,984	\$ 1,530	\$ 1,454
Travel	\$ 18,156	\$ 16,854	\$ 1,302
<b>Grand Total</b>	<b>\$ 6,114,554</b>	<b>\$ 4,173,684</b>	<b>\$ 1,940,871</b>

Preliminary

### WBS 1.2: Drilling and Installation

Enhanced Hot Water Drill repairs and upgrades continue in PY3 at the Physical Sciences Laboratory. Many tasks and procurements slated for completion in PY2 have been delayed as a result of Pandemic inefficiencies at PSL. Some efforts were shifted entirely to PY3. These include:

- Fuel tower upgrades
- Main drill cable procurement



- Refurbishment of main drill cable reel/winch
- Electrical Distribution System updates
- Subsystem assembly and testing
- DOM Handling Facility construction
- Repair component procurements

The design, construction, and testing of a hose reel heating system is well underway and will continue in PY3. The hose reel heating system will be used to maintain a consistent drill hose temperature when installed on the hose reel during overwinter storage at the South Pole. The system includes electric hose heating blankets, a controller, and a sensor package to provide status feedback using an IP address on the station intranet. Working with ASC IT, M & O winterovers will integrate the monitoring system into the South Pole Station intranet and test it.

Development, refurbishment, and testing of control system components including I/O boxes, E-stop boxes, network boxes, pendants, and motor drives as well as integrating them into the user interface will be a focus. EHWD control system includes the components in the Drill Control Center (DCC), Tower Operations Sites (TOS), High Pressure Pump (HPP), Pre-Heat System (PHS), and Main Heating Plants (MHP). Upgrades include simplified Input/Output and better organized wiring, adding a DGH-to-Ethernet gateway and an Ethernet switch to the system, and interfacing E-stops with network boxes. Networked I/O boxes feed data to motor drives from pendants, encoders, sensors, limit switches. The old I/O hardware is not compatible with new motor drives.

Cargo preparations activities will ramp up significantly in PY3. Much of this work was deprioritized with the FY20 summer descope. Crating and packing requires considerable labor resources and thus will be spread out as much as possible during the year to minimize impact on other PSL activities during this time of site personnel capacity limits.

### **WBS 1.3: Deep Ice Sensor Modules**

The series production and final acceptance testing of optical sensors will be the main focus in PY3. The Final Design Review and the pre-production of 50 D-Eggs by Nippon Marine Enterprises in Japan have been successfully completed in PY2. The final sealing of these D-Eggs was delayed due to COVID-19 delays in the Ice Comms Module. Preparation for Final Acceptance Testing of D-Eggs is well underway in Chiba and full production start is scheduled to commence in October 2020. We expect that 88 fully tested Integrated D-Eggs for the first two strings will be ready for shipping to South Pole in August 2021. Shipping plans, direct to Christchurch, are being finalized at the moment.

The readout electronics developed for the D-Egg in a modified layout will also be used to refurbish 20 original IceCube DOMs with Upgrade readout and communications electronics (PDOMs). The refurbishment and testing of the 20 PDOMs that will be used for cross calibration of IceCube Upgrade with the existing IceCube detector will be completed as planned in PY3.

The final design of the mDOM and the construction of the production and final acceptance test facilities are impacted by COVID-19. The Final Design Review of the integrated mDOM is now expected for November 2020. Vendors for all major mDOM components have been identified. Procurement plans and tender preparations are progressing as planned. The MSU production and testing facilities are almost

completed; construction of the DESY production and testing facilities have started with only minor delays. Production of mDOMs will ramp up early 2021 at the DESY production site and, in a staged approach, a few months later at the MSU production site.

The Ice Comms Module (ICM) resident in every in-ice device is a central part of the IceCube Upgrade communication system. Production of the ICM PCB assemblies is ongoing according to plan with only minor delays and will be completed in December 2020. The development of the ICM firmware “Golden Image”, a critical part of the communication system that cannot be updated after sealing of in-ice devices, has been strongly impacted by COVID-19 due to the reassignment of engineering resources at DESY. A strategy has been developed to minimize the impact of the ICM firmware delays on the Upgrade project and additional engineering resources have been allocated at WIPAC. The beginning of PY3 will see large efforts in development, testing and design verification of this important element.

#### **WBS 1.4: Communications, Power and Timing**

The primary focus of effort in Comms/Power/Timing systems in PY3 is the production of the surface cables and main (downhole) cables that will connect the in-ice instrumentation to the readout electronics in the ICL. The shorter surface cables will be produced during the winter of 2020/21 by Hexatronic, at the Swedish facility that fabricated the IceCube cables. Installation of the surface cables and junction boxes at South Pole is scheduled for the 21/22 season. A Request for Proposals for the longer main cable assemblies was issued at the end of PY2, with prototypes for mechanical and pressure testing planned for early PY3. A first article main cable assembly will be completed and tested in summer 2021, with production of the remaining main cable assemblies to follow in late PY3 and PY4.

Production of the penetrator cables (the pigtail connectors that are integrated into the DOMs and other instruments) is ongoing and will be completed in PY3. Designs for the remaining cable elements — the patch panels and cables to be installed inside ICL, and the breakout cable assemblies that will connect the main cables to 4-6 in-ice instruments — will be completed and tested in PY3, with procurement and production to follow in PY4. Following a successful preliminary design review in PY2, final design and production of the power control and distribution system will take place in PY3.

Fabrication of the “mini-FieldHub” readout electronics modules for DOM development and final acceptance testing was completed at the end of PY2, and FieldHub driver software with basic communications functionality will be released in early PY3 to support FAT. This will later be expanded to add slow control, time calibration, and interface functionality for higher-level DAQ software, in parallel with ICM and FieldHub firmware development. Some additional design work on the production FieldHub modules to be installed at South Pole will take place in PY3, with final design and production to follow in PY4. Room renovations for the Northern Test System and network connections to SPTS were completed in PY2, although commissioning of NTS was delayed due to campus occupancy restrictions and COVID-19 impact on DEgg production. NTS commissioning is now expected early in PY3.

#### **WBS 1.5: Characterization and Calibration Systems**

Calibration instruments in mDOMs and D-eggs (cameras and LED flashers): PY3 will see widespread testing of LED flasherboards and cameras prior to integration into mDOMs and D-eggs, and Final Acceptance Testing (FAT) of the first batch of integrated mDOMs and D-eggs. The tests performed prior to integration will be detailed tests of functionality, whereas the scope of FAT testing will be limited to basic functionality. A major focus will be finalizing the software for automating these tests and ensuring

integration of the results into the central database. Testing of the first mDOM flashers is underway and any resulting final changes to the mDOM flasher design will also be made in PY3 prior to mass production.

Standalone calibration instruments: The mini-mainboard, an electronics motherboard for standalone calibration devices and special photosensors, will undergo testing of the initial articles and design review in PY3. The production plan for the mini-mainboard will be finalized when we determine whether the mini-mainboards will all be manufactured in Europe or whether some will be manufactured in the U.S. The standalone calibration devices: the Acoustic Module, the Precision Optical Calibration Module (POCAM) and the PencilBeam will undergo final design review in PY3 (Level 1 Milestone). The Acoustic Module and POCAM have already exited preliminary design review; the PDR for the PencilBeam will be held in PY3.

Dust Logger: A major focus in PY3 will be planning dust logging operations for the IceCube Upgrade. We plan to use the existing Oriented Dust Logger (which has been previously used in the SPICEcore borehole near the Gen1 detector). The logger hardware will be tested in PY3 with updated depth measurement sensors and a new cable, since the existing cable for SPICEcore is not long enough to log the upgrade borehole. We will also determine whether we can use the existing winch or need to purchase a new winch.

### **WBS 1.6: Data Systems Integration**

For PY3, a major focus in WBS 1.6 remains on continued development of software to support the testing of new module types as they are delivered from across the project. First, the start of mass production of sealed D-Egg modules and the start of FAT testing prior to shipment will begin in earnest this year. Software systems to support FAT testing are currently being delivered and tested, but continued support once widespread testing is underway is expected. Furthermore, this project year sees the maturation of mDOM mainboard designs and production of DVT modules, as well as special calibration devices that use the mini-mainboard. These new hardware systems will require modification to verification and testing software suites developed with the DEgg testing effort and will be a priority this project year.

Additionally, work begins in this project year toward preparations of higher-level software systems to support the deployed modules at the South Pole. These include extensions to the data acquisition, experiment control and online filtering systems to handle data from the newly expanded detector array. These changes are planned to use some ongoing refactoring of our current online systems to make them less specialized to IceCube Gen1 DOMs. Similar work is also underway within the IceCube data analysis and simulation toolsets, where the inclusion of D-Egg, mDOM and calibration devices to high fidelity as-designed is underway. All this work prepares the IceCube data flow to be ready to include readouts from the newly deployed instrumentation at project completion.

Due to COVID-19, a few items have been pushed back from PY2. Most notable are some testing hardware purchases for the South Pole Test System (SPTS) software test stand due to time constraints for the primary system admin and winterover manager. As the high-level integration effort at SPTS is getting underway in PY3, this delay has limited impact on software development and testing.