

IceCube Upgrade Sensor Modules

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WBS 1.3

ICNO/Upgrade Project – NSF Site Visit Review

March 17, 2020



Outline

- Scope, Deliverables, and Organization
- Key Requirements
- Schedules, Milestones and Key Activities
- Cost Estimate and In-Kind Contributions
- Risks and Mitigation
- Technical Progress and Reviews
- Remaining Issues and Challenges
- Summary

WBS 1.3 Scope (Unchanged)

- This element is responsible for the **design and production of the deep-ice optical sensor modules**. The modules connect mechanically and electrically to the downhole cable assembly (WBS 1.4.1) and shall communicate with the Field Hub (WBS 1.4.3). The modules must provide interfaces for calibration assemblies (WBS 1.5.2) and shall support in-situ calibration (WBS 1.5.1). **Deliverables are up to 1000 deployment-ready optical sensors** that meet the high-level design requirements of the IceCube Upgrade.

WBS 1.3 Deliverables



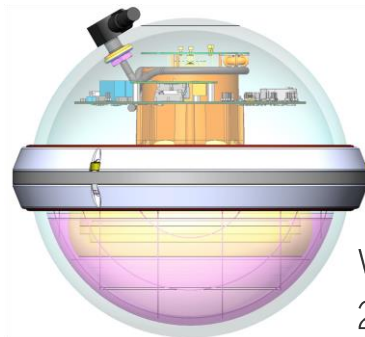
WBS 1.3.1
430 mDOMs



WBS 1.3.2
300 D-Eggs



WBS 1.3.4
900 Ice Comms Modules

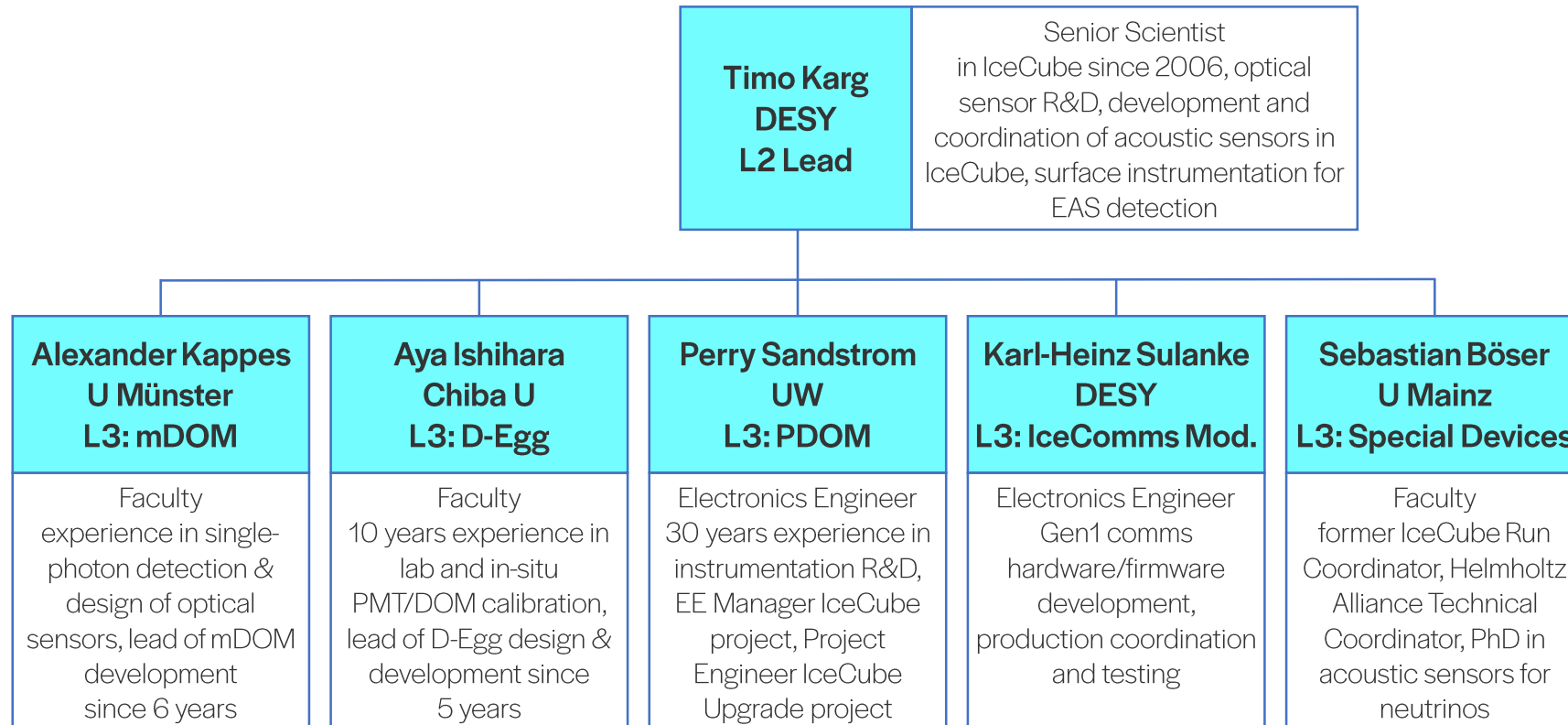


WBS 1.3.3
20 Refurbished IceCube DOMs



WBS 1.3.5
Coordination of R&D Sensors

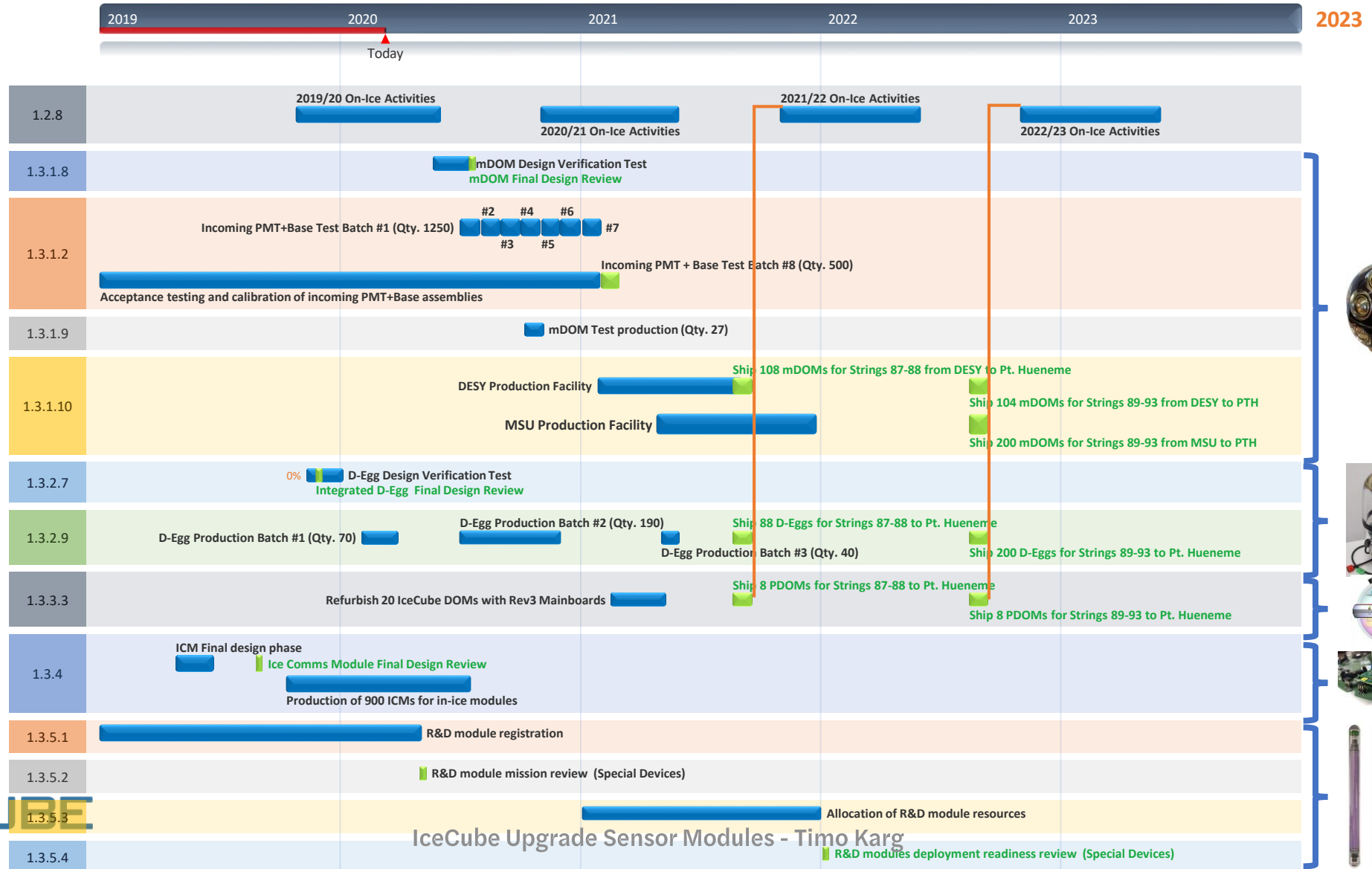
WBS 1.3 Organization (Unchanged)



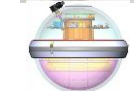
WBS 1.3 Key Requirements (Unchanged)

- Single photon detection
 - Record single photon events (SPE)
 - SPE capability is needed for overall sensitivity, esp. at low energies, testing, and calibration
 - Verification Method: controlled test
- SPE time resolution
 - Timestamp the leading edge of an SPE with a precision of 5 ns or better
 - System timing resolution is directly related to event reconstruction quality
 - Verification Method: controlled test
- Dynamic range
 - Trigger on and record PMT signals ranging from 0.2 p.e. / 15 ns to ≥ 200 p.e. / 15 ns
 - Provides dynamic range capability
 - Verification Method: controlled test
- Pulse pair resolution
 - Resolve pulses separated by 10 ns or more as individual pulses
 - Needed for double pulse events
 - Verification Method: controlled test
- All SPE to surface
 - Timely transmit all SPE signals to the surface DAQ (no local coincidences on the DOM)
 - SPE signals are required for forming triggers, esp. at low energies
 - Verification Method: demonstration
- Reliability
 - Integrated MTBF (mean time before failure) must be ≥ 20 years
 - Significant fraction of DOMs must survive the whole lifetime of the experiment
 - Verification Method: analysis of MTBF of DOM components

WBS 1.3 Schedule



IceCube Upgrade Sensor Modules - Timo Karg



WBS 1.3 Milestones and Key Activities

WBS	Milestone or Activity	Scheduled Finish Date	Forecast Date (Actual if Finished)	Margin (Days)
1.3.1.10	*mDOMs for Strings 87, 88 delivery to Pt. Hueneme	08/20/21	05/18/21	94
1.3.2.9	*D-Eggs for Strings 87, 88 delivery to Pt. Hueneme	08/20/21	01/22/21	210
1.3.3.3	*Refurbished IceCube DOMs for Strings 87, 88 delivery to Pt. Hueneme	08/20/21	03/26/21	147
1.3.1.10	*mDOMs for Strings 89 to 93 delivery to Pt. Hueneme	08/15/22	12/22/21	236
1.3.2.9	*D-Eggs for Strings 89 to 93 delivery to Pt. Hueneme	08/15/22	07/09/21	402
1.3.3.3	*Refurbished IceCube DOMs for Strings 89 to 93 delivery to Pt. Hueneme	08/15/22	03/26/21	507

*Late finish directly delays project schedule

WBS 1.3 Milestones and Key Activities

WBS	Milestone or Activity	Scheduled Finish Date	Forecast Date (Actual if Finished)	Margin (Days)
1.3.2.8	D-Egg production test complete	02/25/19	02/26/19	-1
1.3.4.12	Start of production of Ice Comms Modules	10/11/19	12/02/19	-52
1.3.2.7	D-Egg final design review exit	11/25/19	02/14/20	-81
1.3.2.9	Start of D-Egg production	02/03/20	02/17/20	-14
1.3.5.2	Special Devices mission review	05/01/20	05/09/20	-8
1.3.1.8	mDOM final design review exit	07/15/20	08/15/20	-31
1.3.1.10	Start of mDOM production	01/27/21	01/27/21	0
1.3.5.4	Special Devices deployment readiness review	01/03/22	01/03/22	0
1.3.3.3	Start of refurbishment of IceCube DOMs	02/15/21	02/15/21	0

*Late finish directly delays project schedule

WBS 1.3 NSF Supported Cost Estimate to L3

1.3 Deep Ice Sensors	Project Year					WBS Total
	Year 1* Actuals	Year 2	Year 3	Year 4	Year 5	
1.3.1 mDOM	\$37,359	\$118,959	\$3,222	\$0	\$0	\$122,181
Labor		\$81,354	\$0	\$0	\$0	\$81,354
M & S		\$4,768	\$0	\$0	\$0	\$4,768
Travel		\$32,837	\$3,222	\$0	\$0	\$36,059
1.3.2 D-Egg	\$19,378	\$77,851	\$0	\$0	\$0	\$77,851
Labor		\$66,965	\$0	\$0	\$0	\$66,965
Travel		\$10,887	\$0	\$0	\$0	\$10,887
1.3.3 PDOM	\$24,177	\$160,077	\$102,100	\$0	\$0	\$262,177
CapEx		\$36,500	\$39,828	\$0	\$0	\$76,328
Labor		\$64,560	\$39,755	\$0	\$0	\$104,315
M & S		\$53,509	\$12,461	\$0	\$0	\$65,971
Travel		\$5,508	\$10,056	\$0	\$0	\$15,564
1.3.5 Special Devices	\$12,205	\$88,130	\$37,709	\$40,829	\$0	\$166,668
Labor		\$72,830	\$22,566	\$24,432	\$0	\$119,828
M & S		\$15,300	\$0	\$0	\$0	\$15,300
Travel		\$0	\$15,143	\$16,397	\$0	\$31,540
Annual Total	\$93,119	\$445,018	\$143,031	\$40,829	\$0	\$628,878

* - Year 1 is not included in totals

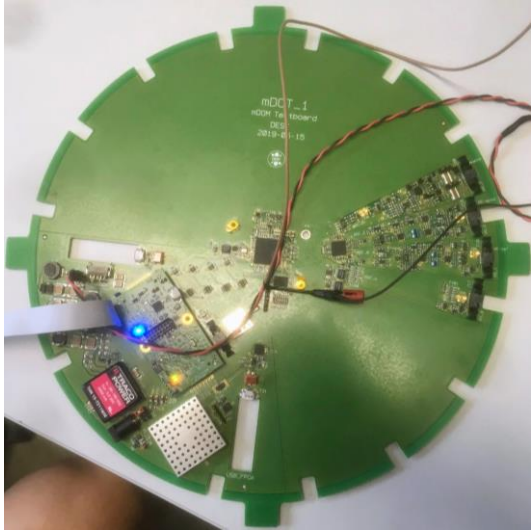
WBS 1.3 Contributions in Kind

WBS	Contribution
1.3.1 mDOM	Integrated mDOM Design (Münster) mDOM Readout Design (DESY) mDOM Harness Design (Wuppertal) mDOM Flasher Production (Mainz) (in WBS 1.5) mDOM Production Facility (DESY) mDOM Production Facility (MSU)
to be assembled at DESY and MSU	→ [10,000 mDOM PMTs (KIT) Remaining parts for 430 mDOMs (DESY) Incoming PMT Acceptance Testing (Aachen, Dortmund, Wuppertal)
1.3.2 D-Egg	300 Integrated D-Eggs (Chiba)
1.3.4 Ice Comms Module	900 ICMs (DESY)

WBS 1.3 Risks and Mitigation

- Higher than expected residual radioactive contamination in glass pressure vessels
 - Monitor manufacturing and test samples at prototype stage
 - May require additional firmware engineering to increase bandwidth
- Hamamatsu starts production of PMTs + μ Base assemblies before full base testing is completed
 - Work with Hamamatsu for a partial production plan to minimize cost impact if different base design required
 - Expedite testing
 - Improve communication between project and Hamamatsu
- One of the planned sensor types does not pass FDR as scheduled
 - Design and plan the production capacity of all production facilities with sufficient flexibility to be able to fall back to a different OM type
- Unable to procure sufficient number of PMTs
 - Qualify alternate PMT manufacturers
 - Keep close contact with Hamamatsu and other experiments using large numbers of PMTs

WBS 1.3 mDOM and D-Egg Development Status



mDOM Test
Mainboard (mDOT)



Ice Comms Module on D-Egg Mainboard

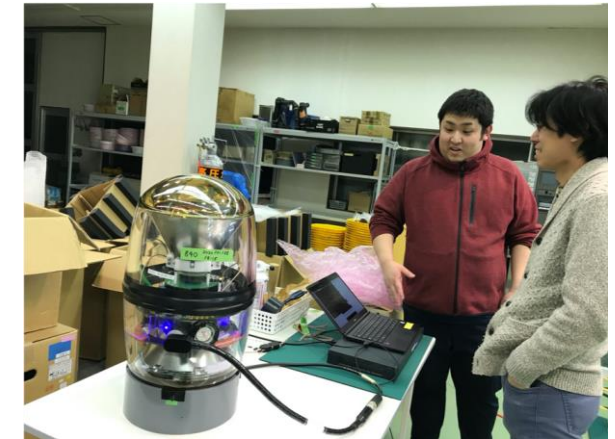


D-Egg Rev. 3
Mainboard



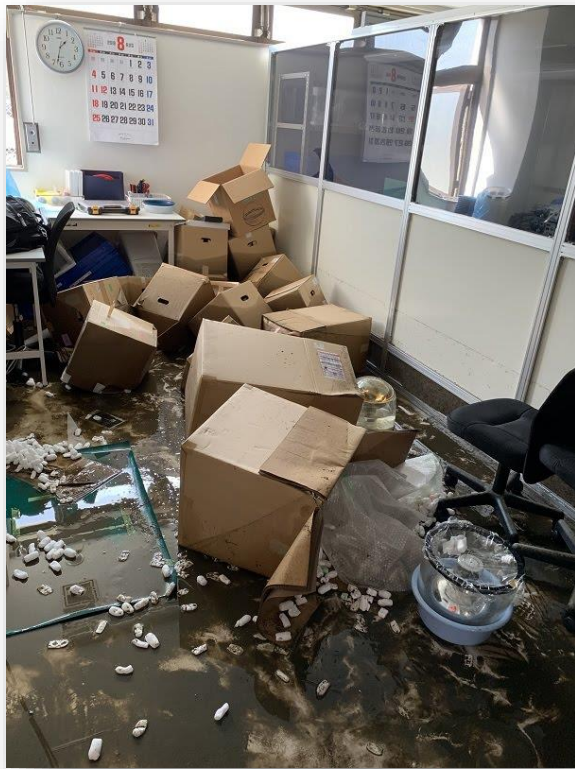
Hamamatsu R15458-20
PMT+ μ Base Assembly

Full DAQ-chain demonstration
w/ Integrated D-Egg



WBS 1.3 D-Egg Production Site Status

Excellent and Fast Recovery of D-Egg Integration Facility After Typhoon Incident



09 / 2019
11 / 2019
clean room in new building

01 / 2020
integration of
design verification modules

WBS 1.3 Previous and Future Reviews

- 09 / 2018 D-Egg Review (PMT + Pressure Vessel FDR) [report](#)
- 12 / 2018 mDOM Review (Mechanics PDR) [report](#)
- 04 / 2019 D-Egg High Voltage Subsystem Review (PDR) [report](#)
- 06 / 2019 D-Egg Various Subsystems Review (informal) [report](#)
- 08 / 2019 mDOM & ICM Review (mDOM Electronics PDR & ICM FDR) [report](#)
- 12 / 2019 mDOM High Voltage Subsystem Review (informal) [report](#)
- 02 / 2020 Integrated D-Egg FDR [report](#)
- 05 / 2020 Special Devices Mission Review
- 07 / 2020 Integrated mDOM FDR
- 09 / 2020 D-Egg Production Readiness Review
- 12 / 2020 mDOM Production Readiness Review
- 01 / 2021 PDOM Final Design Review
- 01 / 2022 Special Devices Deployment Readiness Review

WBS 1.3 Remaining Issues and Challenges

- Ambitious overall D-Egg schedule allows for no slack in hardware development
 - Requires front-loading of significant parts of firmware and software development
- mDOM Mainboard and ICM development are both time critical and share the same resources
 - Mitigation: new lead firmware-developer for ICM identified
- Communication and timing system spans WBS 1.3, 1.4, and 1.6 and corresponding labor is very distributed
 - Mitigation: improved coordination for D-Egg FAT over L2 areas

WBS 1.3 Summary

- WBS 1.3 will deliver the optical sensors for the IceCube Upgrade
- mDOM and D-Egg are the two major sensor designs
 - D-Egg Final Design Review passed, ramping up production
 - mDOM Final Design Review expected this summer
- Unified communication module for in-ice devices (ICM)
 - Hardware design verified and in production
 - Delays in firmware development identified and being addressed

Backup

1.3. Deep Ice Sensor Modules

