IceCube Upgrade
M&O Data Systems Integration

Erik Blaufuss

WBS # 1.6

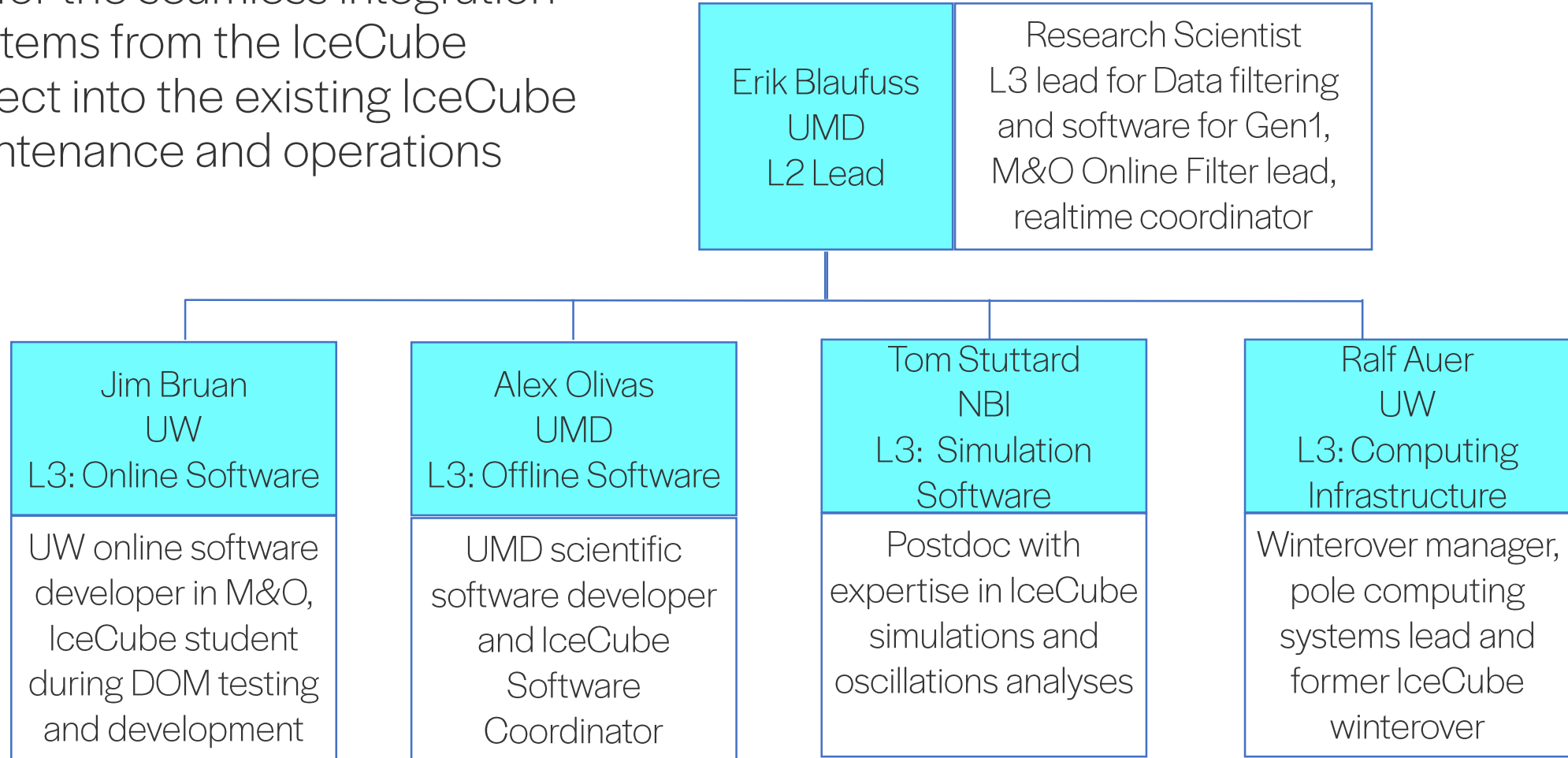ICNO/Upgrade Project – NSF Site Visit Review

March 17, 2020

Outline

- Scope and organization

- Key Requirements

- Schedule and progress

- Key activities and milestones

- Project costs and in-kind contributions

- Technical progress and system reviews

- Issues and challenges

- Summary

WBS 1.6 Scope and Organization

- Responsible for the seamless integration of all new systems from the IceCube upgrade project into the existing IceCube detector maintenance and operations structures

Erik Blaufuss UMD L2 Lead	Research Scientist L3 lead for Data filtering and software for Gen1, M&O Online Filter lead, realtime coordinator

Jim Bruan UW L3: Online Software	Alex Olivas UMD L3: Offline Software	Tom Stuttard NBI L3: Simulation Software	Ralf Auer UW L3: Computing Infrastructure
UW online software developer in M&O, IceCube student during DOM testing and development	UMD scientific software developer and IceCube Software Coordinator	Postdoc with expertise in IceCube simulations and oscillations analyses	Winterover manager, pole computing systems lead and former IceCube winterover

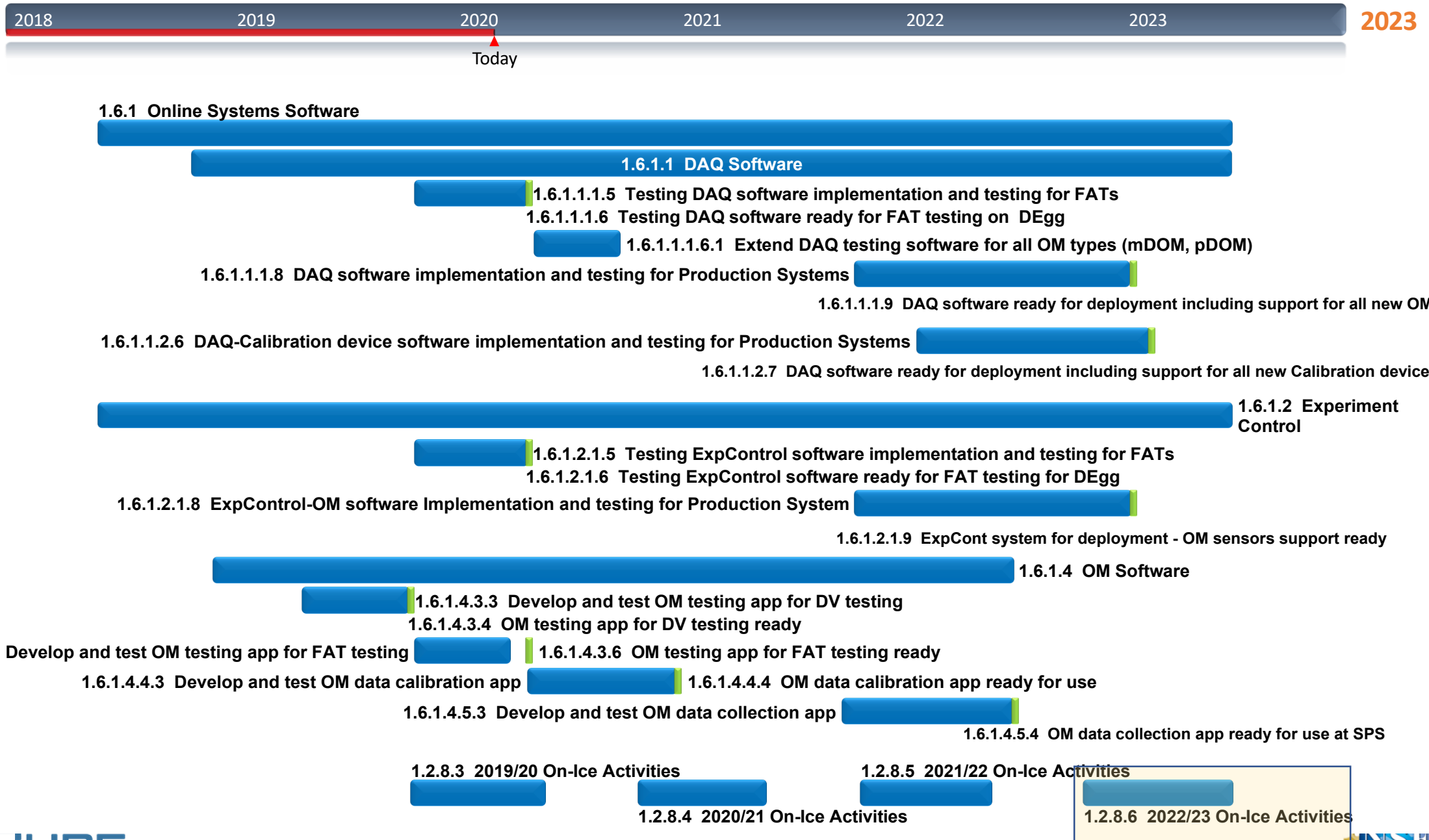# WBS 1.6 Key Requirements

- Deliver a unified online treatment of new OM sensors
  - New OMs added as "additional DOMs" for online systems
  - Provide critical interfaces to high-level DAQ with uniform In-OM software
  - Avoid additional processing/merging steps
  - Reduced long-term support by maintaining single systems
- Deliver a uniform treatment of real and simulated data
  - Single uniform data stream available for physics analyses
  - Data structures, algorithms, calibration and meta-data information naturally include new OMs
  - Optimize use of new data in analyses by collaboration
- Calibration devices added fully under IceCube DAQ/Experiment control
  - "LID" labels prevent interference from calibration activity in analysis data samples
  - Avoids alternative control systems for light-producing devices that we had in Gen1
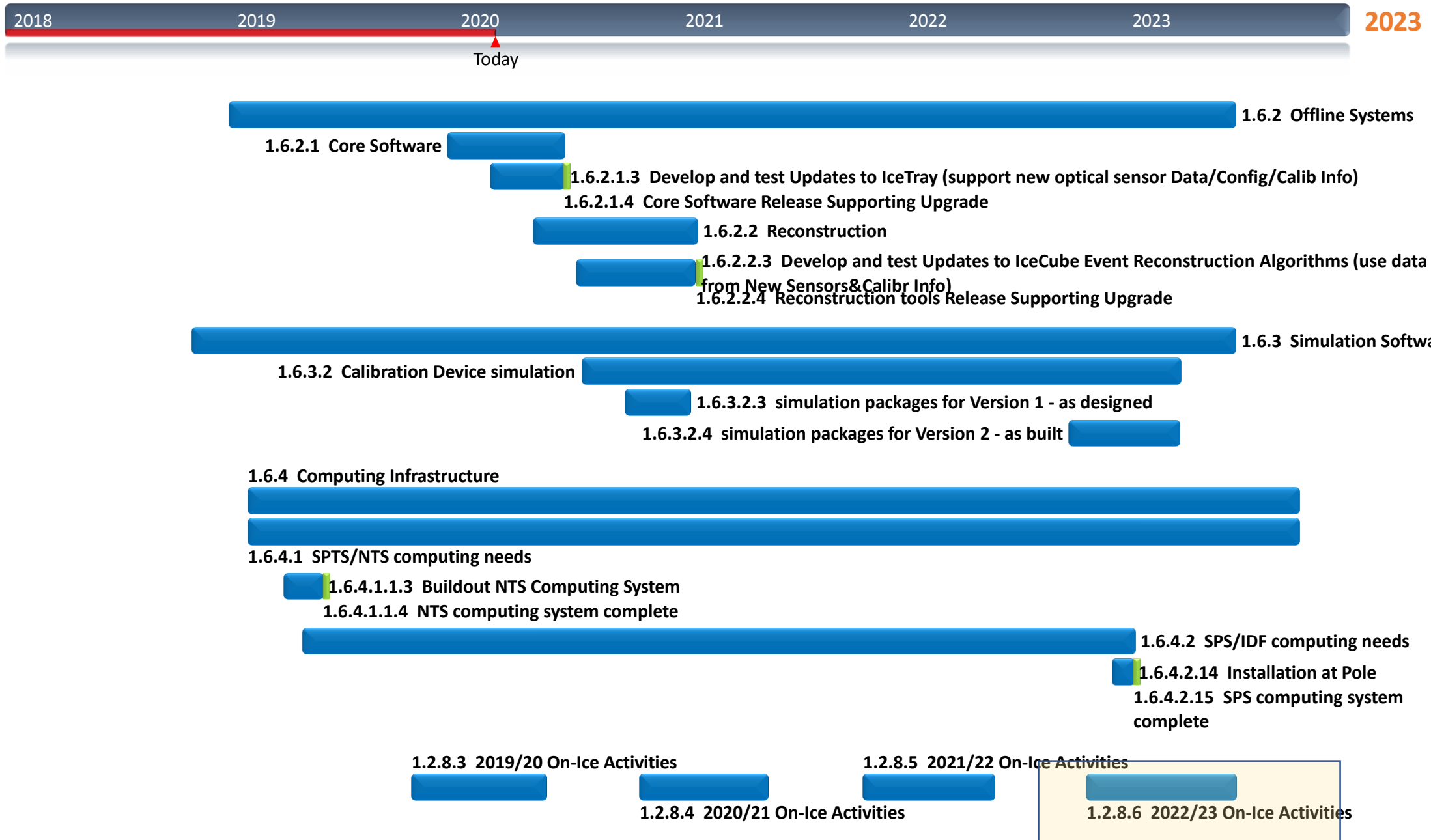
WBS 1.6 Key Interfaces

WBS 1.6 is an area where data interfaces from several Upgrade areas comes together

- WBS 1.3 Sensors
  - OM Software/Hardware level interfaces
    - Calibration/configuration items needed in operation
  - IceCube Communications Module - On-OM software and DAQ interfaces
  - OM hardware details and performance for detailed system simulation
- WBS 1.4 CPT
  - DAQ interface to Field Hub, timing infrastructure and cable systems
  - Shared responsibility to build-out test systems
- WBS 1.5 Calibration devices
  - DAQ/Experiment control of all calibration devices
    - Calibration/configuration items needed in operation
  - Calibration hardware details and performance for detailed system simulation

WBS 1.6 Schedule

2018 — **2019** — **2020** — **2021** — **2022** — **2023** — **2023**

Today

1.6.1

1.6.1 Online Systems Software

1.6.1.1 DAQ Software

1.6.1.1.1.5 Testing DAQ software implementation and testing for FATs

1.6.1.1.1.6 Testing DAQ software ready for FAT testing on DEgg

1.6.1.1.1.6.1 Extend DAQ testing software for all OM types (mDOM, pDOM)

1.6.1.1.1.8 DAQ software implementation and testing for Production Systems

1.6.1.1.1.9 DAQ software ready for deployment including support for all new OMs

1.6.1.1.2.6 DAQ-Calibration device software implementation and testing for Production Systems

1.6.1.1.2.7 DAQ software ready for deployment including support for all new Calibration devices

1.6.1.2 Experiment Control

1.6.1.2.1.5 Testing ExpControl software implementation and testing for FATs

1.6.1.2.1.6 Testing ExpControl software ready for FAT testing for DEgg

1.6.1.2.1.8 ExpControl-OM software Implementation and testing for Production System

1.6.1.2.1.9 ExpCont system for deployment - OM sensors support ready

1.6.1.4 OM Software

1.6.1.4.3.3 Develop and test OM testing app for DV testing

1.6.1.4.3.4 OM testing app for DV testing ready

1.6.1.4.3.5 Develop and test OM testing app for FAT testing   **1.6.1.4.3.6 OM testing app for FAT testing ready**

1.6.1.4.4.3 Develop and test OM data calibration app   **1.6.1.4.4.4 OM data calibration app ready for use**

1.6.1.4.5.3 Develop and test OM data collection app

1.6.1.4.5.4 OM data collection app ready for use at SPS

1.2.8

1.2.8.3 2019/20 On-Ice Activities   **1.2.8.5 2021/22 On-Ice Activities**

1.2.8.4 2020/21 On-Ice Activities   **1.2.8.6 2022/23 On-Ice Activities**

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NSF

WBS 1.6 Schedule

2018 | 2019 | 2020 | 2021 | 2022 | 2023 | **2023**

Today

1.6.2

1.6.2 Offline Systems

1.6.2.1 Core Software

1.6.2.1.3 Develop and test Updates to IceTray (support new optical sensor Data/Config/Calib Info)

1.6.2.1.4 Core Software Release Supporting Upgrade

1.6.2.2 Reconstruction

1.6.2.2.3 Develop and test Updates to IceCube Event Reconstruction Algorithms (use data from New Sensors&Calibr Info)

1.6.2.2.4 Reconstruction tools Release Supporting Upgrade

1.6.3

1.6.3 Simulation Software

1.6.3.2 Calibration Device simulation

1.6.3.2.3 simulation packages for Version 1 - as designed

1.6.3.2.4 simulation packages for Version 2 - as built

1.6.4

1.6.4 Computing Infrastructure

1.6.4.1 SPTS/NTS computing needs

1.6.4.1.1.3 Buildout NTS Computing System

1.6.4.1.1.4 NTS computing system complete

1.6.4.2 SPS/IDF computing needs

1.6.4.2.14 Installation at Pole

1.6.4.2.15 SPS computing system complete

1.2.8

1.2.8.3 2019/20 On-Ice Activities

1.2.8.5 2021/22 On-Ice Activities

1.2.8.4 2020/21 On-Ice Activities

1.2.8.6 2022/23 On-Ice Activities

UPGRADE

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WBS 1.6 Milestones and Key Activities

WBS	Milestone or Activity	Scheduled Finish Date	Forecast Date (Actual if Finished)	Margin (Days)
1.6.3	Provide design verification simulation samples	1/31/19	1/31/19	-
1.6.1	DAQ/experiment control/OM software interfaces defined	6/30/19	9/15/19	-
1.6.4	NTS Upgrade computing infrastructure ready	6/30/19	9/30/19	-
1.6.2	Provide software development tool support for Upgrade	7/30/19	7/30/19	-
1.6.1	Minimal DAQ/experiment control ready for OM testing (DEgg DVT)	10/21/19	2/15/19	-
1.6.1	*Testing DAQ/experiment control ready for DEgg FAT testing	6/15/20	5/1/20	45
1.6.1	*Extend testing DAQ for FAT to all sensor types	11/30/20	10/1/20	60
1.6.2	Core software (IceTray) upgraded to support new sensors	9/30/20	6/29/20	90
1.6.3	Provide full as-designed simulation samples	9/23/21	1/21/21	240
1.6.1	*Online software ready for deployment in 2022/23 season	5/1/23	2/10/23	80
1.6.1	Production In-DOM software ready for Pole season	9/30/22	7/6/22	90
1.6.4	*SPS Upgrade computing infrastructure ready for use	2/15/23	1/16/23	30
1.6.3	*Provide full as-built simulation samples	9/30/23	6/30/23	90

*Late finish directly delays project schedule

WBS 1.6 NSF Supported Cost Estimate at L3

1.6 IceCube Data Systems Integration	Project Year					
WBS L3	Year 1* Actual	Year 2	Year 3	Year 4	Year 5	WBS Total
1.6.0 Management and Engineering	**$0**	**$80,028**	**$59,977**	**$64,936**	**$54,866**	**$259,806**
Labor Hours		$68,904	$47,456	$51,381	$52,132	$219,873
Travel		$11,124	$12,520	$13,556	$2,734	$39,934
1.6.1 Online System Software	**$43,803**	**$239,633**	**$54,030**	**$96,626**	**$13,840**	**$404,130**
Labor Hours		$233,360	$50,781	$93,137	$11,240	$388,518
M & S		$765	$685	$3,489	$723	$5,662
Travel		$5,508	$2,564	$0	$1,878	$9,950
1.6.2 Off-line Systems	**$0**	**$22,769**	**$9,707**	**$10,510**	**$10,663**	**$53,649**
Labor Hours		$22,769	$9,707	$10,510	$10,663	$53,649
1.6.3 Simulation Software	**$0**	**$8,923**	**$9,095**	**$9,847**	**$9,991**	**$37,856**
Labor Hours		$8,923	$9,095	$9,847	$9,991	$37,856
1.6.4 Computing Infrastructure	**$1,021**	**$12,754**	**$0**	**$18,841**	**$0**	**$31,595**
CapEx		$10,000	$0	$9,500	$0	$19,500
Labor Hours		$0	$0	$6,565	$0	$6,565
Annual Total	**$44,824**	**$361,352**	**$132,809**	**$197,984**	**$89,361**	**$781,506**

* - Year 1 is not included in totals

WBS 1.6 Contributions in Kind

- Much of the planned work in 1.6 focuses on integrating with existing IceCube systems from M&O and the collaboration
  - Upgrade budget focused on new software (in OM) and hardware to support Upgrade work
  - All activities (in-kind with no cost) tracked in integrated project schedule with low-level milestones tracking delivery

- IceCube M&O provides in-kind support for:
  - DAQ, Experiment Control, Online filtering system updates needed to support IceCube Upgrade hardware inclusion
  - Core offline software, software development and computing infrastructure.

- IceCube collaboration provides in-kind support for:
  - Simulation and reconstruction software development

WBS 1.6 Risks and Mitigation

- Most risks in this area focus on schedule delays in other areas and their impact on scheduled work
  - Delays in delivery of new hardware/software for testing

- To mitigate impacts, designs are factored to reduce dependencies between design details
  - Established shared testing setups to effectively share development/prototype hardware
    - DRTS system at UW
  - Focus on robust interfaces that work across multiple types of hardware
    - DEgg software will not be totally recreated for mDOM, pDOM, calibration devices
  - Prioritize communication between technical work groups
    - Small group, topical phone calls (low level DAQ) and wider calls (Tech Board) effective.

In-DOM software

Most Upgrade DAQ software development so far has focused on the embedded software needed to readout and control the built-in items that are planned for OM mainboards.

- FPGA firmware and embedded programs for microcontroller.
- Focus so far has been on D-Egg mainboard and components
  - Extensions planned to mDOM and mini-Mainboard systems as they become
- More information is [here](#) and [here](#)

DRTS selfie taken with embedded camera system.

DVT software for D-Eggs

Half D-Egg sq0290
V_Cntl = 3.6
Peak to Valley = 5.4077

[Presentation](#) Colton Hill - Chiba
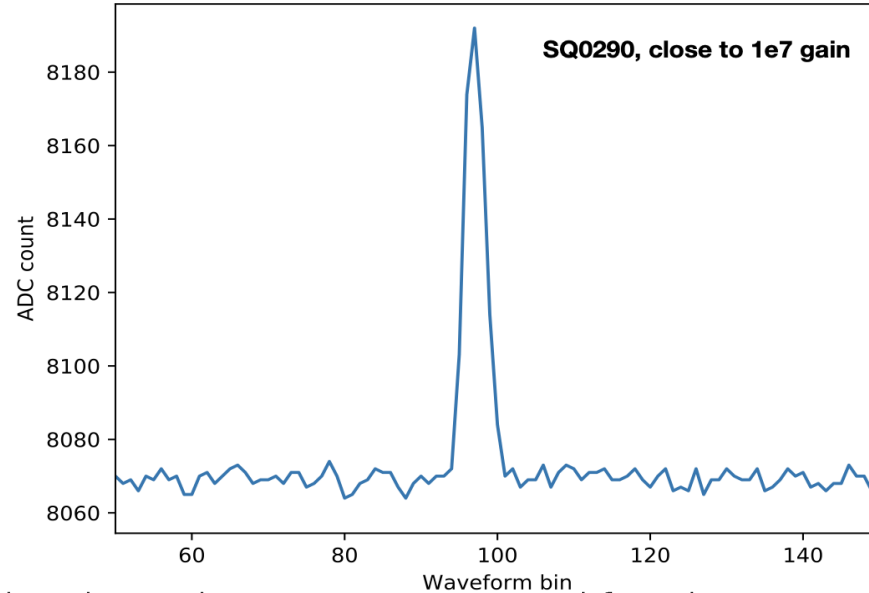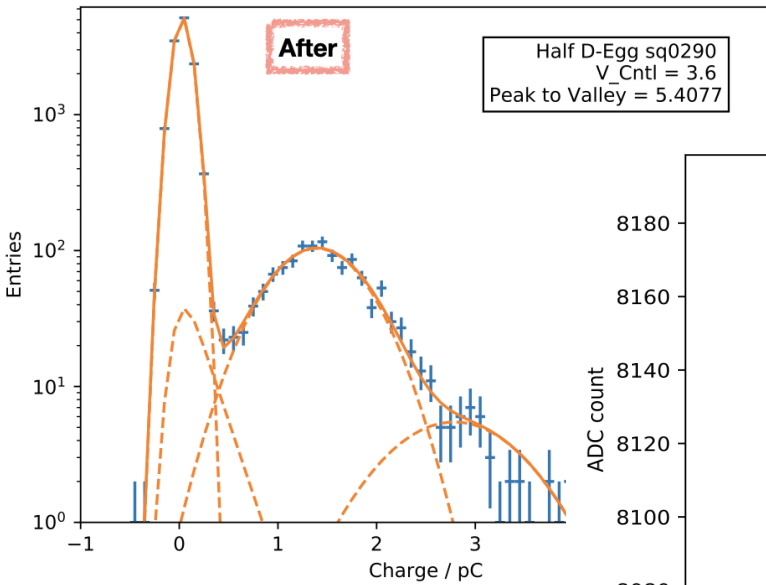
SQ0290, close to 1e7 gain

```
(env3) blaufuss@bender[stf]% python runset.py I2C_Sensors --host localhost --port 5012
Starting test run with iceboot settings:
        host=localhost
        port=5012
        debug=False
New IceBoot session: FPGA version ffff Software version 1b beccc83 Tue Feb 11 16:52:17 2020 -0600
INFO >>> Running AccelerometerSensor:base
New IceBoot session: FPGA version ffff Software version 1b beccc83 Tue Feb 11 16:52:17 2020 -0600
INFO >>> checking flash for /Users/blaufuss/icework/STMWorkspace/stf/data/degg_fw_v0x101.rbf ... stat
INFO >>> checkCommsAndFirmware -> configuring fw file from flash: degg_fw_v0x101.rbf)
INFO >>> tearing down ... initiating reboot()

========= test: AccelerometerSensor  outcome: PASS =========

INFO >>> Finished AccelerometerSensor
INFO >>> Running MagnetometerSensor:base
New IceBoot session: FPGA version ffff Software version 1b beccc83 Tue Feb 11 16:52:17 2020 -0600
[-1.29494e-05, 4.72815e-05, -3.1979e-05]

============ test: Magnetometer  outcome: PASS ============

INFO >>> Finished Magnetometer
INFO >>> Running PressureSensor:base
New IceBoot session: FPGA version ffff Software version 1b beccc83 Tue Feb 11 16:52:17 2020 -0600

============ test: PressureSensor  outcome: PASS ============

INFO >>> Finished PressureSensor
INFO >>> Running TempAccelerometerSensor:base
New IceBoot session: FPGA version ffff Software version 1b beccc83 Tue Feb 11 16:52:17 2020 -0600

======= test: TempAccelerometerSensor  outcome: PASS =======

INFO >>> Finished TempAccelerometerSensor
INFO >>> Running TempMagnetometerSensor:base
New IceBoot session: FPGA version ffff Software version 1b beccc83 Tue Feb 11 16:52:17 2020 -0600

======= test: TempMagnetometerSensor  outcome: PASS =======

INFO >>> Finished TempMagnetometerSensor
INFO >>> Running TempPressureSensor:base
New IceBoot session: FPGA version ffff Software version 1b beccc83 Tue Feb 11 16:52:17 2020 -0600

========= test: TempPressureSensor  outcome: PASS =========
```

We have ~10 DEggs that have been constructed for design verification testing software prepared
- Electrical performance (MB electrical performance, digitizer and power noise,etc)
- Physics response (SPE and large pulse responses)

Offline Software

Focus on adding upgrade system support to software used to analyze events (IceTray, reconstruction, etc)

- Core Software
  - Add needed support in IceTray for new sensors and devices, including data structures, calibration and configuration information available to analyzers, decoding software for raw data readout formats
  - All combo projects need to make sure they are prepared to process data from non-DOMs
    - Alex Olivas pushing this effort over next combo release cycles
    - Task list: https://wiki.icecube.wisc.edu/index.php/Upgrade_Task_List
- Reconstruction software
  - Improve reconstruction software to take full use of new sensort/devices in event reconstruction algorithms
  - Longer term focus…
- Simulation - Ensure new systems are accurately simulated
  - Focus now on simulating the details of newly designed electronics

Computing Infrastructure

Provide computing systems needs (including COTS hardware, networking and admin tasks) to support new systems

- SPTS/NTS - computing needs for northern test systems
    - NTS: Upgrade focused testing system at MSU for testing OM/calibration devices
        - Cable+OM+surface electronics
        - Fully integrated into existing SPTS system
    - Able to perform full system integration testing
- SPS - computing needs for ICL computer systems at Pole
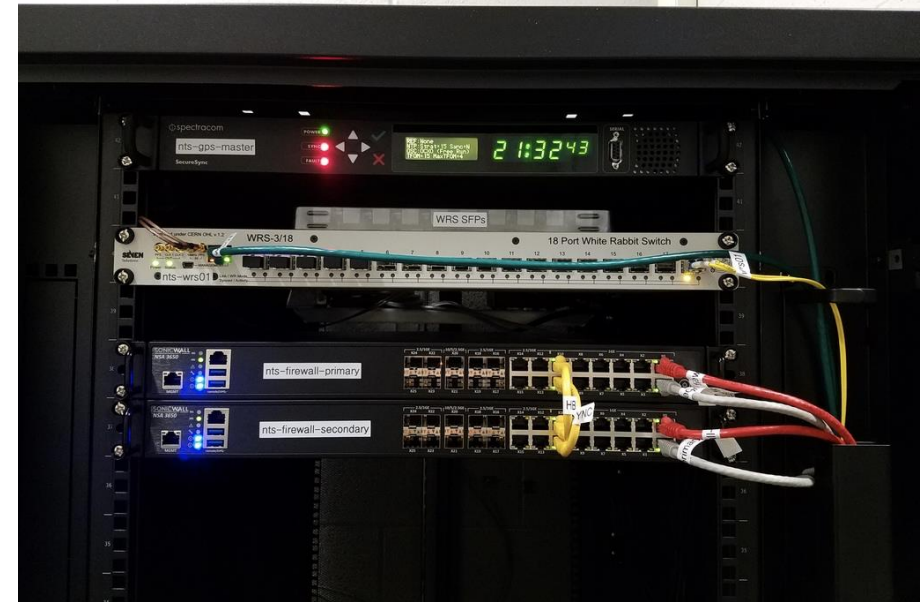
WBS 1.6 Previous and Future Reviews

- Software is a critical part of many hardware systems, and software designs are often reviewed as part of individual system reviews.
  - Calibration device review (Oct 2019)

- Additionally, we are planning to review the high-level integration plans for Upgrade components into existing IceCube systems, including:
  - In-OM operating software (mid 2021)
  - IceCube DAQ and online systems (late 2021)

- Other systems will be reviewed as part of their ongoing development within IceCube technical groups
  - Core software systems (ongoing in 2020)
  - Simulation and reconstruction tools (2020-21)

WBS 1.6 Remaining Issues and Challenges

- Early, aggressive schedule in hardware development and testing has dominated our resources
  - Has left little time for planning for higher level DAQ plans, etc
  - DEgg FAT testing will be starting at similar time to mDOM Design verification testing.

- Late arrivals of test hardware and limited quantities
  - Adds pressure to quickly develop software needed for full functionality testing

- Late and incomplete deliveries in ICM functionality
  - Required design verification test plan to be modified to accommodate missing functionality.

- Coordinating in-kind contributions in the collaboration to analysis software ahead of the Upgrade deployment.
  - Development and testing of simulation and reconstruction tools is a collaboration deliverable

WBS 1.6 Summary

- Data Systems and Integration efforts here will ensure that new sensors and calibration devices deployed in the Upgrade become first-class members of the overall uniform IceCube data systems
  - Triggering and DAQ readout
  - Treatment in online and offline data processing and filtering
  - Inclusion in analysis level simulation and data samples
- Leverage our rich software ecosystem from IceCube to speed progress to analysis results that take advantage of new OM sensors and calibration devices
- Strong team from M&O in place to lead this effort
  - Supplemented by some key additions for the in-OM software
- First full year of work has been a busy one
  - Lots of good progress, and lots more to worry about.

Backup

WBS 1.6 Technical Progress

DEgg Mainboard "selfie" with Camera System

NTS Infrastructure

1.6 Design and IceCube Gen1 Heritage

- IceCube Online and Offline software systems serve as a robust starting point for Upgrade
- Design focused on targeted additions to existing systems
  - Online DAQ and Experiment control
  - Offline Software and simulation
  - Computing and Infrastruture
- New designs strongly follow successful Gen 1 designs as well
  - OM Software
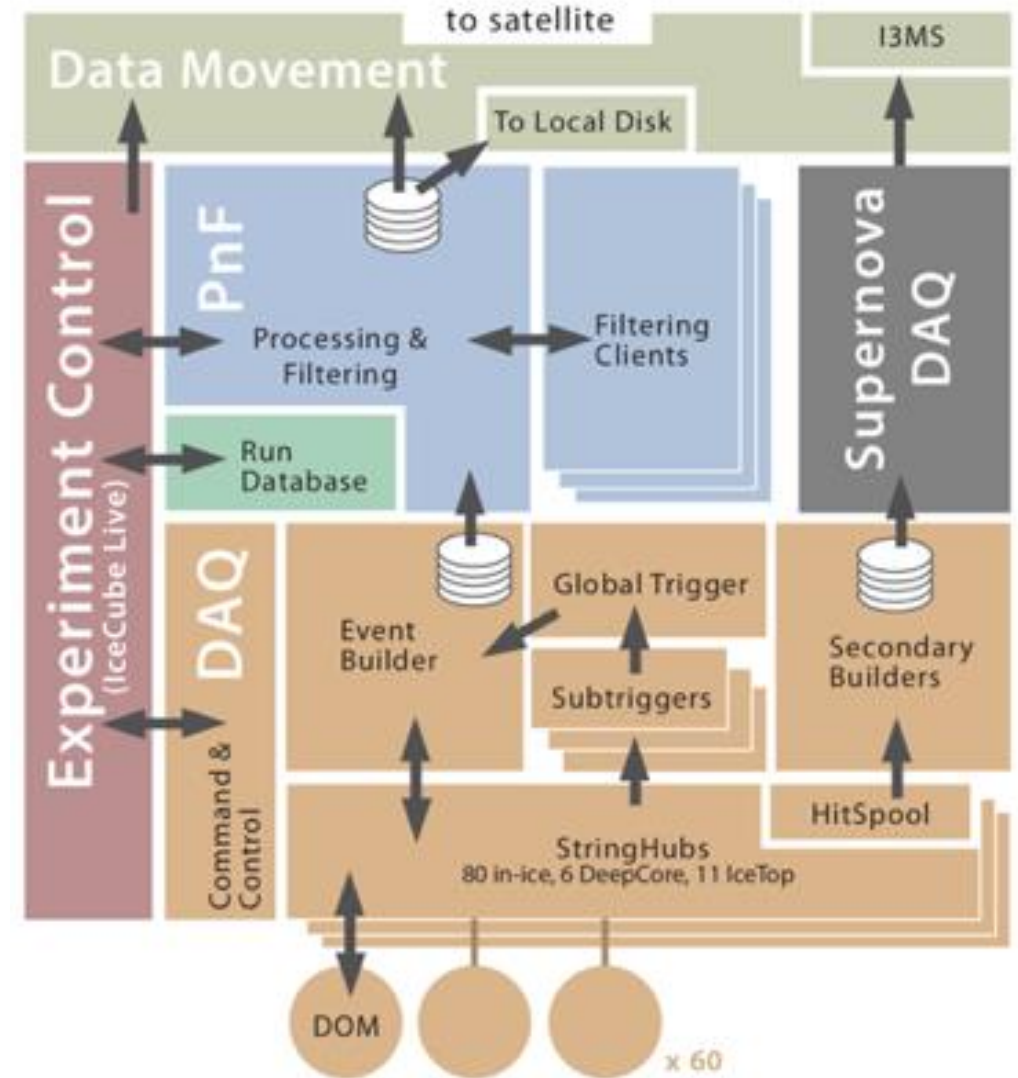
IceCube Online System

1.6 Verification Plans

- Integration and verification plans focus on high-level integration of Upgrade hardware with IceCube Systems
- July 2021 - End-to-end OM sensor hardware/software tests at NTS
  - Demonstrate data communications from all OM sensor types thru full length quads to surface systems.
- January-February 2023 - Verification and commissioning for new strings
  - Verify functionality of new sensors and calibration devices before inclusion in IceCube operations
- Through 2023: Final high-level data quality checks and comparisons with simulation samples.