IceCube Upgrade NSF Rebaseline Review
April 26-28, 2022

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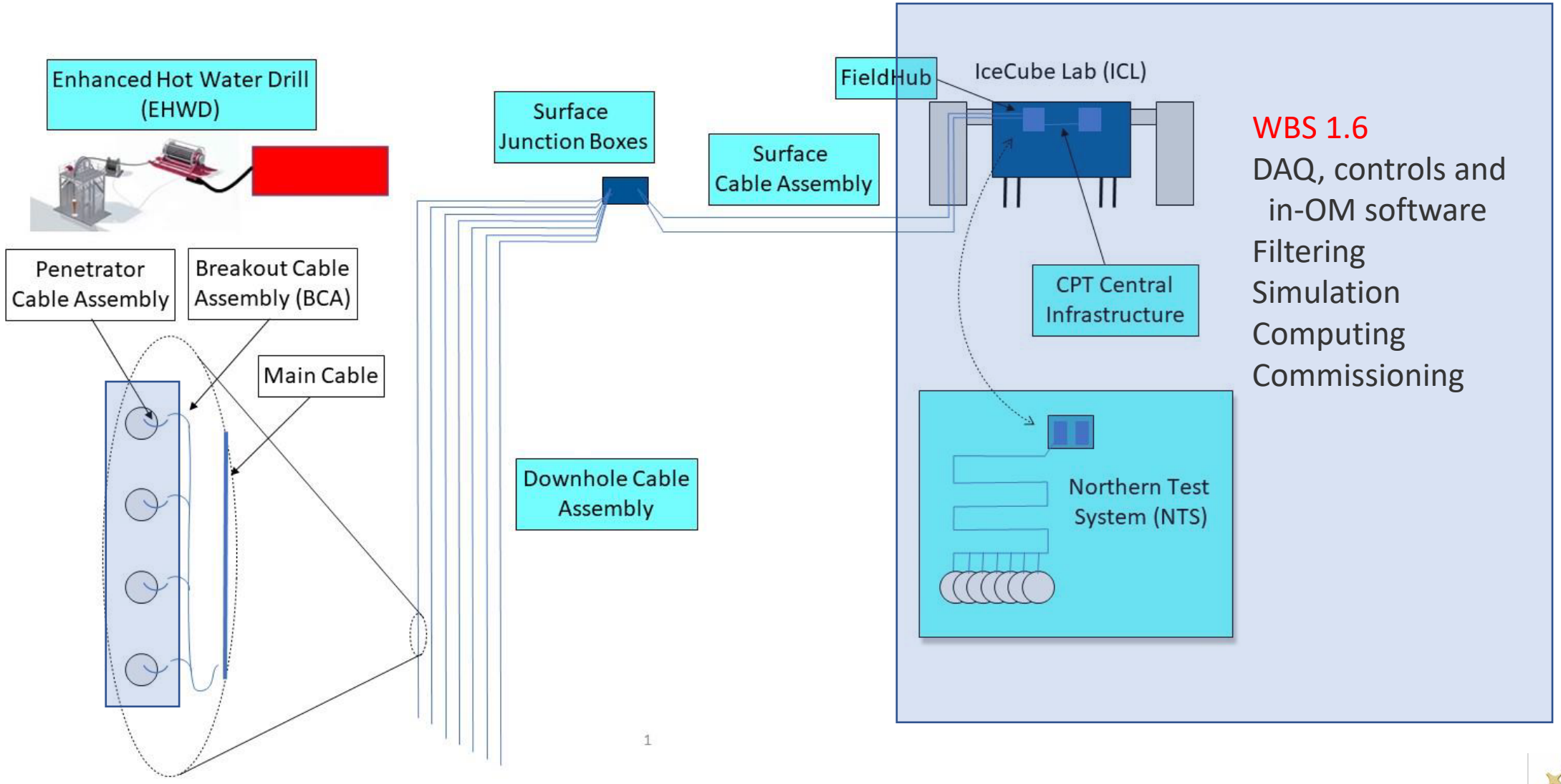
1.6 – Data Systems and Icecube Integration
Breakout session

1.6 critical areas



WBS 1.6

DAQ, controls and in-OM software

Filtering

Simulation

Computing

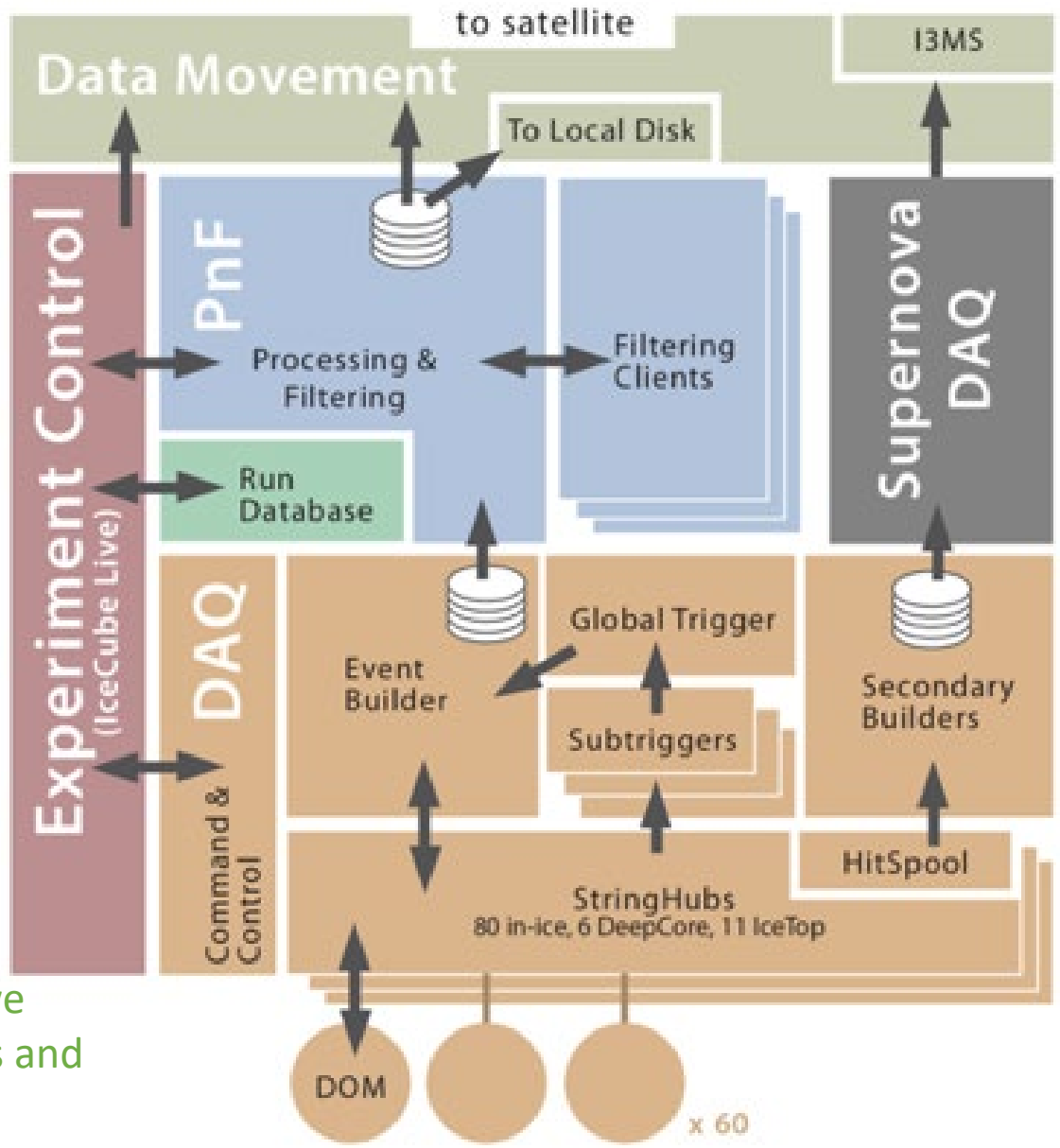
Commissioning

WBS 1.6 Scope

- Targeted additions to key online systems to support new OMs
  - On-board OM Software and field hub software
  - DAQ, experiment control, online filtering
  - Computing systems
- Add support for Upgrade devices to offline software systems
  - IceTray framework and classes
  - Simulation
  - Reconstruction tools
- Provide device commissioning for newly deployed devices before operating

Regardless of who pays for the work, we track the activity in schedule with tasks and milestones

IceCube Online Systems

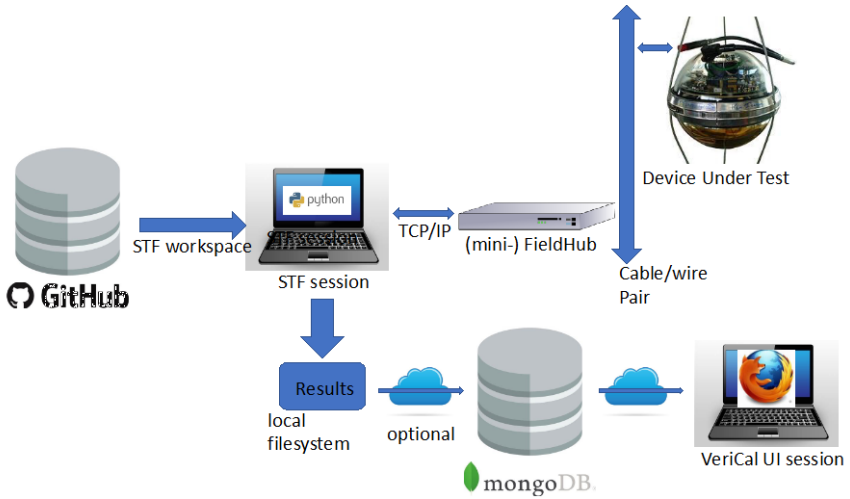


Technical status -

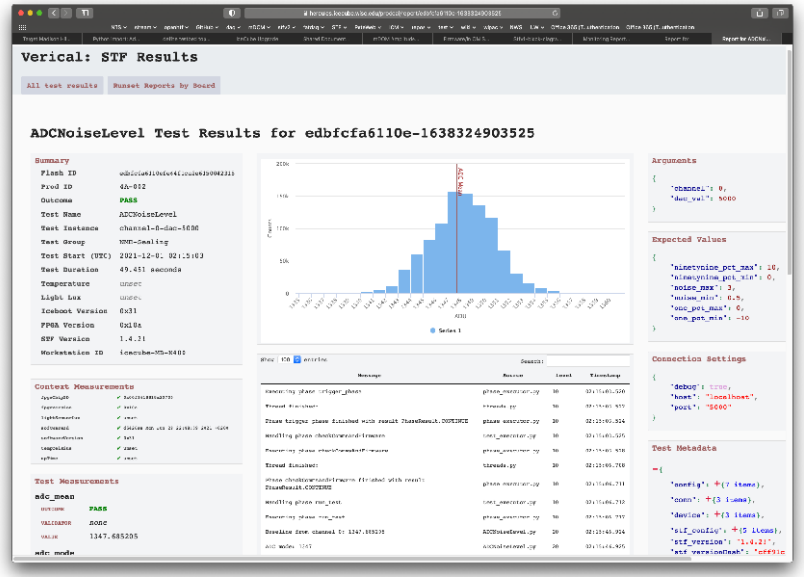
1.6.1 Online Software & in OM software (On project and in-kind M&O)

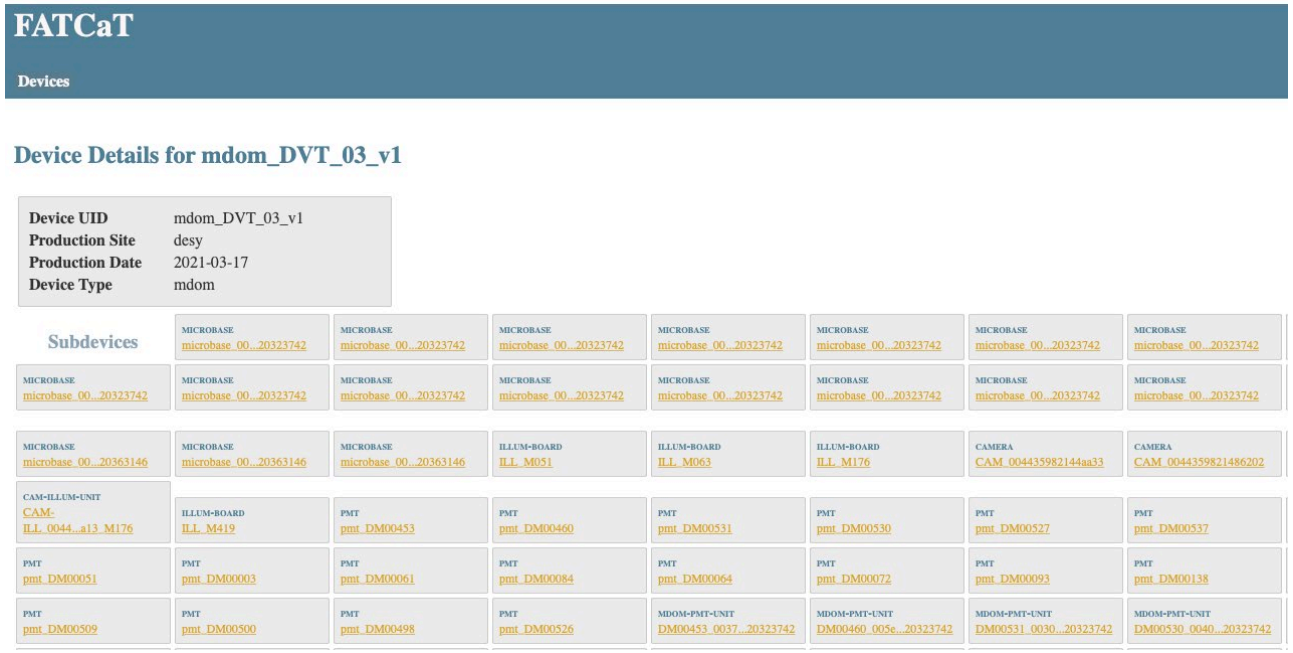
- Work completed
  - DVT/FAT testing – full software suite available that enables end to end testing of:
    - Stand alone mainboards, integrated OMs, groups of OMs with linked GPS timing
    - FAT/DVT test results fed directly to testing DB and visualization site
      - STF and FAT
- Work remaining
  - Full implementation of self-triggering ”DAQ mode” for in-OM software
  - Existing IceCube DAQ, Experiment control, online filtering extended to support both Gen1 IceCube DOM data AND Upgrade OM data
    - Work being done by M&O system experts ahead of deployment
    - Plan reviews of system extension plans for OMs (2023) and Special devices (2024)
    - Will use NTS (fully integrated with our current Gen1 test area SPTS) for development and testing
  - Support and integration of special and calibration devices
  - SPAT testing suite and detailed plan

Technical status -



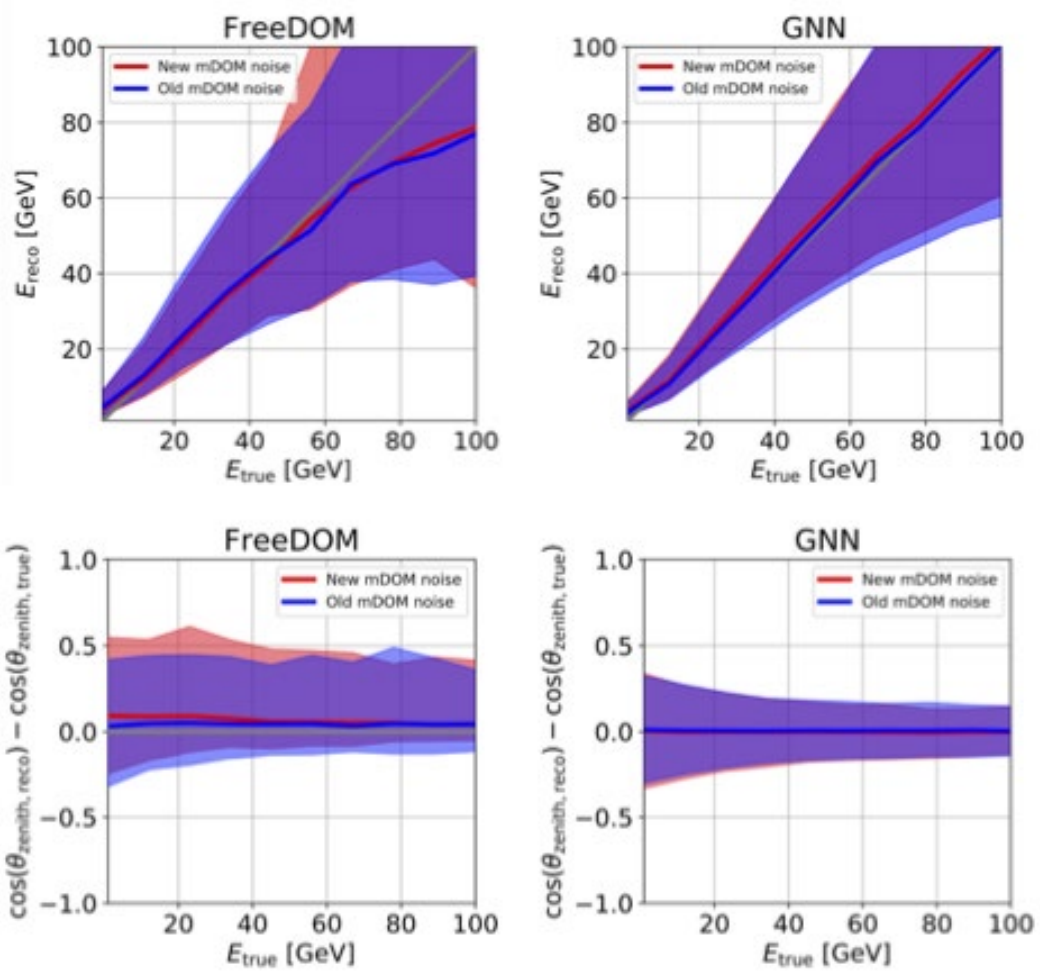
VeriCal UI to MongoDB





Technical status -

- 1.6.2 Offline software (In kind M&O and IceCube collaboration)
  - Ensuring data analysis framework and reconstruction tool are ready for Upgrade data processing and analysis
    - Base support in IceTray framework (as designed simulation use)
    - Support for more advanced reconstructions of Upgra data expected from collaboration to need support.
- 1.6.3 Simulation software (IceCube collaboration)
  - Delivered “as designed” simulation samples for DEgg/mDOM simulations
    - Lacks some of the details needed for final simulation, but allows for other software development efforts to make progress.
  - Final “as built” simulation planned post-deployment that will be used for analysis work.



Upgrade simulation of mDOM impacts

Technical status -

- 1.6.4 Computing Infrastructure (On project (HW) and in kind M&O)
  - Provide and support COTS computing infrastructure needed for online and test system HW
  - Project provides computing to support additional DAQ processes in Upgrade
  - Delivered: computing infrastructure and support for NTS, Pole SPS expansion planned
- 1.6.5 String Commissioning (In kind M&O)
  - Intended as final checkout and operational readiness test of newly deployed instrumentation
    - Monitor hardware during freeze-in
    - Find initial operating values for HW settings based on calibration and testing
    - Will largely use DVT/FAT/SPAT tools
    - Will deliver to M&O for standard operations post commissioning

Milestones

- Completed milestones
  - Test DAQ ready Plan: 12/30/2019 Delivered: 11/1/2020
  - Review in OM Software development plans Plan: 10/31/2021. Delivered: 12/17/2021
  - Offline software and as-designed sim release. Plan: 11/1/2021. Delivered: 2/25/2022
- Major Upcoming:
  - May 2023: Review Online systems support plans for operating Upgrade Oms
  - May 2024: Review Online systems support plans for operating Calibration and special devices
  - Dec 2025: Online software systems ready for use at Pole
  - Mar 2026 – IceCube simulation and reconstruction tools available for analysis of IceCube data including Upgrade devices.

1.6 Critical Path

- WBS 1.6 has few critical deliveries needed to enable module deployment
  - SPAT testing at Pole of ALL modules post-transport.
    - Ensures modules in good condition, ready to deploy with correct software preloaded
    - Field Season 2: First 2 strings of devices tested – Dec 2024 – Feb 2025
    - Field Season 3: Test remaining hardware pre deployment – Nov 2025 – Jan 2026
- Post deployment: 1.6 IS the critical path to new modules being prepared for data taking:
  - Commissioning of new devices: Dec 2025 – March 2026
    - Will begin immediately after strings are deployed and connected
  - Deliver online software systems ready to integrate new modules into IceCube operations
    - Delivery Jan 2026 for OM devices, Feb 2026 for special devices.
    - Expect routine operations to begin AFTER commissioning efforts complete

Transitions to IceCube M&O

- Final milestone: **Mar 2026** – Deliver commissioned strings to IceCube M&O for inclusion in standard ops
  - The IceCube Upgrade delivers
    - Deployed strings, including OMs, special devices and calibration devices
    - Surface communication hardware (+spares)
    - Full in-OM software suite for debugging and operating hardware
    - Online software systems to operate new hardware as a fully integrated portion of overall IceCube detector.
      - DAQ, Experiment Control, data filtering, core data processing software
    - Detailed “as-built” documentation of hardware systems
    - Full characterization of all hardware from commissioning activities
- Then Upgrade strings to be included in standard IceCube operations
  - Modest impact on “online” raw data bandwidth – Multi-sensor modules produce more data
  - Limited impact on data transfer requirements
    - Effective data volume compression and veto-filtering methods used in IceCube will continue to function effectively for IceCube + Upgrade.

Conclusion

- Experts from across M&O team and wider IceCube Collaboration are ready to bring the IceCube Upgrade online as part of IceCube.
- WBS 1.6 activities well underway
  - Delivered testing software for optical module design verification and production testing
- Replan schedule has been developed that delivers needed software and integration efforts ahead of deployment activities at Pole in all scenarios
  - Effort largely provided as an in-kind effort by the IceCube M&O team and collaboration
  - Regardless, detailed schedule tracks effort across all source

Backup Material

1.6 Risks

- Primary risks still being tracked in 1.6 now are related to scaling table-top/lab readout of handfuls of modules to full-string readouts via the full Field-Hub systems. These remain important with higher mDOM PMT noise rates.
  - Tech47, Tech 48, Tech49, Tech50, Tech51
  - In-OM processing needs sufficient processing power to format, transmit and perform in-device noise mitigations
  - IceCube surface DAQ must be able to handle additional rate of DEgg and mDOM hits into trigger system
  - FieldHub data throughput and processing capacity must be able to handle total data rate from all devices on an Upgrade string.
- Active mitigations being pursued for these in the next 6-9 months
  - Retire: Data rate scaling tests using prototype systems and/or simulated data volumes to ensure full string readouts are working
  - Mitigations: Software mitigations available to further reduce noise-like events to reduce data volumes with small impact on physics.

1.6 Interfaces

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

- WBS 1.3 Sensors – *DVT and FAT testing of mDOM and DEgg devices well underway*
  - Provide on-board OM software to support testing and operation of in-ice devices
  - 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 – *Software controlling mDOM/DEgg in use for mini-FieldHub*
  - DAQ interface to Field Hub, timing infrastructure and cable systems
  - Shared responsibility to build-out test systems
- WBS 1.5 Calibration devices – *Control and readout of common Mini-Mainboard in place*
  - Provide on-board OM software to support testing and operation of calibration devices
  - DAQ/Experiment control of all calibration devices
    - Calibration/configuration items needed in operation
  - Calibration hardware details and performance for detailed system simulation

1.6 Major Milestones

- WBS 1.6 milestones are focused on targeted software/firmware readiness reviews and deliverables ahead of programmatic needs
- Major milestones in the project schedule for 1.6 include:
  - May 2023 – Review online system (DAQ, Experiment Control, Filters) plans to support operations of new OM modules in IceCube standard operations
  - May 2024 - Review online system (DAQ, Experiment Control, Filters) plans to support operations of new Calibration/Special devices in IceCube operations.
    - All deployed special devices will be controlled by IceCube DAQ/Exp. Control.
  - June 2024 – Review South Pole Acceptance Testing (SPAT) plans
    - Dec 2024 & Nov 2025 – SPAT testing at Pole for modules pre-deployment
  - **Dec 2025** – Online software systems ready for deployment to pole supporting new Oms
    - Feb 2026 – Online software systems ready for special device operations.
  - Dec 2025 – Computing system at SPS expanded to support Upgrade strings
  - **Mar 2026** – Deliver commissioned strings to IceCube M&O for inclusion in standard ops
    - Major component of Upgrade ”Project Deliverables” document
  - Mar 2026 – IceCube simulation and reconstruction tools available for analysis of IceCube data including Upgrade devices.

Charge Question O-1

Current Technical Status and Work to Go

- Full testing control and readout system available and in wide use for module testing and development
  - High-level scripted control of modules
  - Mini-FieldHub control of multiple OM devices per wire-pair via ICM-enabled string communication
  - GPS-corrected time stamping of data
  - On-board OM software and firmware with the ability to readout waveforms, perform self-tests, self-calibrated devices.
- Work to go primarily focuses on integration into existing IceCube data systems:
  - OM-software data acquisition app under control of IceCube DAQ
  - Experiment control of all Upgrade OMs and Special devices
  - Integration into full IceCube data stream for analyses
    - Simulation and reconstruction
- String commissioning after deployment and refreezing

PCTS setup at UW mDOM and DEgg MBs

NTS setup – integrated w/ SPTS test system

IceCube Upgrade

1.6: Cost and Main Cost Drivers

- WBS 1.6 effort largely an in-kind effort
  - IceCube M&O team experts in DAQ, Experiment control, online and offline software contributing effort to complete Upgrade integration.
  - Broader IceCube science collaboration provides support for Upgrade simulation and reconstruction software efforts.
- Upgrade project funded efforts focused in a few key areas
  - Project management ($450K total, $250K to go)
    - Fractional L2/L3 manager support
    - Travel for reviews and development workshops
  - In-OM software and testing software development building toward self-sufficient data collection units controlled by higher level IceCube DAQ. ($1,150K total, $800k to go)
  - Modest computing hardware to support expanded DAQ systems at test systems and at SPS computing setup. ($50K total, $15k to go)
  - Deployments for SPAT and commissioning on-ice efforts.($180K total/to go)

1.6: Cost and Main Cost Drivers

- WBS 1.6 effort largely an in-kind effort
  - IceCube M&O team experts in DAQ, Experiment control, online and offline software contributing effort to complete Upgrade integration.
  - Broader IceCube science collaboration provides support for Upgrade simulation and reconstruction software efforts.
- Upgrade project funded efforts focused in a few key areas
  - Project management ($260K)
    - Fractional L2/L3 manager support
    - Travel for reviews and development workshops
  - In-OM software and testing software development building toward self-sufficient data collection units controlled by higher level IceCube DAQ. ($675K)
  - Modest computing hardware to support expanded DAQ systems at test systems and at SPS computing setup. ($15K)
  - Deployments for SPAT and commissioning on-ice efforts.($150K)