IceCube Upgrade NSF Rebaseline Review
April 26-28, 2022

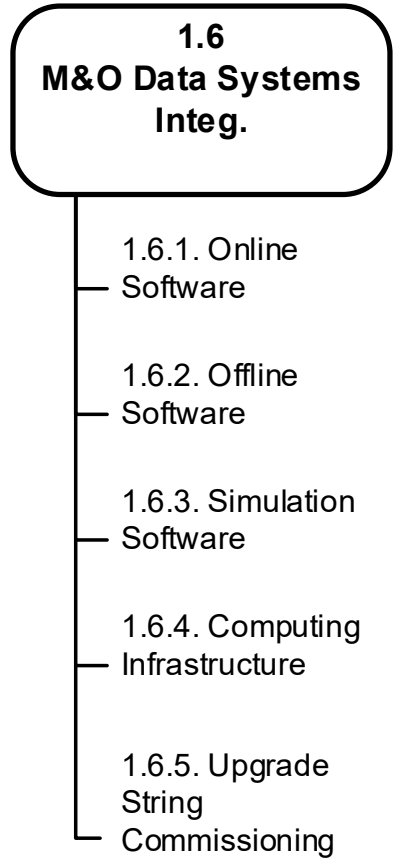
Erik Blaufuss

1.6 – Data Systems and Icecube Integration

Brief Bios – 1.6 leads

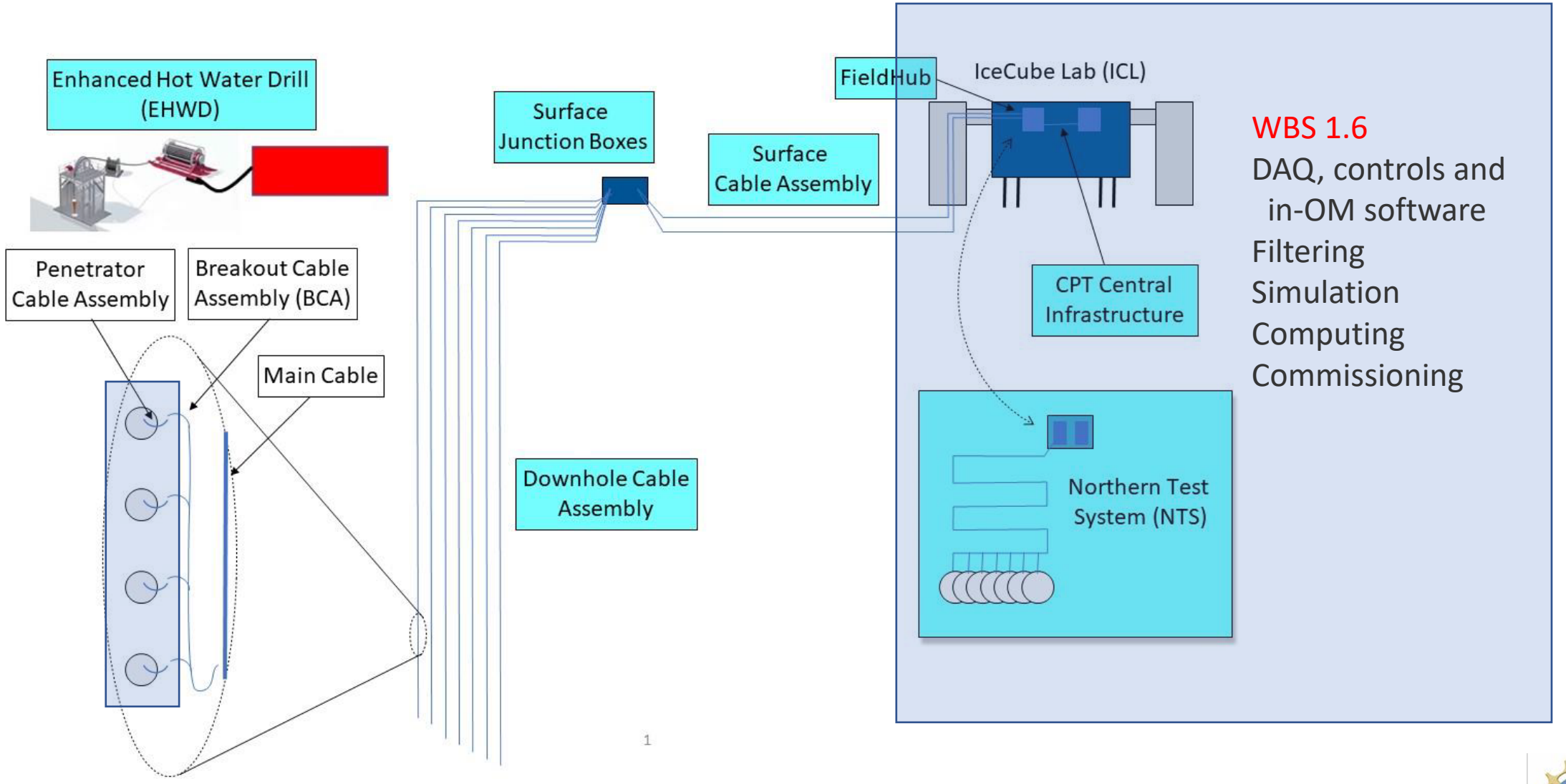
- Erik Blaufuss – University of Maryland Research Scientist
  - IceCube Gen1 MREFC L3 lead for Data Filtering and Software
  - M&O operations lead for online filtering and realtime alerts
  - Former WG lead, collaboration analysis coordinator

- Supported by an experience team from across IceCube collaboration and M&O team
  - 1.6.1 Jim Braun – UW Scientist - L3 lead for Upgrade Online Software
  - 1.6.2 Alex Olivas – UMD Scientist* – L3 for offline software and tools
  - 1.6.3 Tom Stuttard – NBI Postdoc – Expert in IceCube simulation and oscillation analyses.
  - 1.6.4 Ralf Auer – UW Engineer – Pole computing and Winter-over manager



* Left IceCube in Feb 2022 – replacement TBD

1.6 critical areas



WBS 1.6

DAQ, controls and in-OM software

Filtering

Simulation

Computing

Commissioning

1.6 Overall Deliverables

- Responsible for the seamless integration of all new systems from the IceCube upgrade project into the existing IceCube detector maintenance and operations structures and systems. Including:
  - Online DAQ, Experiment Control, and Online Filter software systems
  - In OM and special device software and firmware
  - FieldHub command and control software
  - Offline software systems
  - Simulation software
  - Computing systems at Pole and in the north for testing
  - String commissioning – Final checkout of newly deployed strings before handover to IceCube M&O
- In the end, Upgrade provided strings, OMs and special devices will become a part of the larger IceCube detector, participating in triggered events, calibration data, detector simulation and physics analysis at equal levels to the Gen1 hardware.

Charge Question ST1

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 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

- Upcoming 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.

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 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.
  - 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.

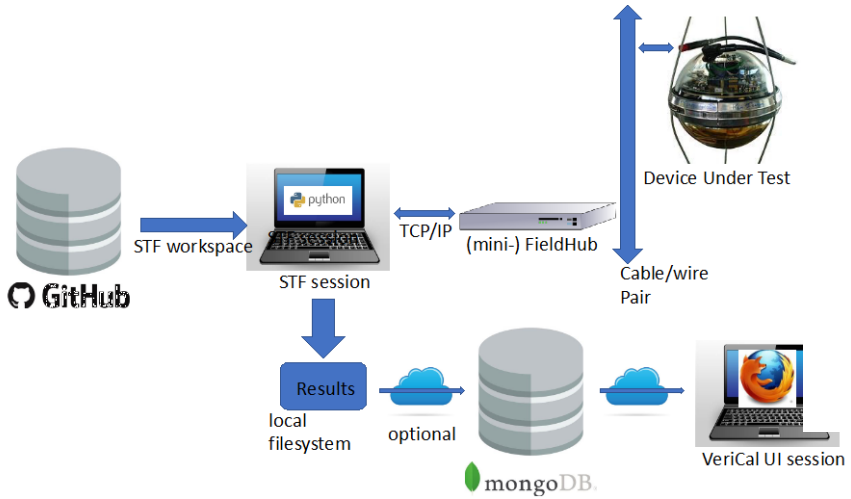
Conclusion

- WBS 1.6 activities well underway
  - Delivered testing software for optical module design verification and production testing
  - Experts from across M&O team and wider IceCube Collaboration are ready to bring the IceCube Upgrade online as part of IceCube.
- 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 sources

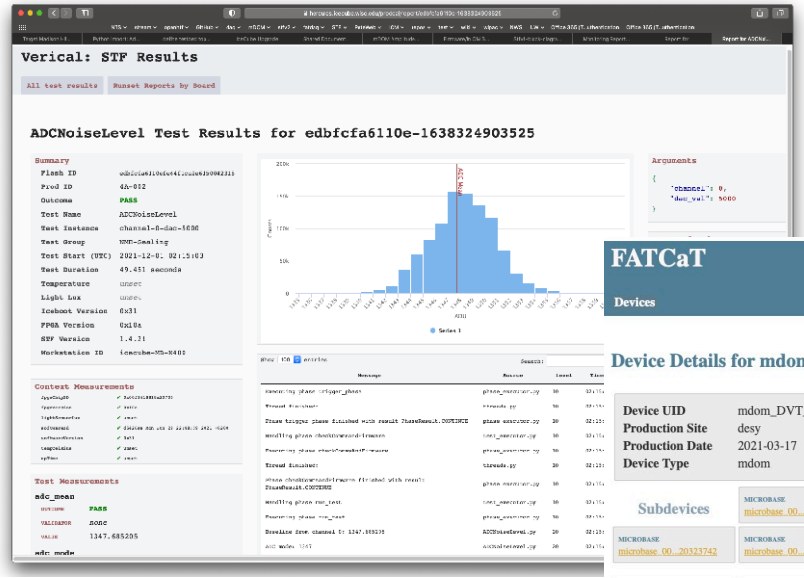
Backup Material

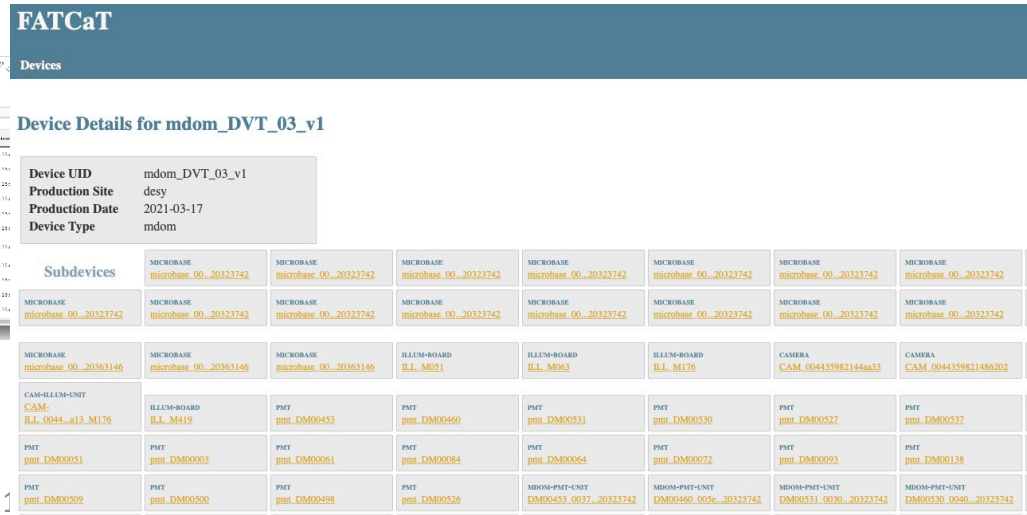
Technical status - all 1.6.X areas (1)

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



VeriCal UI to MongoDB





Work to complete:
- Full implementation of Self-triggering “DAQ” mode
- Support for large number of special devices
- SPAT testing

Technical status - all 1.6.X areas (2)

- 1.6.1 Online systems – Surface software (In kind M&O)
  - Existing IceCube DAQ, Experiment control, online filtering need to be modified to properly deal with 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
    - Delivery at time of string deployment
- 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

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
- 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

IceCube Online Systems