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The DUNE DAQ Roadmap

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CSAID Meeting

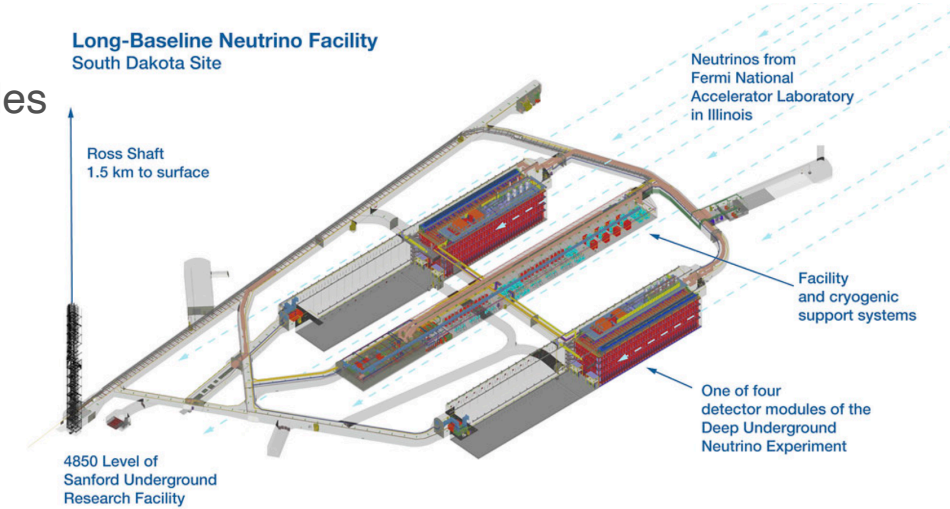
30 March 2023

In partnership with:

DUNE

DUNE, from 30,000 feet

- Scheduled to begin full data taking in 2029
- But DAQ needs to be ready for basic integration testing in 2026
- Delta CP measurement, supernova burst detection, proton decay, etc…
- Hundreds of thousands of readout channels, demanding uptime and buffering requirements. Also: it's a mile underground.
- Far detector is composed of LArTPC modules with 10kt fiducial liquid argon volume each
  - Self-triggered, first of its kind
- *Developing a DAQ for this is a challenge*



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SURF installation plan

- *Caveat that this is from a schedule snapshot, and full links to other consortia schedules are still ongoing*
- For FD1 and 2, currently five phases for installation
  1. Initial installation of surface equipment (1 Jul 25 – 30 Oct 25)
     - Requires availability of surface computing room, with racks, power, and networking available (curr. 1 May 25)
  2. FD1 underground equipment installation (10 Mar 26 – 9 Jul 26)
     - Requires availability of barracks underground, with racks, power, and networking available (curr. 9 Mar 26)
     - **DAQ ready to support basic FD1 detector integration**
  3. Final FD1 surface equipment installation (complete 3 Sep 26)
     - **Ready to begin full FD1 DAQ integration testing**
  4. FD2 underground equipment installation (7 Apr 27 – 6 Aug 27)
     - Requires availability of barracks underground, with racks, power, and networking available (curr. 6 Apr 27)
     - **DAQ ready to support basic FD2 detector integration**
  5. Final FD2 surface equipment installation (complete 5 Oct 27)
     - **Ready to begin full FD2 DAQ integration testing**

- This slide was taken from Wes's talk at the FDR meeting in February.
- SURF == "Sanford Underground Research Facility". FD1 = "Far Detector 1" = one of the two initial modules

Some details

An APA

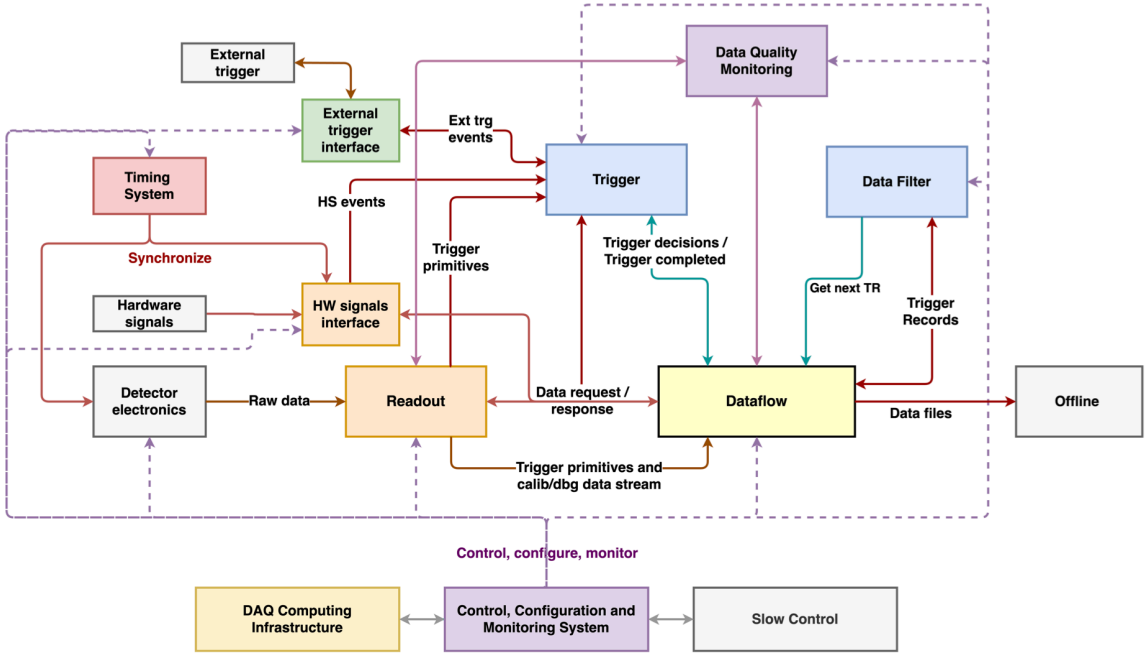
- Module (Far Detector) #1: horizonal drift, composed of
  - 150 Anode Plane Arrays of 2560 channels each = 384,000 readout channels
  - Photon Detection System (PDS) of 6000 channels
- Module (Far Detector) #2, vertical drift, composed of
  - 160 Charge Readout Planes of 3072 channels each = 491,520 readout channels
  - PDS of 1280 channels
- ~320 back-end servers dedicated to the DAQ running O(1000) processes per DAQ session
- Focus of this talk is on Far Detectors, but Near Detector also in the works
- Additional modules for after DUNE Phase-I (cf. “Module of Opportunity” workshop in November)

Some Requirements

- < 30 PB/yr to tape
- DAQ should store selected data at an avg. rate of 10 Gb/s, handling a peak 100 Gb/s
  - A couple TB raw data will be produced by the experiment each second
- > 95% efficiency for SuperNova burst within 20 kiloparsecs; store 100s of data from the burst
- > 90% efficient for any interaction leaving >100 MeV ionization energy in a module
- Each module uptime >95%, including time for infrastructure maintenance
  - DAQ “shall operate continuously, dynamically adjust to changing conditions, tolerate faults, and recover from errors autonomously”

Requirements quoted/paraphrased from “Trigger and Data AcQuisition (TDAQ) System Design”, https://edms.cern.ch/ui/file/2812882/1/DUNE_DAQ_System_Design_v1.1.pdf

What This Will All Look Like



- Fig. 2.3 from the same document. Gray boxes are external to the DAQ.

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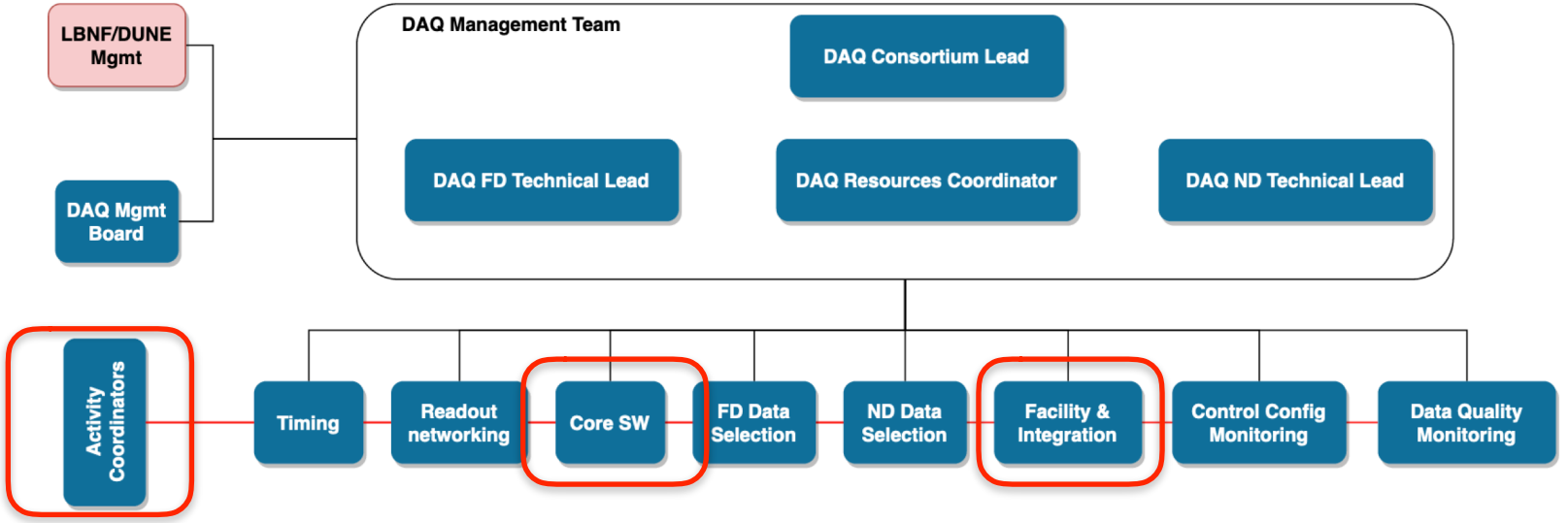
The DUNE DAQ Consortium



- Significant Fermilab contributions: Kurt Biery (co-head, Core SW), Pengfei Ding (head, Software Coordination; also CoreSW), Eric Flumerfelt (Core SW), John Freeman (Software Coordination, Core SW), Wesley Ketchum (ProtoDUNE Operations Activity Coordinator), Bonnie King (co-head, Facility&Integration), Ron Rechenmacher (Core SW), Patrick Riehecky (Facility&Integration)

History of the DUNE DAQ, Pt. I

- LBNE 35ton, FNAL: 2014 (Phase 1), 2016 (Phase 2) (https://iopscience.iop.org/article/10.1088/1748-0221/15/03/P03035/pdf)
  - DAQ software based on artdaq + DAQInterface for RC duties
- ProtoDUNE I, CERN (2018-2020) https://iopscience.iop.org/article/10.1088/1748-0221/15/12/P12004/pdf
  - Coldbox 2017, beam 2018, cosmics 2018-2020.
  - DAQ software based on artdaq, proprietary JCOP (Joint Controls Project) based RC
- ProtoDUNE II, CERN (2023?-202X)
  - Coldbox 2022-2023
  - Same DAQ software as DUNE (more on this in a moment)

These experiments are smaller than DUNE - ProtoDUNE ~5% the size - but are useful as proof-of-principle

History of the DUNE DAQ, Pt. II

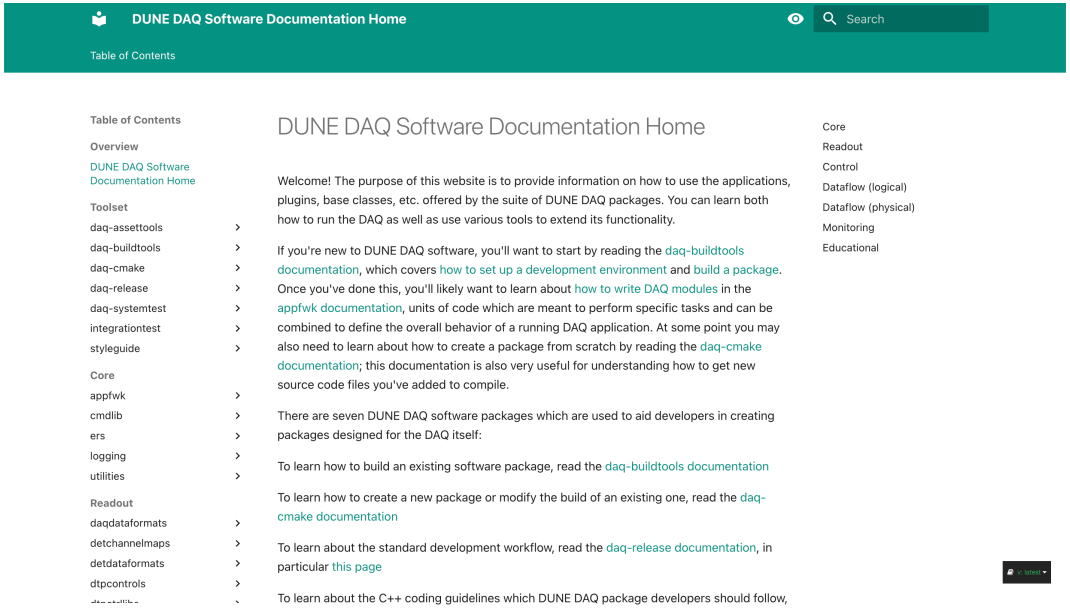
- February 2020, a weeklong workshop was hosted at CERN to focus on DUNE DAQ software
  - https://indico.fnal.gov/event/22384/
  - Yes, the timing was excellent
- Due to the greater number and variety of DAQ application types needed to satisfy DUNE requirements vs. lbne 35ton or ProtoDUNE I, software was built from scratch
  - A generic process `daq_application` whose behavior is almost completely determined by configuration
  - DAQ modules, meant to accomplish discrete tasks, combine and communicate within a `daq_application` instance
- Other foundational activities: dedicated build tools, CMake functions, developer Style Guide, official documentation page (https://dune-daq-sw.readthedocs.io/en/latest/)

The Development Process

- DUNE DAQ software is developed on a release cycle which typically lasts a couple of months
  - Early in the cycle, priorities are established among the working group leaders in consultation with the consortium management team
  - A Release Coordinator, new for each cycle, insures these priorities are being followed
  - A 1-2 week period of code freezeout and testing occurs at the end of the cycle
    - Unit tests, integration tests (spreadsheet checklist). Only agreed-upon bugfixes allowed in at this point, with regression testing.
  - Release Coordinator for this current cycle is Kurt; myself, Eric, Pengfei and Wes have also served as Release Coordinators in the past

The DUNE DAQ Software

- 45 DUNE DAQ-specific packages, 33 external packages
- O(100) collaborators, though not 100 FTEs!
- GitHub org: https://github.com/DUNE-DAQ
- Official documentation: https://dune-daq-sw.readthedocs.io/en/latest/



An Overview of Our Contributions

- Sysadmin and maintenance of the np04 and np02 clusters at CERN, etc. Bonnie, Pengfei and Patrick. OS installation, microservices (kubernetes, etc.)
- Software coordination. Tools for developers (daq-buildtools, daq-cmake), code checking, nightly builds in GitHub + copy to cvmfs. Pengfei, John.
- Control, Configuration & Monitoring: name is self-evident. Some work we (FNAL) do relates to this (e.g., investigation of using ATLAS config mgt. system)
- CoreSW: lots of work from FNAL here. Labeling and organization of data, connectivity service, dataflow, logging etc. Kurt, Eric, Ron.
- General coordination: ProtoDUNE II (Wes), group leadership (Bonnie, Pengfei, Kurt)

Some Recent Accomplishments

- Coldbox testing at CERN (APAs, CRPs + running recent versions of DUNE DAQ software)
- Connectivity service (groundwork for reconnections, needed for uptime)
- Source IDs and data/file formats (how we label and arrange data)
- Switch from UPS to Spack
- Emulated Top Drift Electronics readout (TDE used to read out top of CRP)
- Last but (very much) not least: Final Design Review back on February 22-23
  - Desire was to have the various DUNE FDRs complete prior to CD 2/3, in September
  - My understanding is the reviewers provided positive preliminary feedback

Some Ongoing/Remaining Tasks

- “Standardization”
  - Upgrade from SL7/Centos8 to AlmaLinux9
  - Run `daq_applications` in Kubernetes pods
  - Minimize hassle in event of node reboots (automatic relaunches, etc.)
  - Asset files in standard locations on cvmfs (binaries for emulation, etc.)
- Upgrade Run Control
  - Current ad-hoc standalone CLI has served us well, but time to upgrade
- Far Detector planning
  - Online server infrastructure (Bonnie, Fermilab networking)
  - LAN/WAN from Fermilab networking/ESnet, core services design (help from Core Computing)
- Upgrade Configuration Management
  - ATLAS’s OKS being investigated

Some Ongoing/Remaining Tasks (Ct'd)

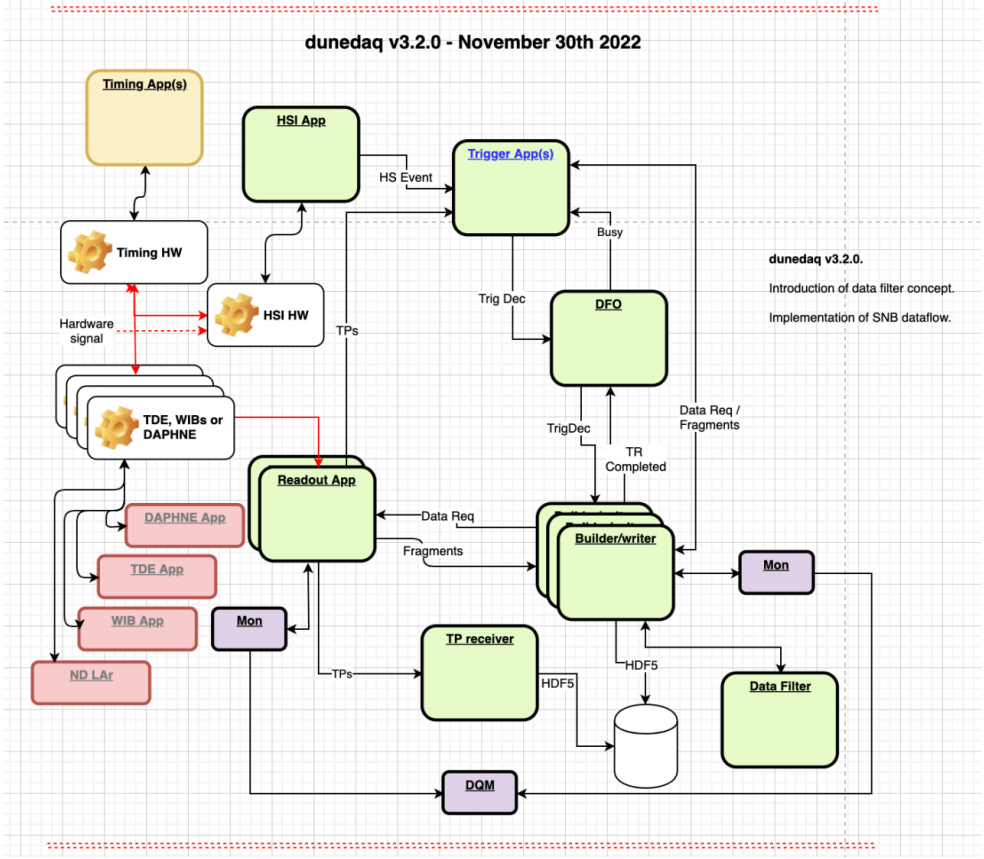
- Complete switch to ethernet UDP readout (vs. FELIX boards)
- Support for additional electronics (DAPHNE-specific plugin code, e.g.)
  - DAPHNE == "Detector electronics for Acquiring PHotons from NEutrinos"
- Continued support for Iceberg operations
  - Plans to feed TPC data to computer with GPU. Generating trigger primitives using machine learning. Pass off to existing trigger application to make trigger decisions.
  - This, as opposed generating trigger primitives in a DAQ module

Conclusions

- The DUNE DAQ is an irreducibly complex system intended to satisfy a demanding data acquisition environment
- Many motivated collaborators, regular code development cycles, good software development practices: all have allowed us to accomplish a great deal to date
  - And we're happy about the FDR
- A good deal of work remains to be done between now and 2026

Backups

Last Minor (3.2.0) Version of our Software (pre-4.0)



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