WBS 1.08: DAQ/Control Overview

L2 Lead - Laura Newburgh
L2 Deputy - Nathan Whitehorn
L2 Control Account Manager - John Joseph

Presenter Introduction

Nathan Whitehorn

Michigan State University

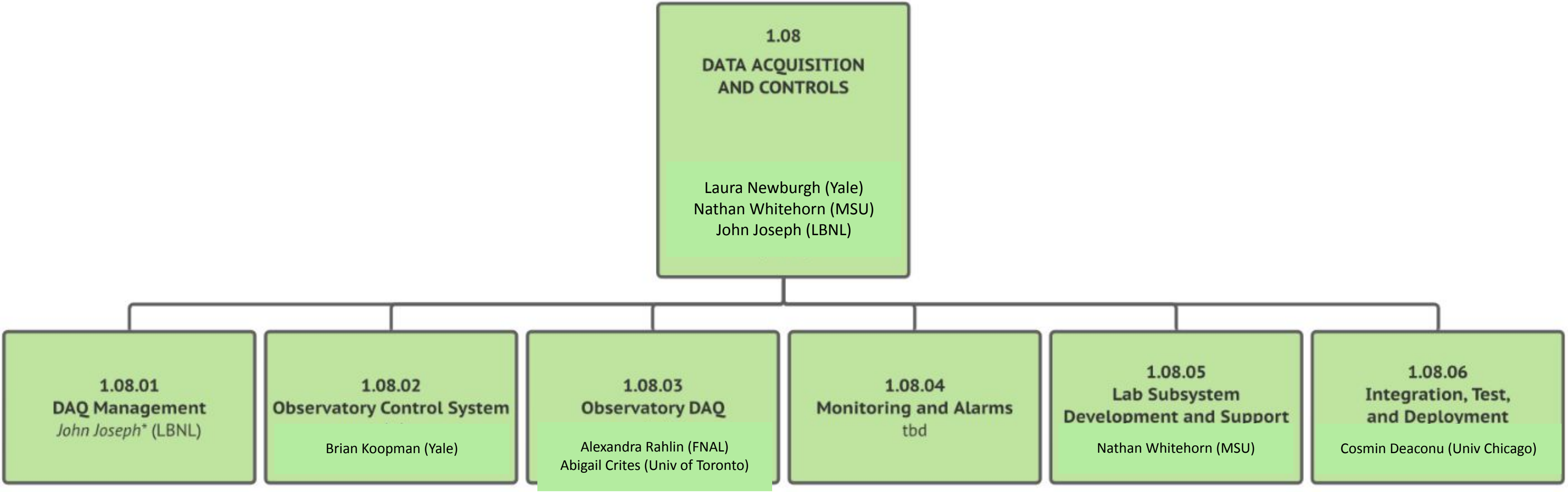
Discipline: HEP, Cosmology

Previous experience: SPT-3G DAQ, PB-2 DAQ, limited involvement with SO DAQ, SPT-3G miscellany (readout, software, analysis), IceCube (calibration, software, analysis)

Some Key Contributors in this L2

- Laura Newburgh (the real L2, Yale, expertise on SO DAQ, ACT)
- John Joseph (CAM, LBL)
- Cosmin Deaconu (U. Chicago, Observatory Control Development, history with RNO-G/ANITA/ARA)
- Abigail Crites (Cornell, Readout Interface, history with SPTpol, TIME)
- Brian Koopman (Yale, Observatory Control, SO Observatory Control, ACT)
- Alexandra Rahlin (FNAL, Data Management Interface, SPT-3G + SPIDER)
- Chris Weaver (MSU, Readout Interface, history on IceCube)

DAQ L2/L3 Organization includes experienced CMB scientists



Important Numbers for Reference

Chile:

- **2 x Large aperture telescope (LAT):**
  - 85 optics tubes per LAT
  - 6m telescope
  - **134,592 dets each LAT (269,184 LAT dets total)**
  - 100mK cryogenics (cooled with dilution refrigerator)
  - **400Hz detector data rate per det**

South Pole:

- **1 x Large aperture telescope (LAT)**:
  - Same #’s as Chile
- **6 x Small aperture telescope (SAT)**
  - In ‘3 shooters’ = 3 optics tubes per telescope
  - ~0.5m telescope
  - **25,880 dets per telescope (155,280 SAT dets total)**
  - 100mK cryogenics
  - **100Hz data rate per det**

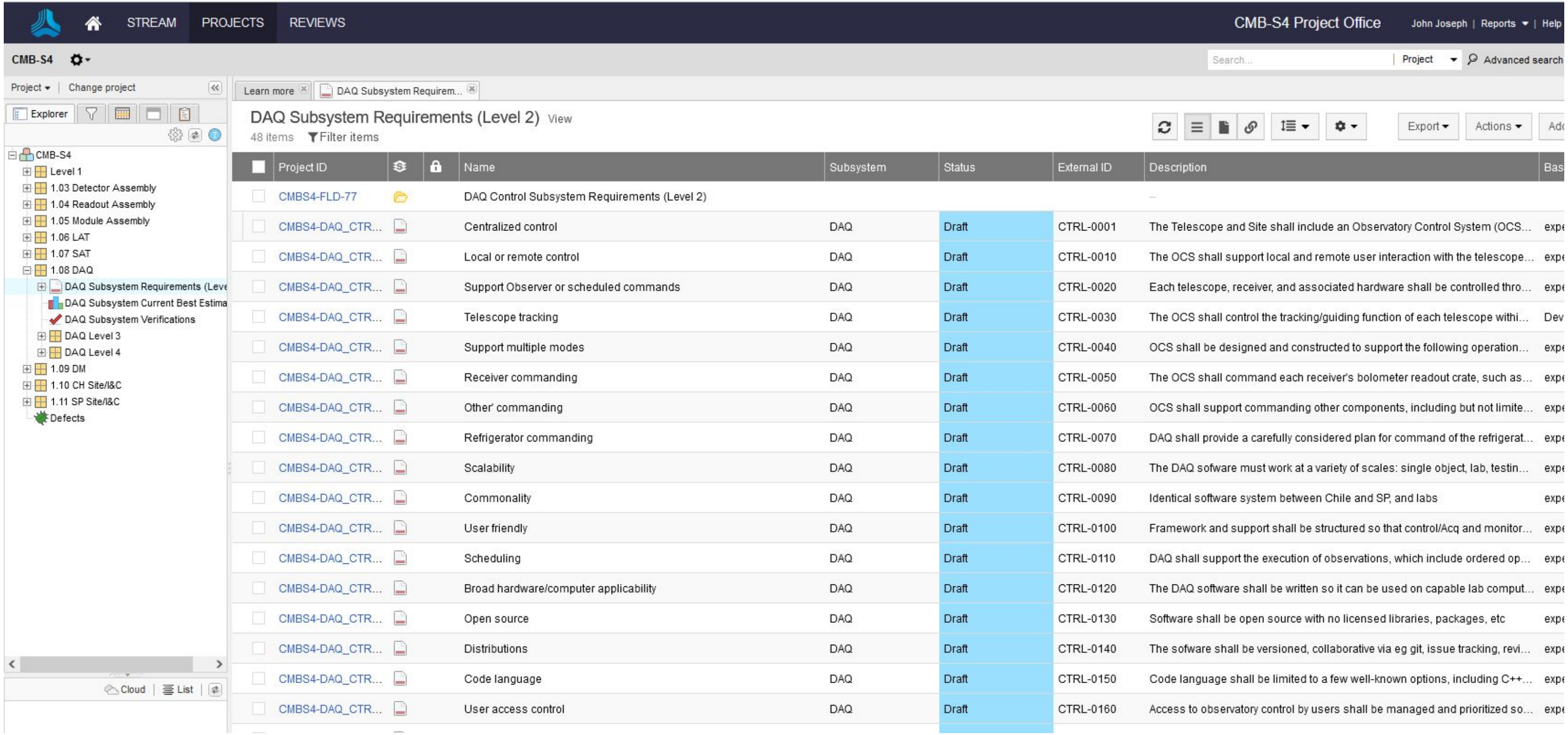
Number Origins:

- Detector count from sensitivity
- Sample rates from beam widths and scan speed (angular resolution and low-frequency noise requirements)

Requirements (Level 1 and down) are managed in the Jama software tool

Total of 48 L2 requirements for the DAQ/Control WBS

CQ1



Project ID	Name	Subsystem	Status	External ID	Description	Bas
CMBS4-FLD-77	DAQ Control Subsystem Requirements (Level 2)				--	
CMBS4-DAQ_CTR...	Centralized control	DAQ	Draft	CTRL-0001	The Telescope and Site shall include an Observatory Control System (OCS...	expe
CMBS4-DAQ_CTR...	Local or remote control	DAQ	Draft	CTRL-0010	The OCS shall support local and remote user interaction with the telescope...	expe
CMBS4-DAQ_CTR...	Support Observer or scheduled commands	DAQ	Draft	CTRL-0020	Each telescope, receiver, and associated hardware shall be controlled thro...	expe
CMBS4-DAQ_CTR...	Telescope tracking	DAQ	Draft	CTRL-0030	The OCS shall control the tracking/guiding function of each telescope withi...	Dev
CMBS4-DAQ_CTR...	Support multiple modes	DAQ	Draft	CTRL-0040	OCS shall be designed and constructed to support the following operation...	expe
CMBS4-DAQ_CTR...	Receiver commanding	DAQ	Draft	CTRL-0050	The OCS shall command each receiver's bolometer readout crate, such as...	expe
CMBS4-DAQ_CTR...	Other' commanding	DAQ	Draft	CTRL-0060	OCS shall support commanding other components, including but not limite...	expe
CMBS4-DAQ_CTR...	Refrigerator commanding	DAQ	Draft	CTRL-0070	DAQ shall provide a carefully considered plan for command of the refrigerat...	expe
CMBS4-DAQ_CTR...	Scalability	DAQ	Draft	CTRL-0080	The DAQ sofware must work at a variety of scales: single object, lab, testin...	expe
CMBS4-DAQ_CTR...	Commonality	DAQ	Draft	CTRL-0090	Identical software system between Chile and SP, and labs	expe
CMBS4-DAQ_CTR...	User friendly	DAQ	Draft	CTRL-0100	Framework and support shall be structured so that control/Acq and monitor...	expe
CMBS4-DAQ_CTR...	Scheduling	DAQ	Draft	CTRL-0110	DAQ shall support the execution of observations, which include ordered op...	expe
CMBS4-DAQ_CTR...	Broad hardware/computer applicability	DAQ	Draft	CTRL-0120	The DAQ software shall be written so it can be used on capable lab comput...	expe
CMBS4-DAQ_CTR...	Open source	DAQ	Draft	CTRL-0130	Software shall be open source with no licensed libraries, packages, etc	expe
CMBS4-DAQ_CTR...	Distributions	DAQ	Draft	CTRL-0140	The sofware shall be versioned, collaborative via eg git, issue tracking, revi...	expe
CMBS4-DAQ_CTR...	Code language	DAQ	Draft	CTRL-0150	Code language shall be limited to a few well-known options, including C++...	expe
CMBS4-DAQ_CTR...	User access control	DAQ	Draft	CTRL-0160	Access to observatory control by users shall be managed and prioritized so...	expe

Effort is ongoing to update and refine the requirements content

DAQ/Control Major Responsibilities/Requirements

CQ1

1. Acquire and aggregate high-speed data from detectors (400 Hz per detector, ~ 10 Gbit/s total) and hand off to data management

2. Provide control framework of observatory, including telescope drive systems, readout boards, and other on-telescope hardware

3. Acquisition of housekeeping and other low-rate data streams into specified format

4. Browser-based monitoring and hierarchical alarms system based on housekeeping data

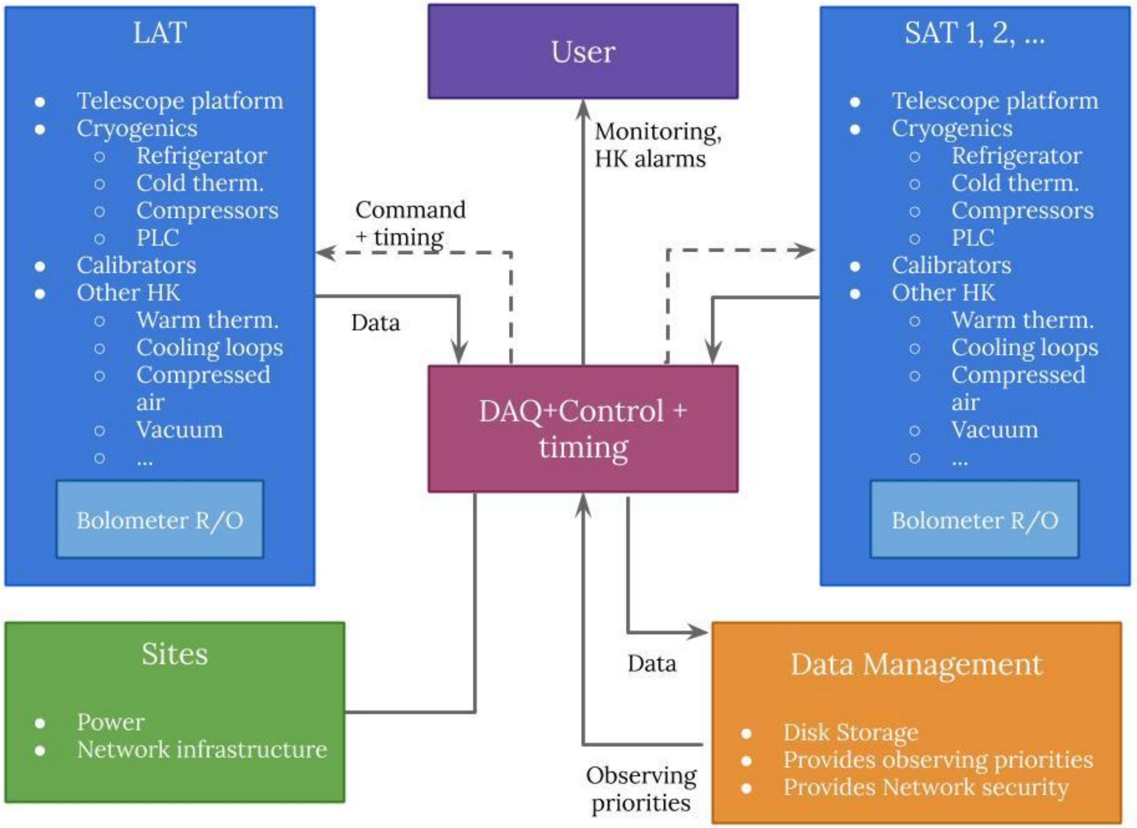
5. Provide observatory-wide timing and frequency references to readout and telescope control hardware

Overview/Scope

CQ2

Scope:

- To deliver a control and data acquisition software package for all subsystems
- Live and historical monitoring of ‘housekeeping’ data and meta-data
- Timing
- Non-safety alarming.



DAQ+Control Design Principles

- Be usable by all hardware groups
  - Hardware groups should prefer interacting with “real” DAQ to parallel home-grown systems -- **avoids duplicated effort, gives early testing and evaluation**
- Use commodity hardware to the extent possible
- Enable hardware experts to contribute to DAQ directly: DAQ component ownership ideally goes with device (except detector readout)
- Be modular:
  - Many pieces need to plug into it
  - Scale from single-lab to full Observatory, and the same for both sites (Chile, SP)
  - Allow non-DAQ personnel to write control interfaces for small hardware pieces
- Be open source, versioned, tracked, CI’d, reviewed, and distributed, common language
- The DAQ+Control interface to the hardware is digital:
  - DAQ is software-only and Ethernet/IP-based

Design drivers: Risk Mitigation and Value Engineering

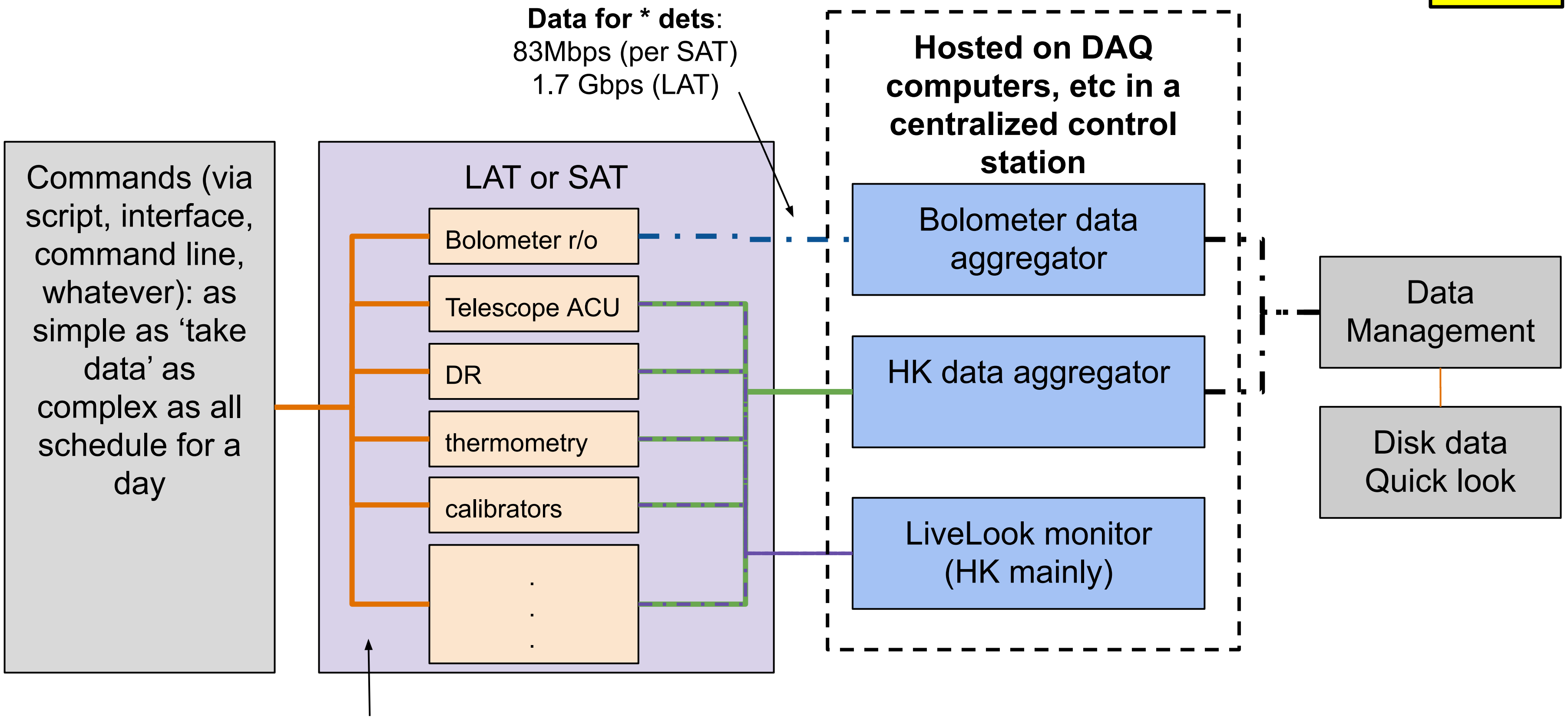
Effort Breakdown: Key Components

- Control and low-rate DAQ (talks by C. Deaconu, B. Koopman)
  - Major current and future work area
  - Huge heterogeneity of systems under DAQ supervision
  - Many sensors and controls, but low data rates (KB/s)
  - **Trade study recently concluded for baseline design**
    - Planning to adopt system developed for Simons Observatory (SO)
    - Substantial code and design reuse, risks burned down by SO
    - Community familiarity with system
    - Clearly the best-aligned with requirements
- High-rate DAQ from detectors (talk by A. Crites)
  - Multi-gigabit homogeneous data stream
  - Tightly coupled to readout L2, interface definition in progress, engineer hired (C. Weaver)
  - **Designed from existing approaches in SPT-3G, SO**
- Hand-off to Data Management (talk by A. Rahlin)
- Interface to sites and test labs (talks by C. Deaconu, N. Whitehorn)
  - NB: Safety alarms are in scope of sites L2, *not* DAQ

Connection Scheme

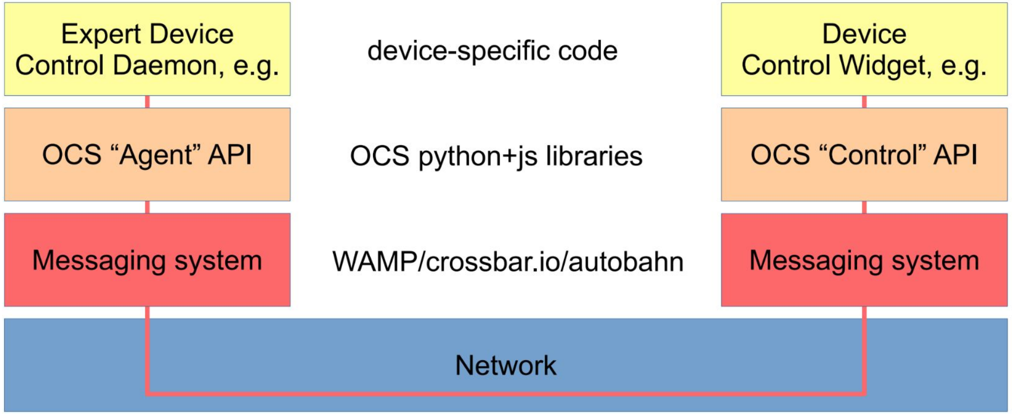
Details: Talks by C. Deaconu, A. Rahlin

CQ2



Timing *on the network* via PTP/SyncE provided

Technical Design: Low-Rate DAQ



Key features:

- Diverse collection of low-rate, low-data-volume sensors (structure thermometers, pressure gauges, power supply voltages, etc.)
- Handoff point in software
- Uses same OCS system as control, pushing small amounts of data through pub/sub system
- Design follows SO, substantial code reuse
- Designed for in-lab deployment as well as at-site
- **Low barrier-to-entry agent production**

Details: Talks by C. Deaconu, B. Koopman

Slow Control Worked Example: SO

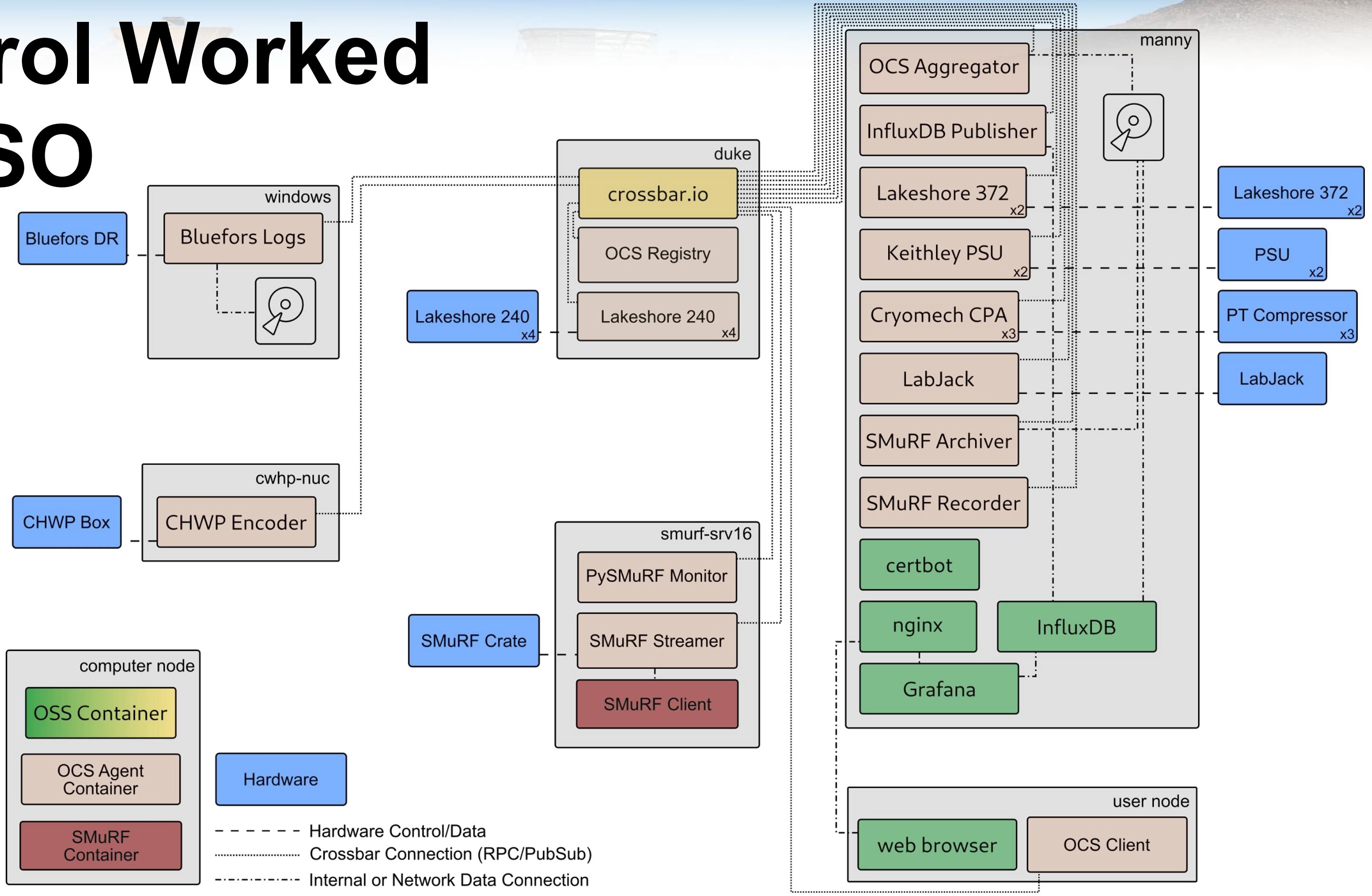


Figure from B. Koopman

‘Messaging system’

Details: Talks by B. Koopman, C. Deaconu

Key features:

- Crossbar.io is SO’s router for WAMP, providing a routed RPC/PubSub interface.
- Has been running in labs for 12+months.
- SO uses it to issue commands and also HK data (low rate)
- Scale testing @ SO scale: 16,000 writes/s (in line with claims of 10’s of thousands of messages/s)
- Distributed, Commercial
- Variety of supported languages, including python

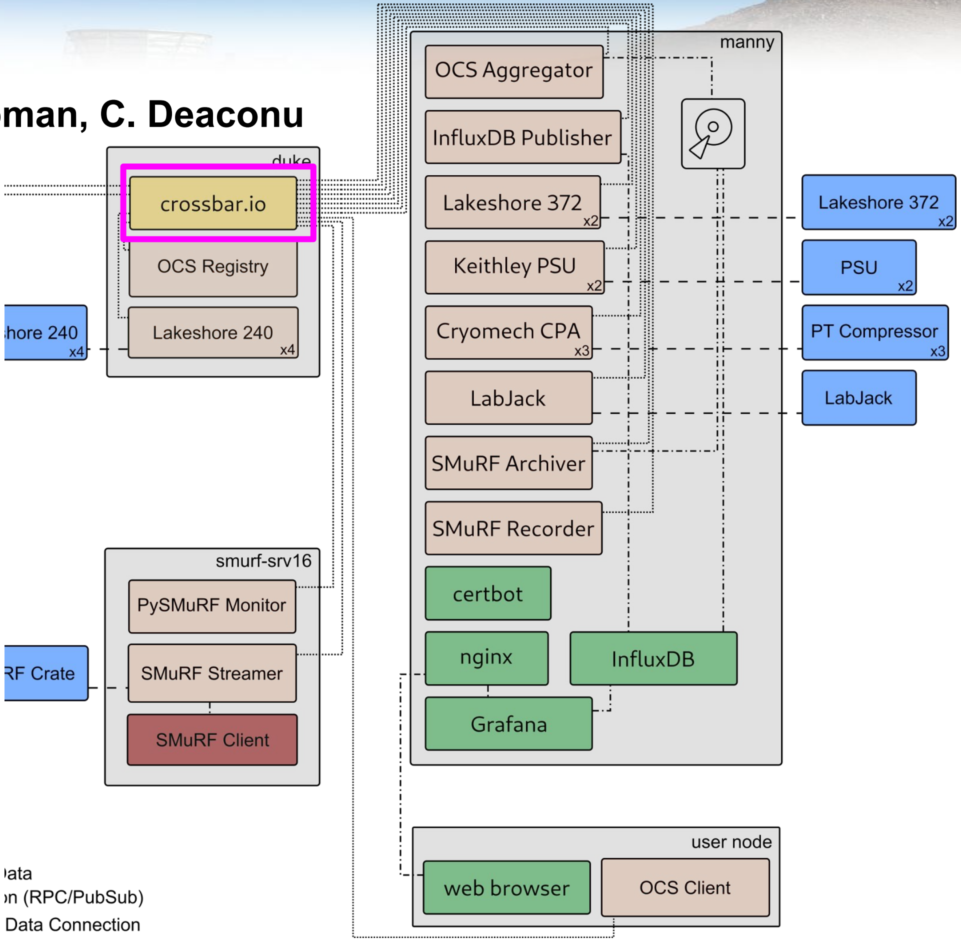


Figure from B. Koopman

Monitoring

Details: Talks by B. Koopman, C. Deaconu

Key features:

- An InfluxdB agent subscribes to the relevant housekeeping data feeds and writes to influxdB
- That serves as a backend for Grafana as a web display
- Allows a great deal of user configurability with no coding
- Combination of live look (~5s) and historical data (likely decimated/downsampled after ~1 week).
- **Also being validated in the field at pole today (SPT-3G)**

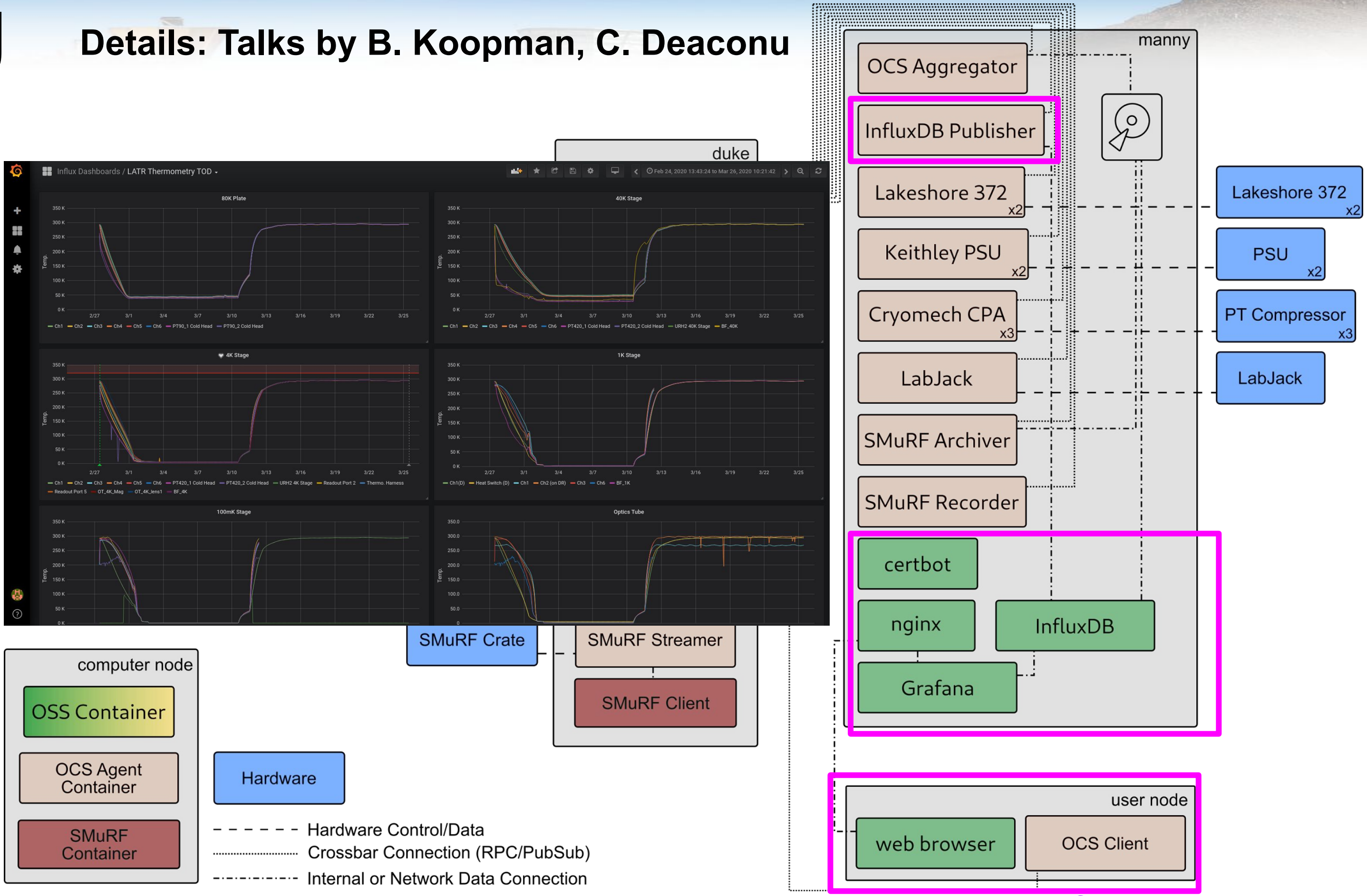
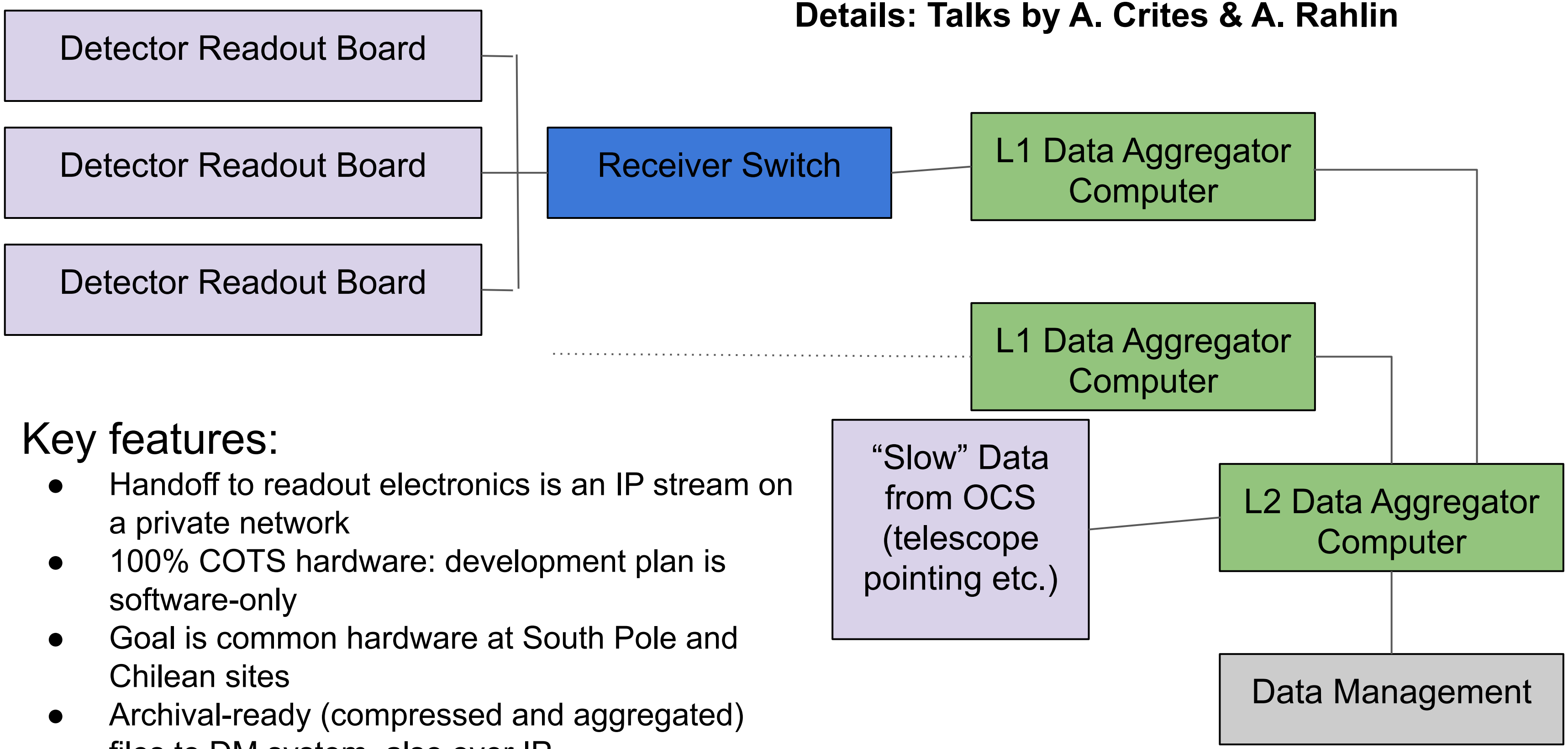


Figure from B. Koopman

Technical Design: High-Rate DAQ

Details: Talks by A. Crites & A. Rahlin



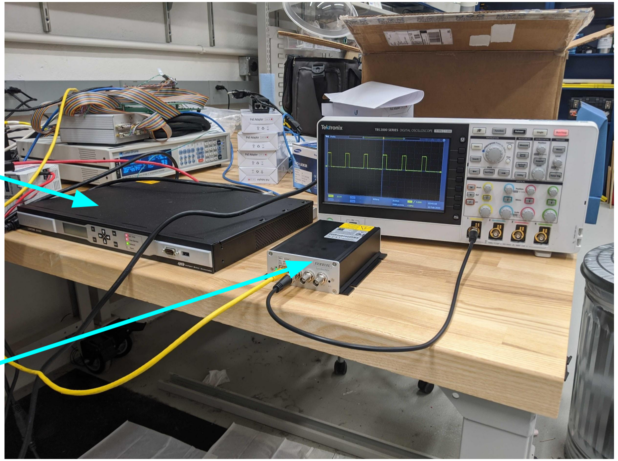
Key features:

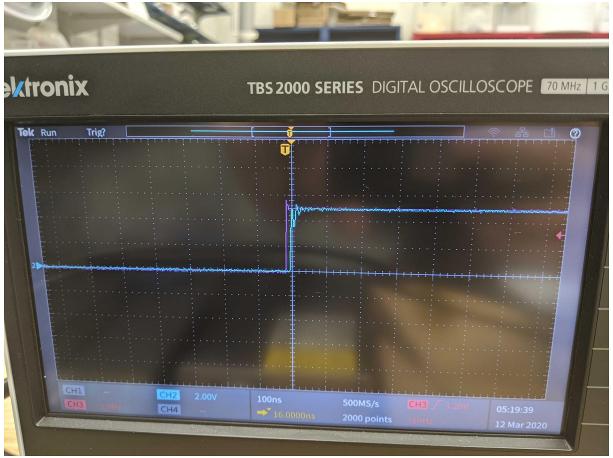
- Handoff to readout electronics is an IP stream on a private network
- 100% COTS hardware: development plan is software-only
- Goal is common hardware at South Pole and Chilean sites
- Archival-ready (compressed and aggregated) files to DM system, also over IP

Timing System

Meinberg Grandmaster GPS Time card (outputs PTP, IRIG, 10MHz, PPS, … highly configurable

Boundary clock: PTP timing to IRIG, 10MHz, PPS (configurable)





Boundary clock and Grandmaster aligned to 16ns (fluctuates within 100ns spec)

Key features:

- Low- and high-level timing signals: support electronics of varying complexity
- **Single timing domain per site**
- Meets requirements from known readout: Following design from SPT-3G (10 MHz + IRIG) and SO (near clone of this + PTP), limiting risk
- Assumption is that we will need to support asynchronous data (at minimum between housekeeping objects), and thus time stamps will be required for each data field

Prototyping Plans

Key idea is to provide DAQ for hardware when and where hardware is available

- Finalizing software and hardware frameworks now
  - These frameworks are the interface for “miscellaneous” parts of the system without another defined interface
  - Get these lab-tested
  - Encompasses timing hardware system and general slow-control system
- Working on key interfaces
  - Interface definition with readout system
    - Needed for detector testing in lab
    - Encompasses hardware handoff (electrical interface), control system (network interface), data-streaming data and transmission, and where everything physically sits
  - Interface definition with telescope control
    - Less advanced
    - Not critical for lab testing

Schedule drivers

CQ6

Key schedule drivers:

1. Late 2021: Readout board prototypes
2. July 2022: S4 cryogenics: (driven by SAT DR procurement)
3. Apr 2023: SAT telescope mount (installation and test fixture)
4. May 2024: LAT telescope mount: (LAT control system I&T)
5. Mar 2023: Majority of housekeeping:
    - Mar 2023: SAT telescope mount ‘structure housekeeping’
    - May 2024: LAT Receiver components