MIT Haystack / NASA VGOS Signal Chain

12th IVS TOW Workshop

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Agenda

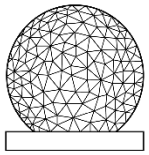
- Historical Overview of Signal Chain
- Haystack / NASA stations Signal Chain
- Frontend Systems
- Backend Systems
- Calibration Systems
- Monitor and Control
- Command / Control Architecture
- Documentation Highlights

Historical Overview

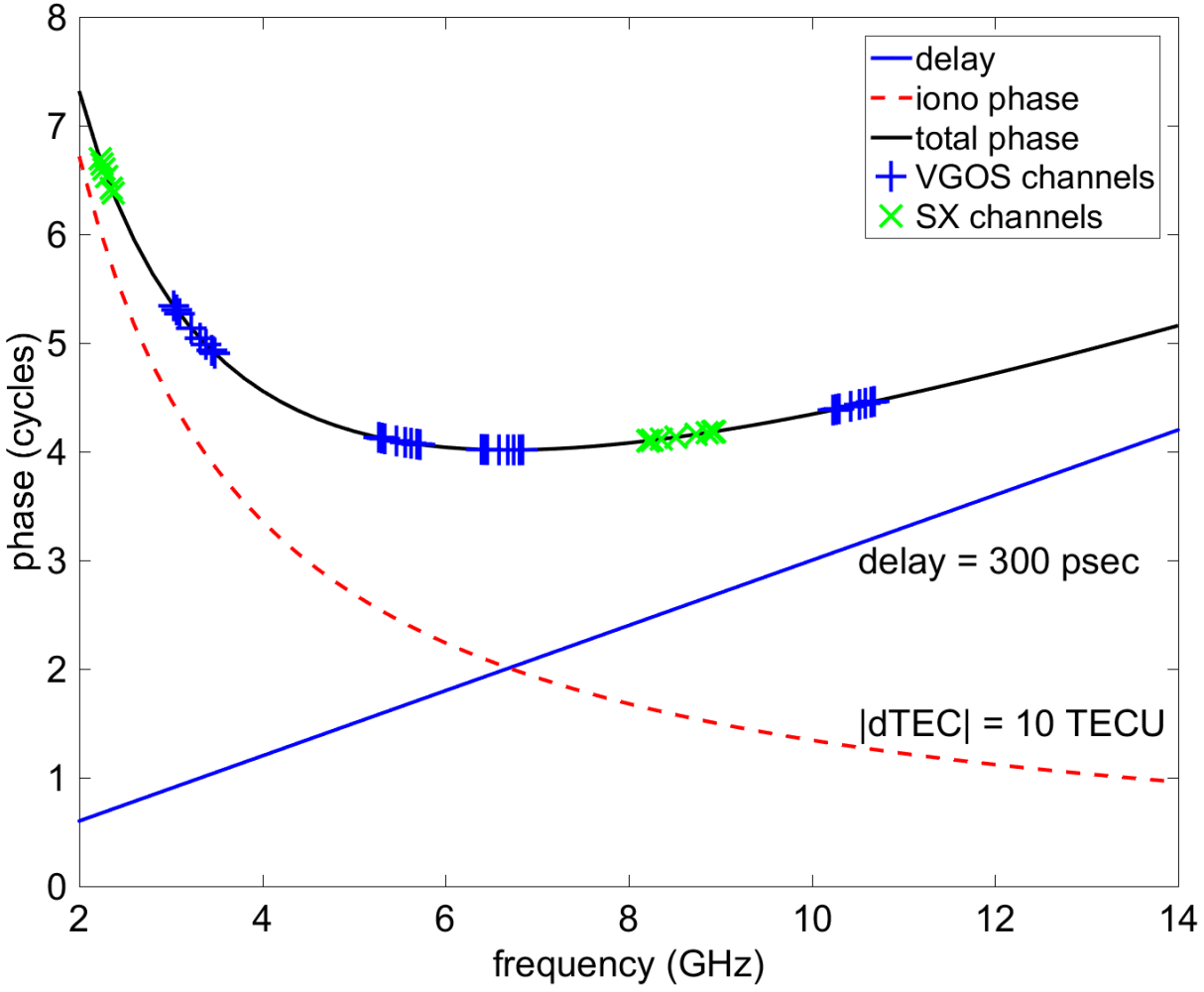
- Why the system is setup as it is (AEN)?

VGOS goals

- Early 2000s: what new VLBI system would provide an accuracy of approximately 1 mm in position on a global scale? S/X accuracy 5 – 10 mm
- The characteristics of the new system were derived by the VLBI2010 Committee (Petrachenko et al 2009)
  - Primary goal: delay precision of 4 picoseconds or better
    - Four bands of 1024 MHz spanning 2.2 GHz to 14 GHz
  - Smaller, faster antennas with SEFD of 2500 Jy or less
    - Dual polarization used to increase the sensitivity
    - Linear polarization required to achieve recorded bandwidth



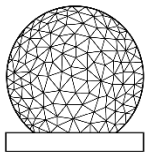
VGOS frequencies



VGOS choices: GGAO12M – Westford prototype

VGOS compliant

	Goal	Achieved	Limitations
Spanned freqs	2.2-14 GHz	2.2-12 GHz	prototype feed 2-11 GHz fiber links
Band bandwidth	1024 MHz	512 MHz	available samplers
Observ/minute	> 2	~1	prototype 12m antenna existing 18m antenna
Scan length	5 seconds	30 sec used	higher SNR to study systematics
Delay precision	4 ps	2 ps (median)	goal achieved!



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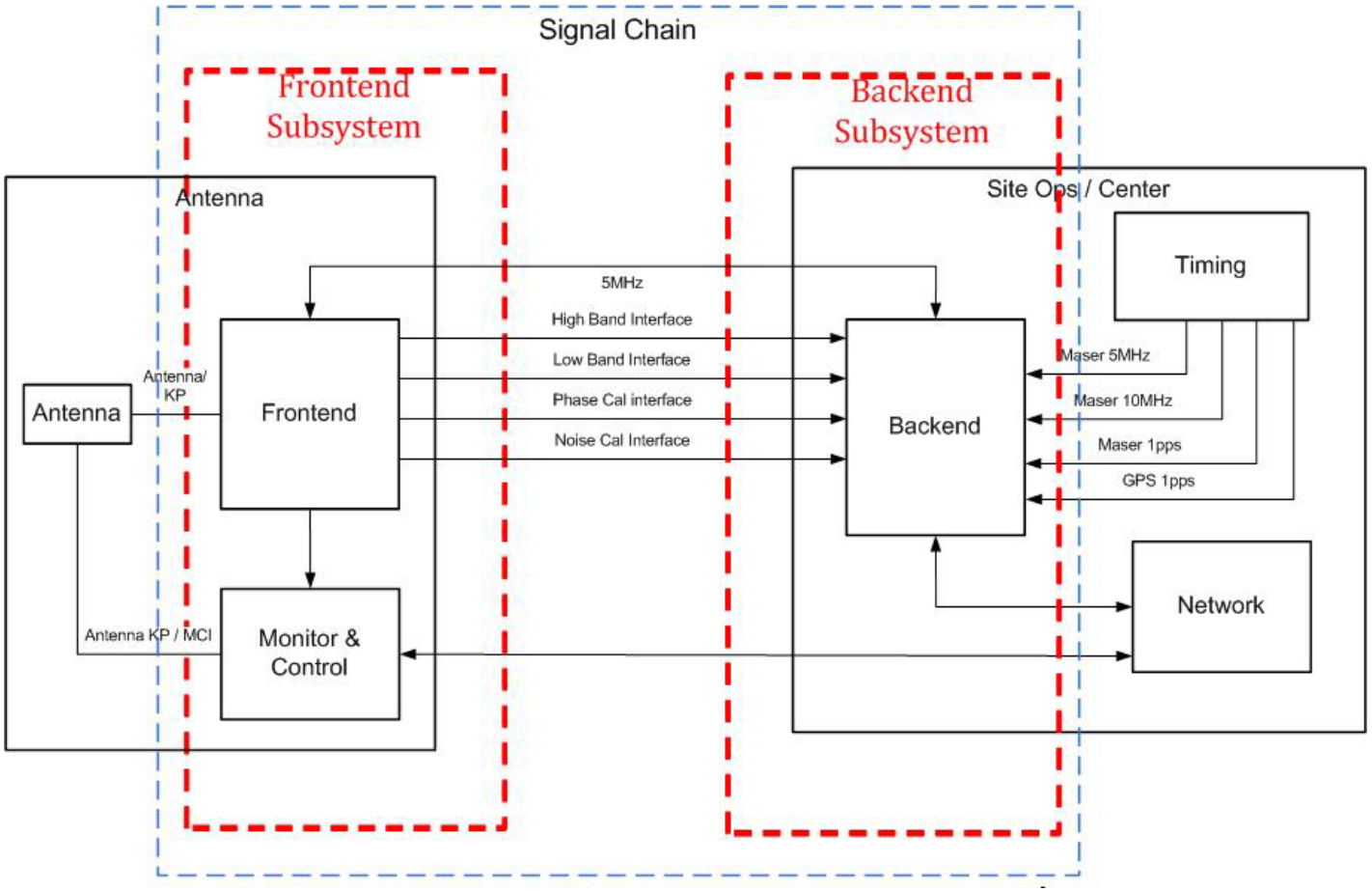
Haystack / NASA Signal Chain Overview

- Three versions of MHO Signal Chain
  - Version 1 : Developmental (non-VGOS compliant – 512MHz bands)
    - 2.2 – 12 GHz (GGAO)
  - Version 2 : First generation (VGOS capable)
    - 2.2-14 GHz (KPGO, MGO)
    - Equipment in signal chain makes it non-VGOS compliant
    - Operationally consistent between sites
  - Version 3: Second generation (VGOS compliant – 1024 MHz bands)
    - 2.2 – 14 GHz (Westford)
    - Roll out to other NASA sites expected 2023 / 2024
  - Working to get all NASA stations to the same configuration
- A complete signal chain consists of mechanical / network electrical distribution / instrumentation

High Level Block Diagram



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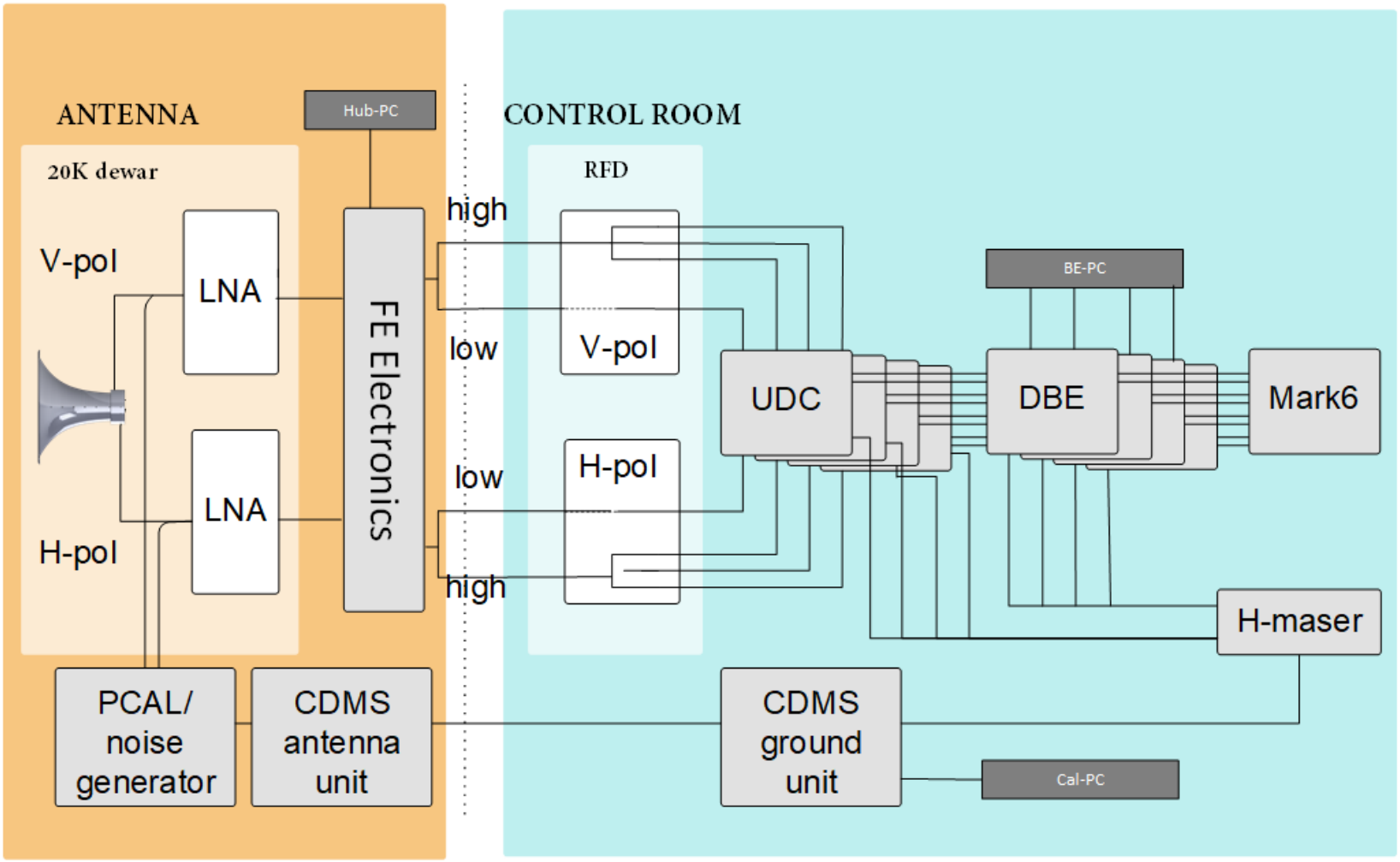
Detailed Block Diagram



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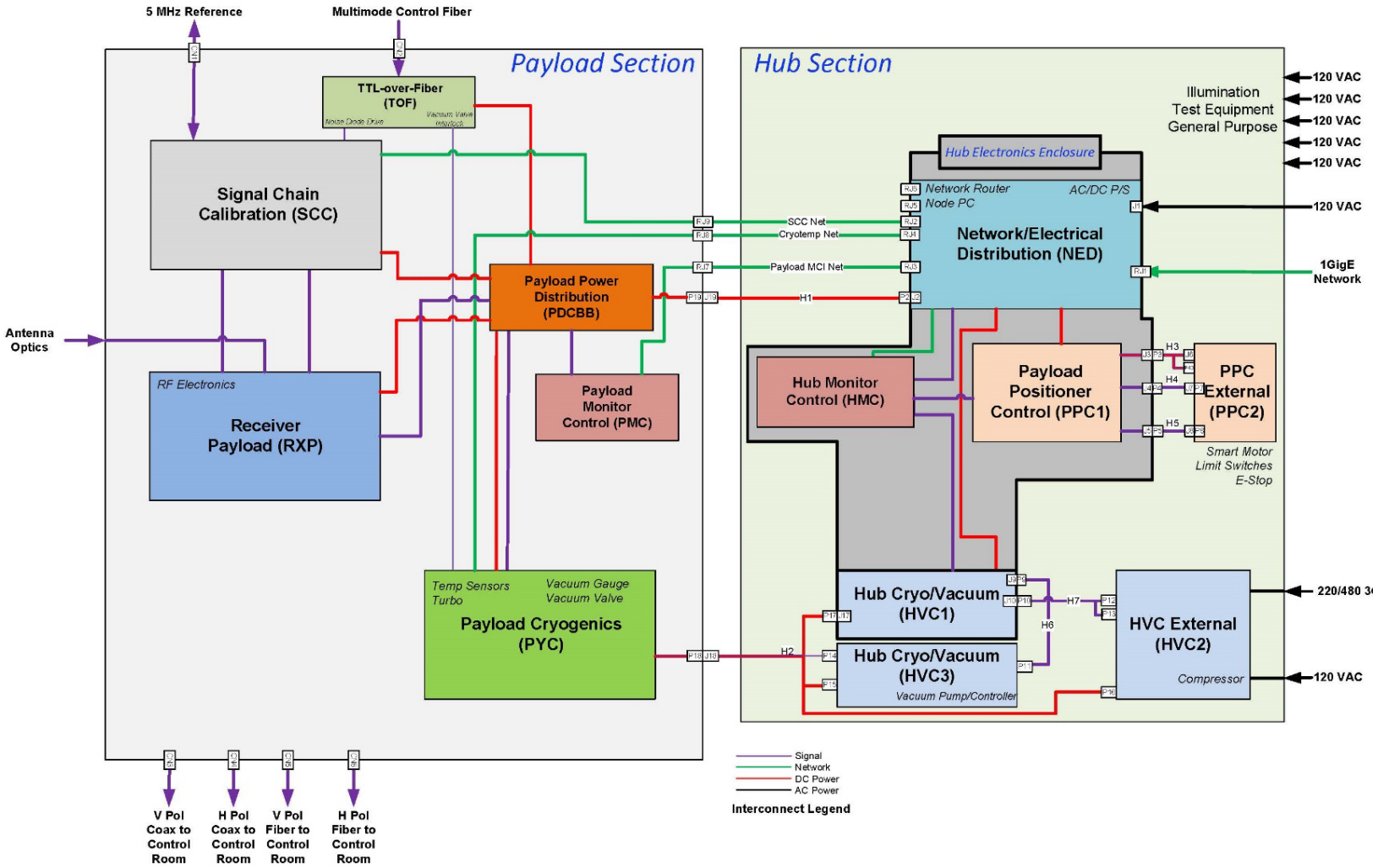
Frontend Block Diagram



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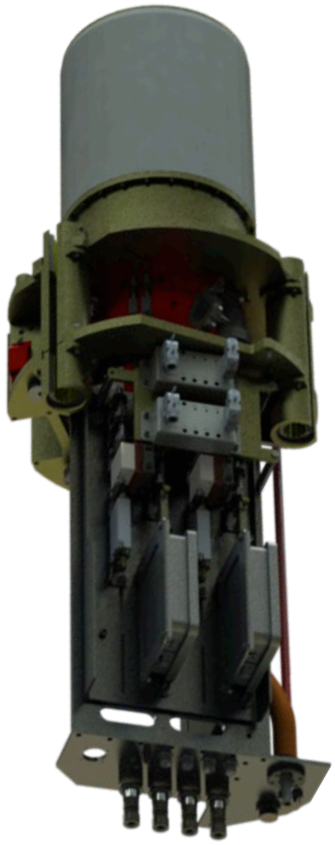
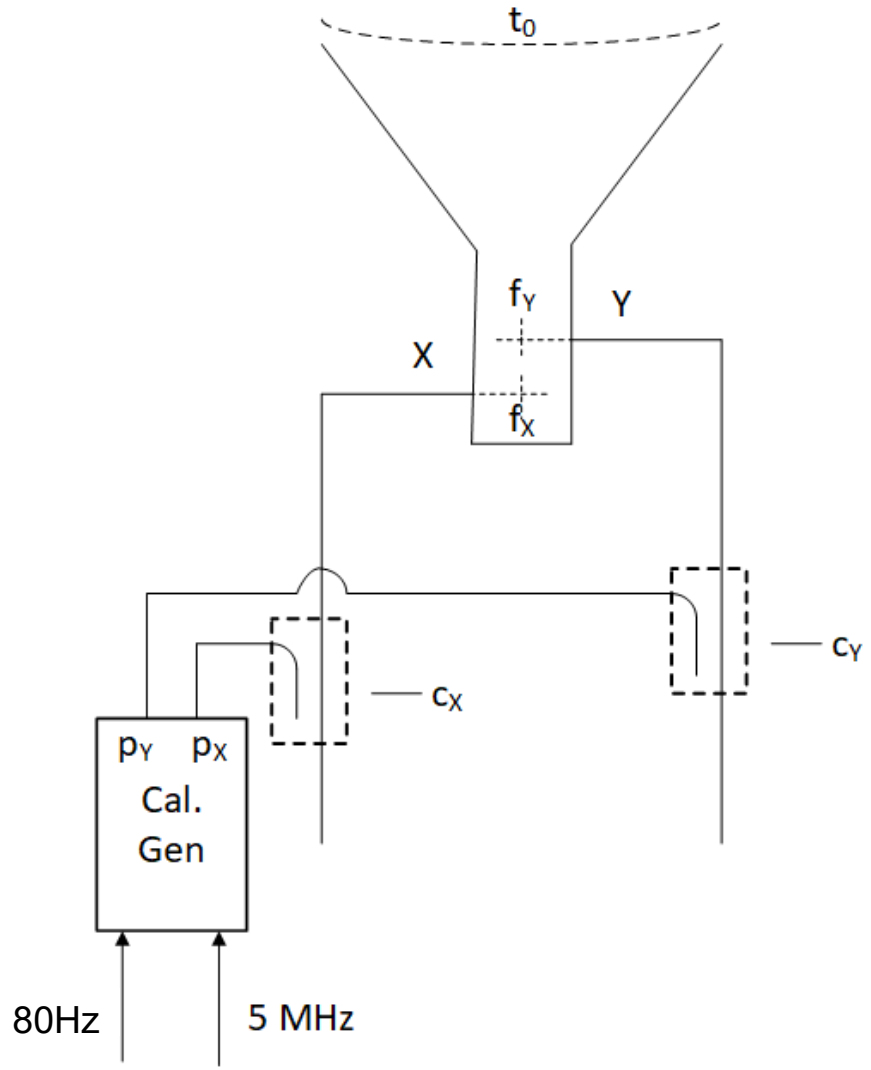
Receiver Payload

- 2-14 GHz Cryogenically cooled receiver
  - FE noise temperature of 40K max
- QRFH Feed
  - Efficiency > 50%
- Dual linear H/V polarization
  - Low band 2 – 5GHz
  - High band 4 - 14 GHz
- Supports
  - Pre-LNA instrumental phase / amplitude monitoring
  - Operational servicing
  - Operational control / monitoring



Signal Chain Calibration Subsystem

- Covered as a complete system for the VGOS signal chain
- Injection of phase & noise cal pre-LNA



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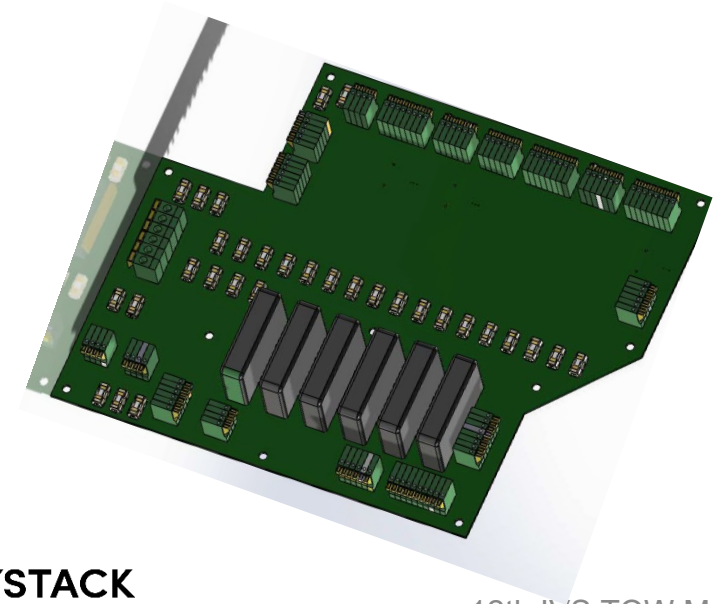
Frontend Payload Power Distribution Subsystem

- DC Breakout Board
  - Evolved from lessons learned during the KPGO12m FE troubleshooting
    - Short resulted in loss of FE subsystems
  - Power distribution / monitoring capabilities
  - Environmental monitoring
  - Accelerometer and Gyro monitoring

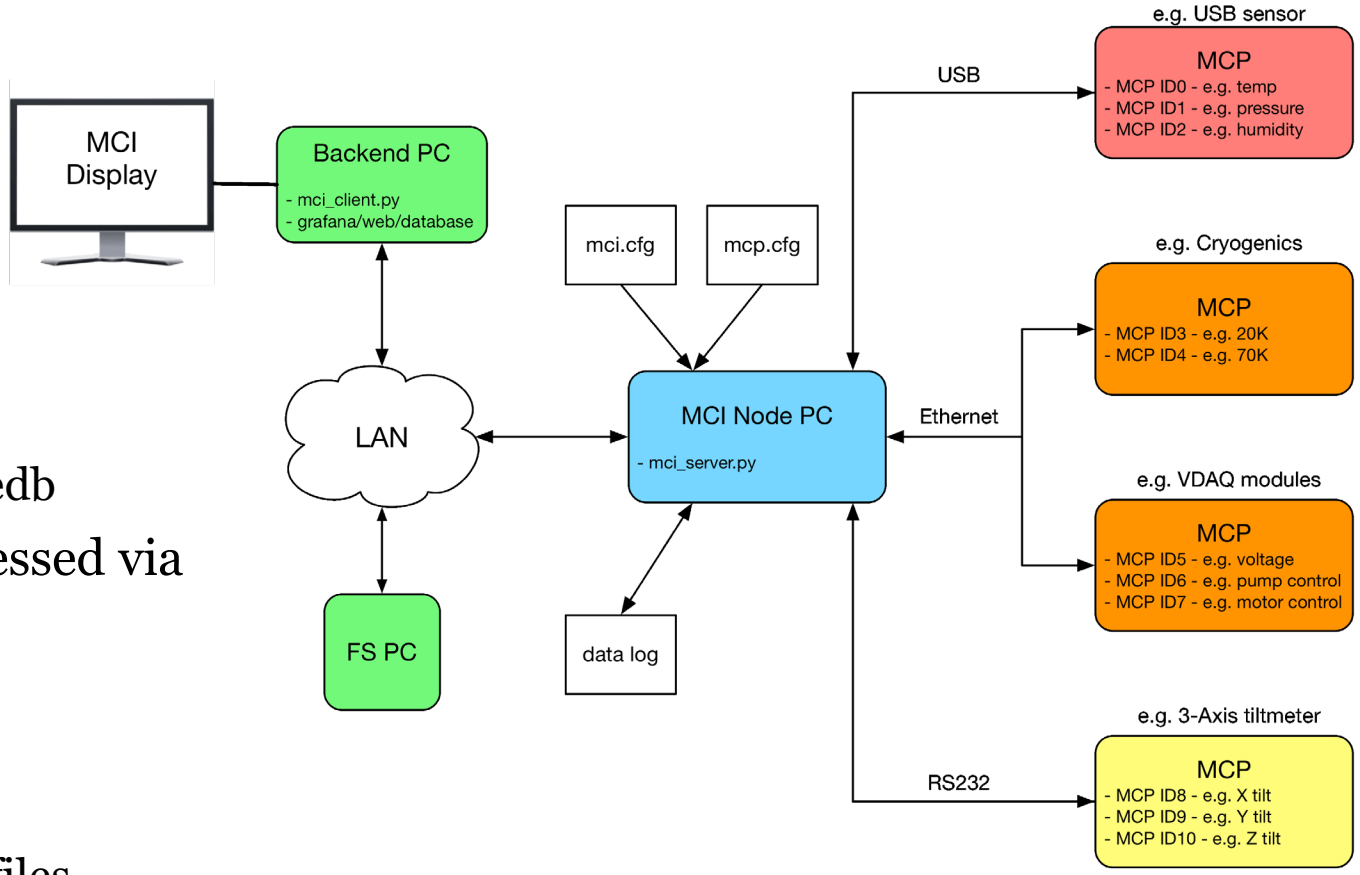


Monitor and Control Subsystem

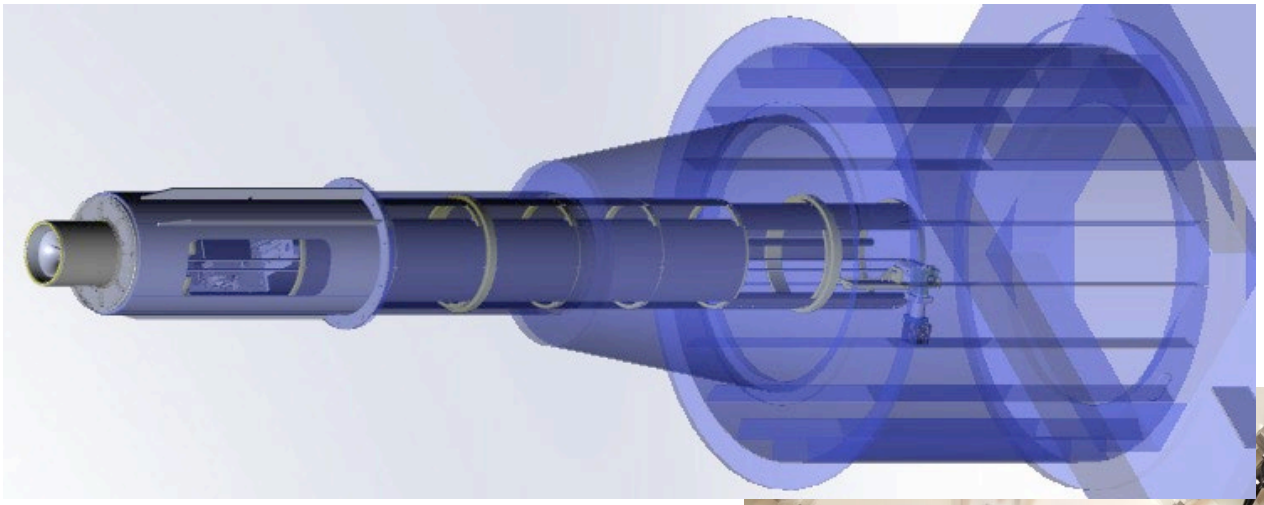
- Frontend centralized monitor / control of the payload and antenna hub
  - 81 Monitor Control Points (MCP)
- Monitor subsystems
  - Environmental (temperature / humidity / pressure)
  - DC Voltage (-5V, +5V, +15V)
  - DC Current
  - RF Power
  - Alarms (e.g. Compressor)
  - Linear Displacement (positioning system)
- Control
  - Variable Attenuators
  - Compressor functions
  - DC Power (Pre-amplifies, Calibrator, Compressor)

Monitor and Control Architecture

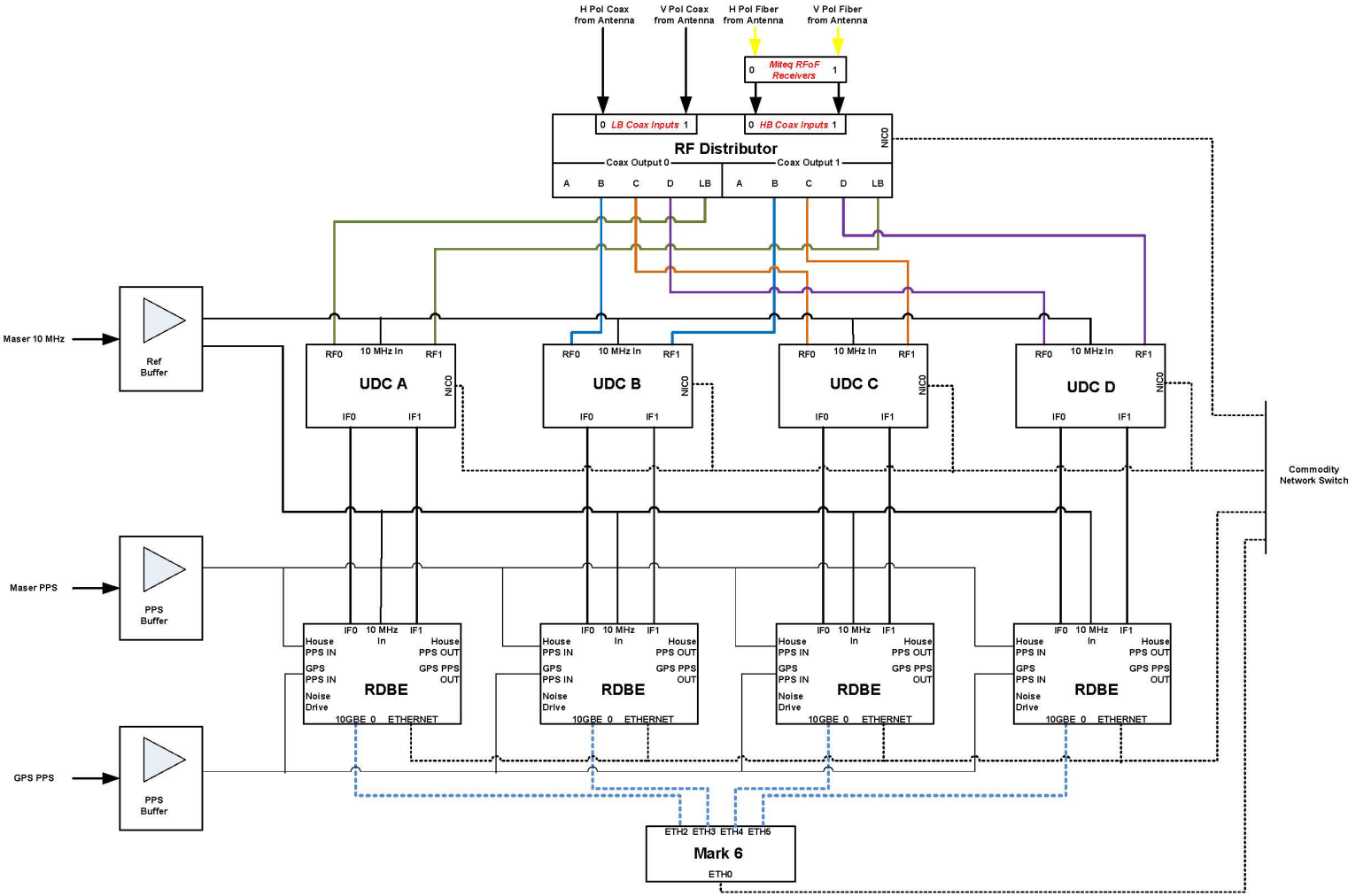
- Accessible to
  - PCFS
  - Grafana/infusedb
- Information accessed via
  - Ethernet
  - USB
  - RS232
- Nodes defined
  - Configuration files
- Data are logged periodically



Frontend System



Backend Block Diagram



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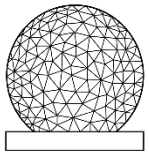
UpDown Converter (UDC)

- UDC's support a 2-14GHz RF to IF frequency conversion
- Two versions exist:
  - 2.0 with KPGO/MGO
    - IF Output 512-1024MHz
    - Tuning range 2-12 GHz. 400 kHz resolution
  - 2.1 at Wf
    - IF output 512-1536MHz
    - tuning range 2-16 GHz. 40 Hz resolution
    - Upgrade plan for NASA stations 2020
- Require 4 UDCs for VGOS signal chain
  - 1 low band (2.3 – 5 GHz)
  - 3 high band (4 -14 GHz)
- Configurable via Ethernet, e.g. PCFS, or front panel (manually)
- Variable attenuation 0-31.5dB

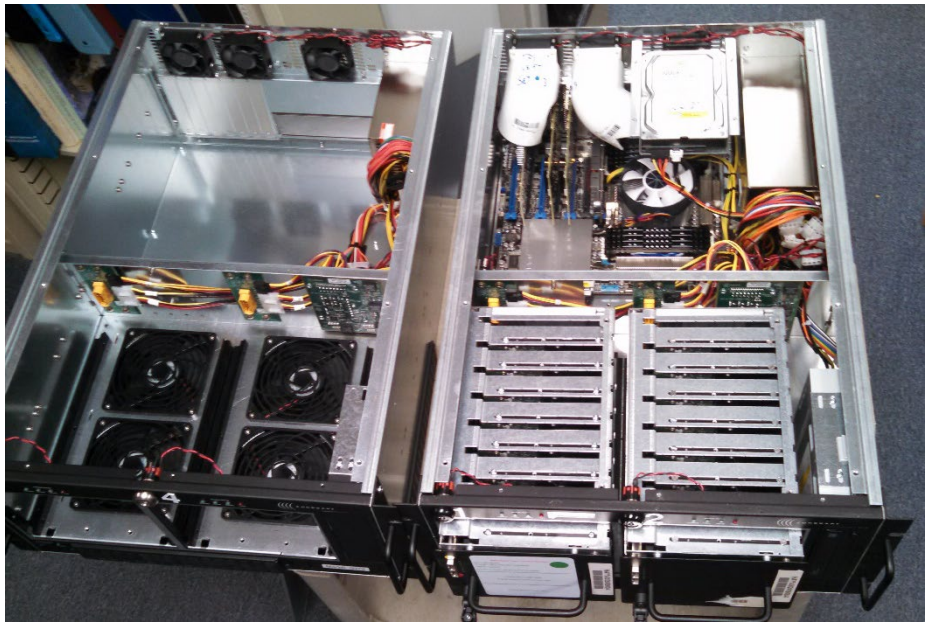
Roach Digital Backend (RDBE)

- Roach DBEs supports 512 or 2 GHz IF BW to digital conversion output on 10 Gbps Ethernet Interface
- Two versions exist:
  - Roach1 (RDBE-G) at KPGO/MGO / Yj
    - 512 MHz band IF Input
    - Polyphase filter bank (PFB) FPGA personality
    - 16 Channels of complex data at 2Gbps
  - Roach2 (R2DBE-G) at Wf and Yj
    - 2 GHz band IF Input
    - Polyphase filter band (PFB) FPGA personality
    - 16/32/64 Channels complex data at 2 / 4/ 8 Gbps, respectively
  - Upgrade planned for NASA stations 2023
- Outputs 10-100 MHz diode control for oise calibration system
- Require 4 DBEs for VGOS signal chain

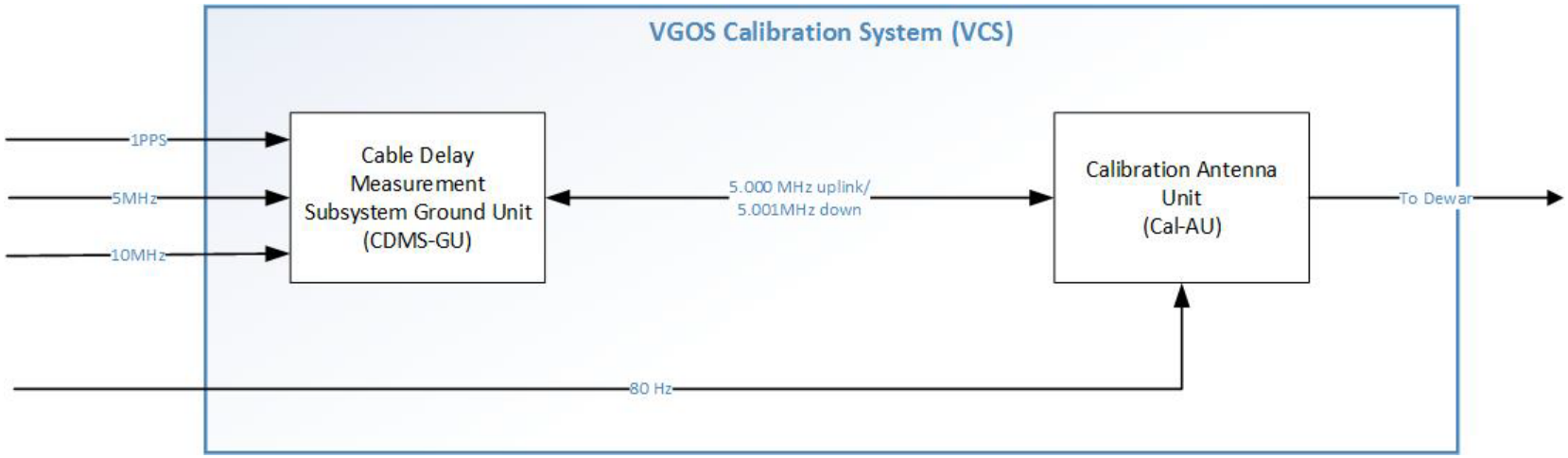


Mark6

- 16Gbps data recorder (2013)
  - Astronomy / Geodesy dual use
- Records data to disk module
  - 4 Gbps per module guaranteed
  - Data can be shipped or e-transferred from system to correlator
  - Supports 8-X TB disk modules
- NASA sites have 2 systems per site
  - Spare
- Software
  - control-plane and data-plane
- OS distribution
  - Debian
  - CentOS 7

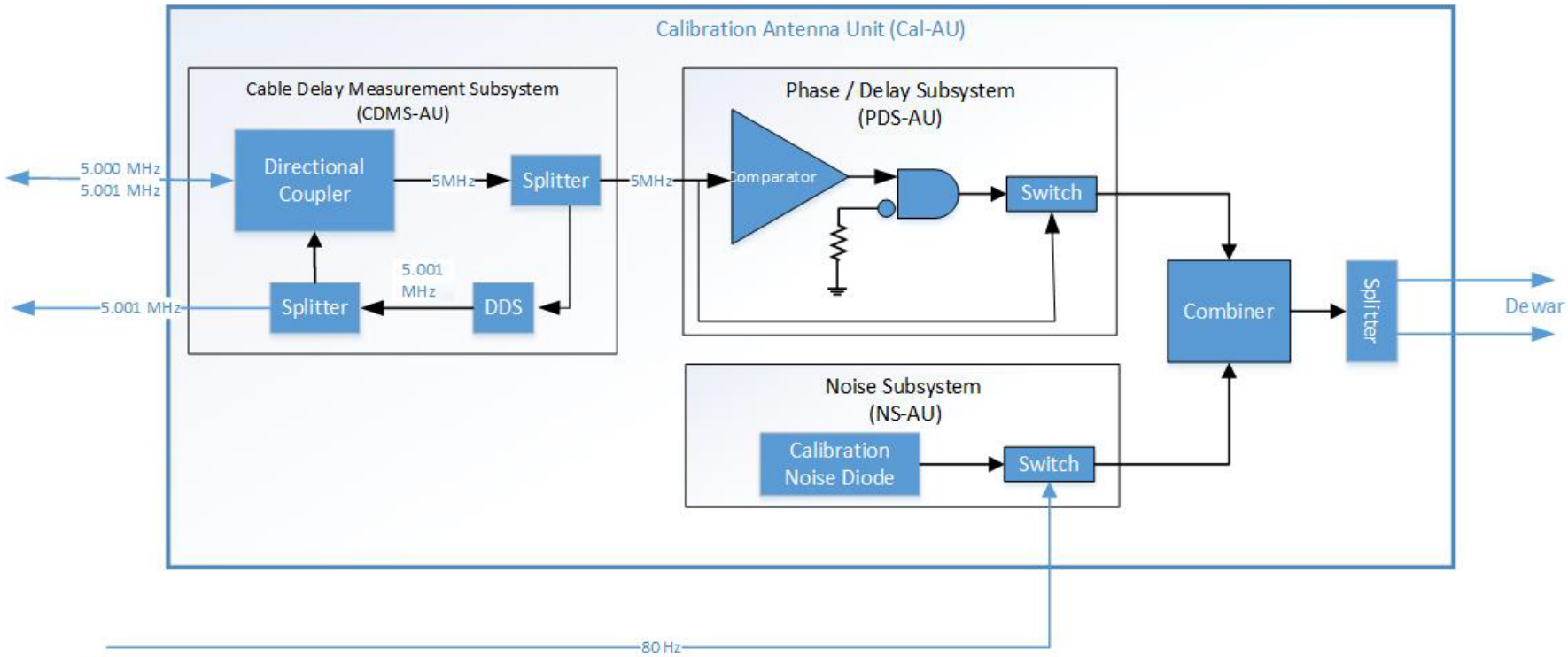


VGOS Calibration System

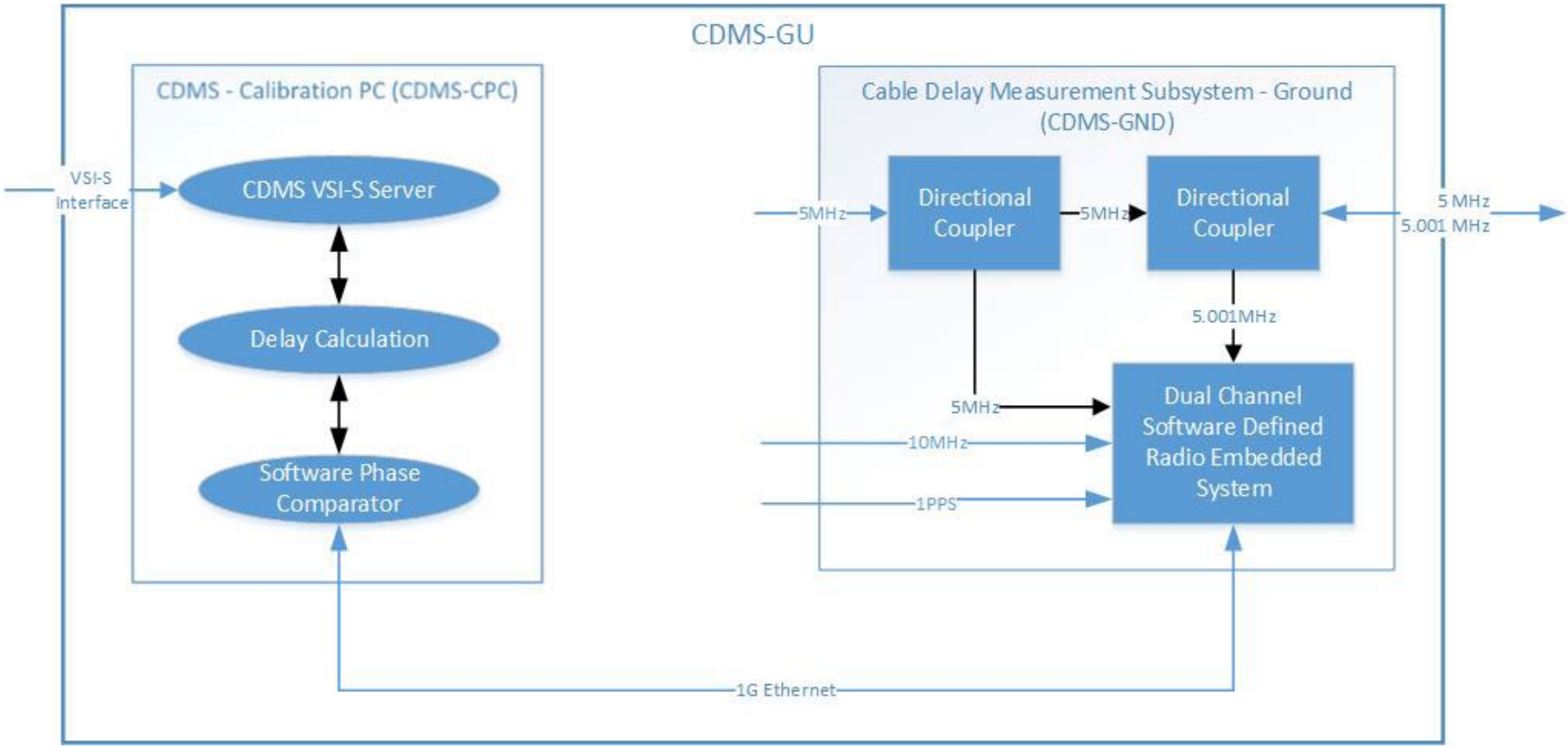


- Calibration Antenna Unit
  - Phase calibration injection
  - Noise calibration injection (sourced from one RDBE-G Unit – 10-100MHz)
  - Cable Delay Measurement System - AU
- CDMS Ground Unit
  - Cable Delay Measurement System – Gnd
  - Calibration PC - recorder

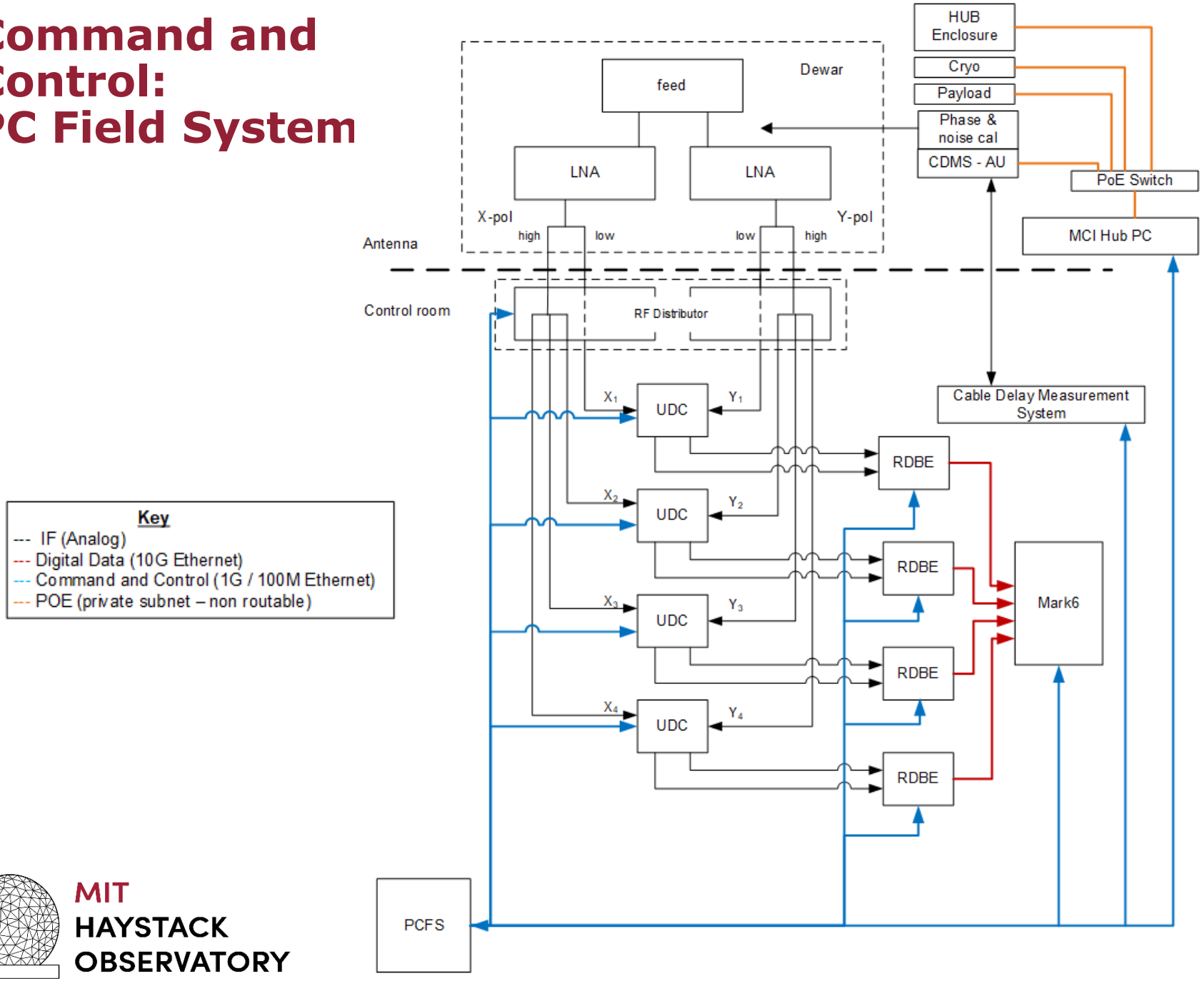
Calibration Antenna Unit



CDMS Ground Unit



Command and Control: PC Field System



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Documentation

- For all systems
  - Users Manuals
  - Verification and Validation methods and results
  - Interface control documents
  - Installation procedures
    - Required for NASA safety
  - Safety analysis
  - Spare(s) guidelines
  - Maintenance procedures
  - Version control of all documents and systems

Questions?