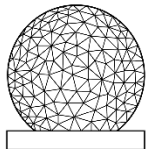


MIT Haystack / NASA VGOS Signal Chain

13th IVS TOW Workshop

Chet Ruszczyk

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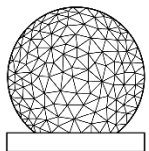
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Agenda

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

VGOS goals

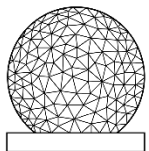
- Early 2000s: what new VLBI system would provide an accuracy of approximately 1 mm in position on a global scale? S/X accuracy 5 – 10 mm
- The characteristics of the new system were derived by the VLBI2010 Committee (Petrachenko et al 2009)
 - Primary goal: delay precision of 4 picoseconds or better
 - 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 choices: GGAO12M – Westford prototype

VGOS compliant

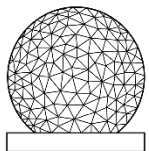
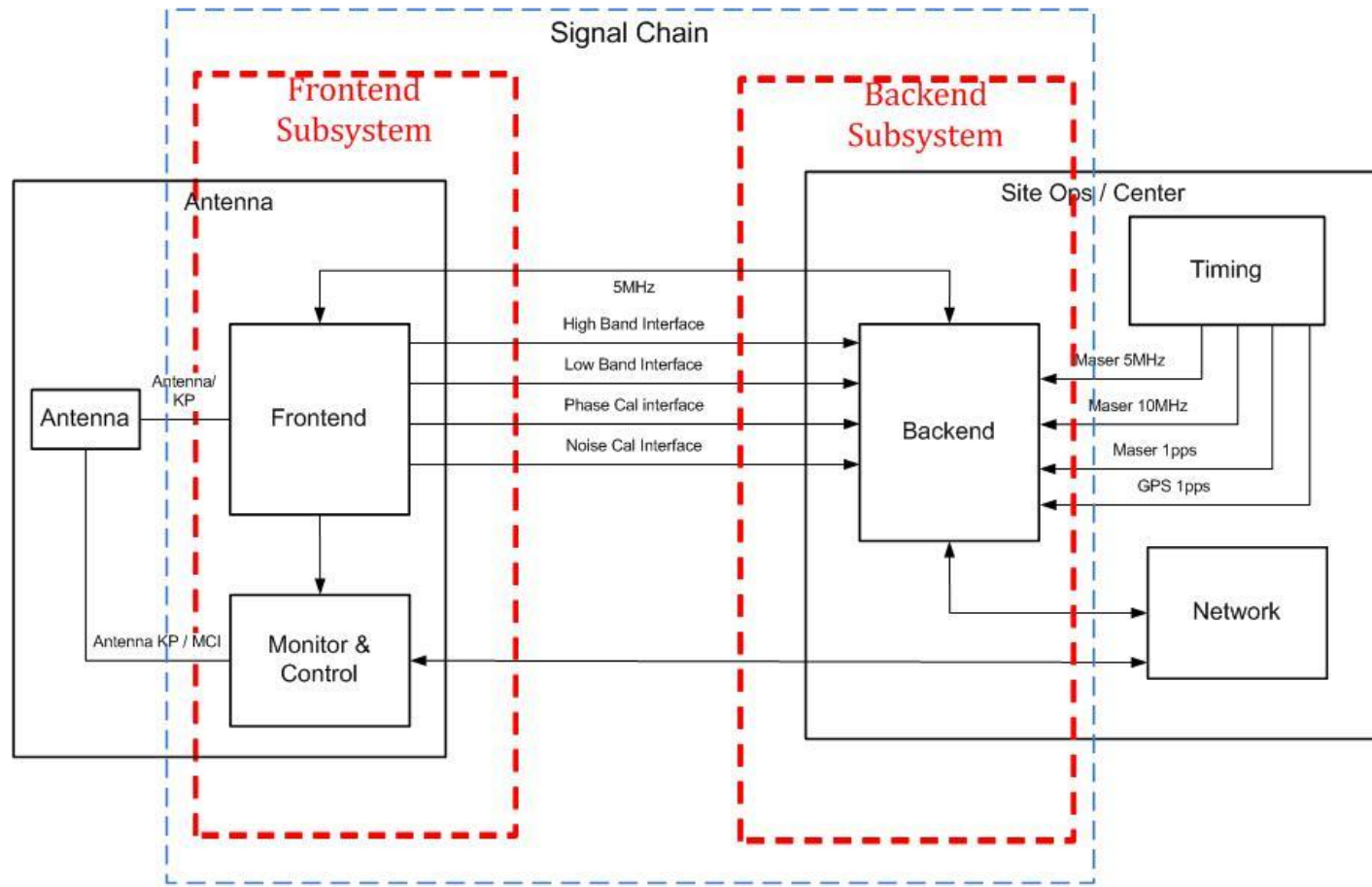
	<u>Goal</u>	<u>Achieved</u>	<u>Limitations</u>
Spanned freqs	2.2-14 GHz	2.2-12 GHz	prototype feed 2-11 GHz fiber links
Band bandwidth	1024 MHz	512 MHz	available samplers
Observ/minute	> 2	~1	prototype 12m antenna existing 18m antenna
Scan length	5 seconds	30 sec used	higher SNR to study systematics
Delay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



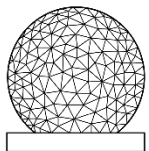
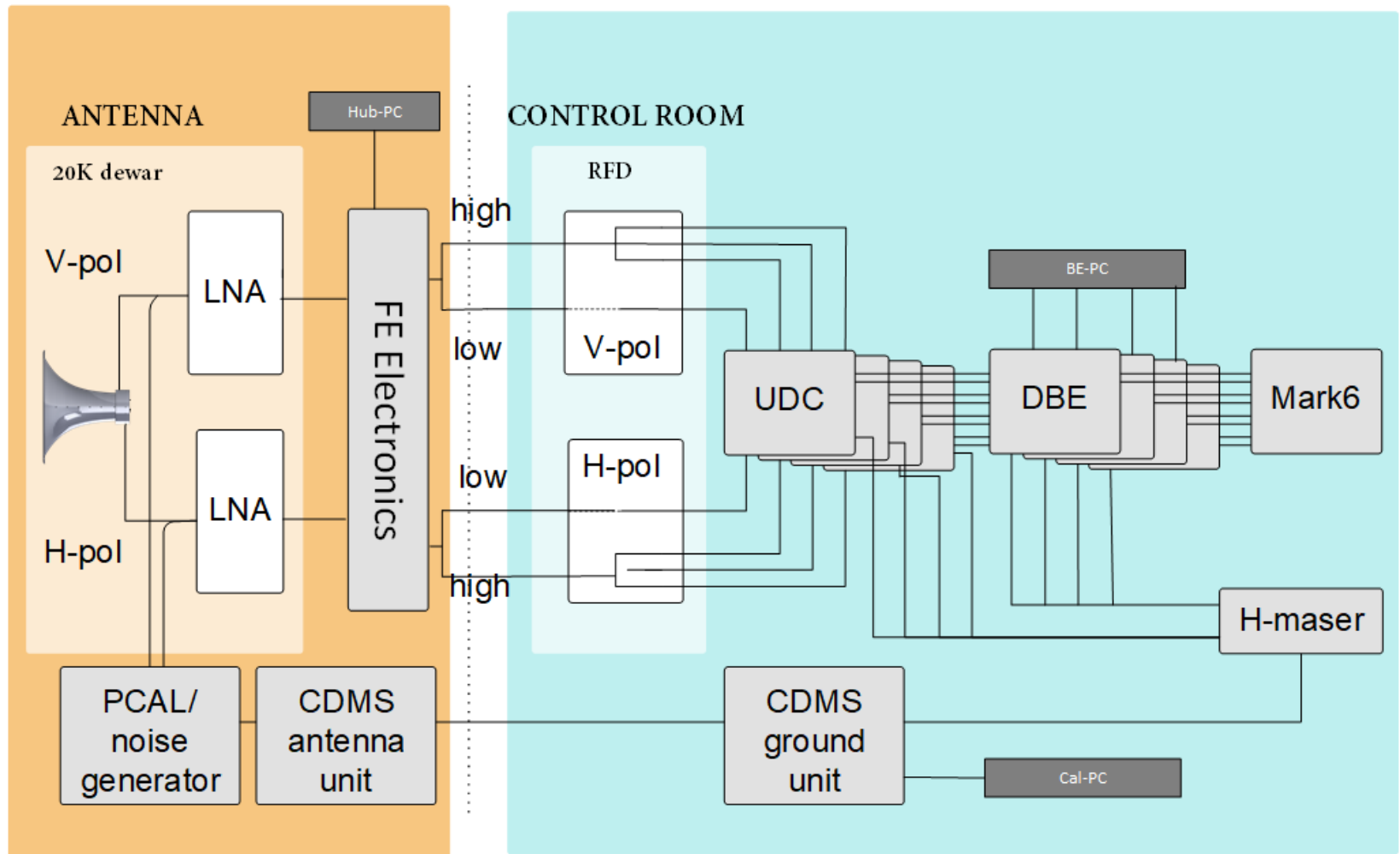
Haystack / NASA Signal Chain Overview

- Three versions of MHO / NASA 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 (UDC / DBEv3)
 - Operationally consistent between sites
 - Version 3: Second generation (VGOS compliant – 1024 MHz bands)
 - 2.2 – 14 GHz (Westford, FGO, Tahiti?)
 - Roll out to other NASA sites expected 2025 / 2026
 - Working to get all NASA stations to the same configuration
- A complete signal chain consists of mechanical / network electrical distribution / instrumentation

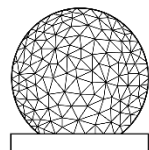
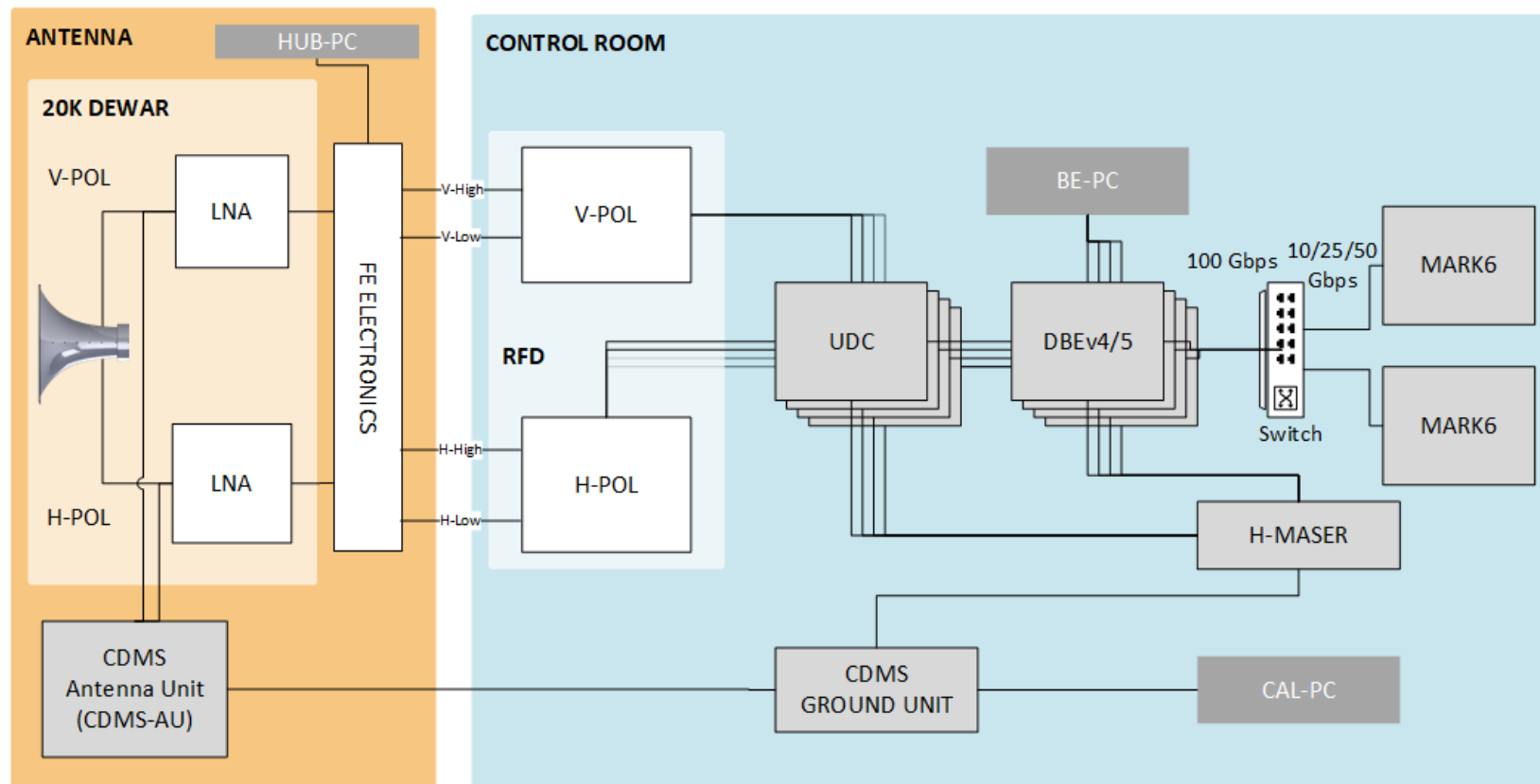
High Level Block Diagram



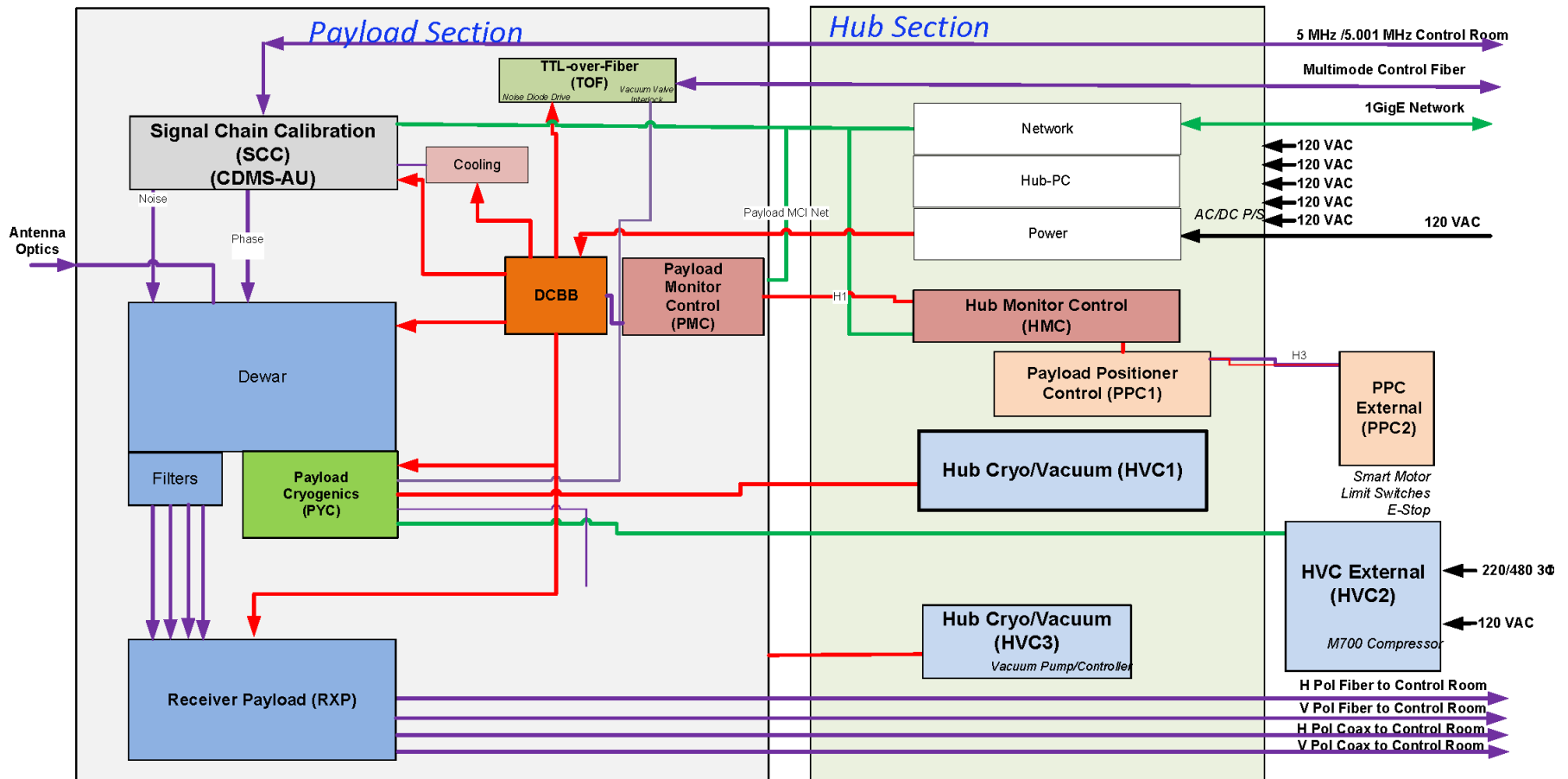
Detailed Block Diagram (Gen 1)



Detailed Block Diagram (Gen 2/Gen3)

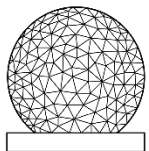
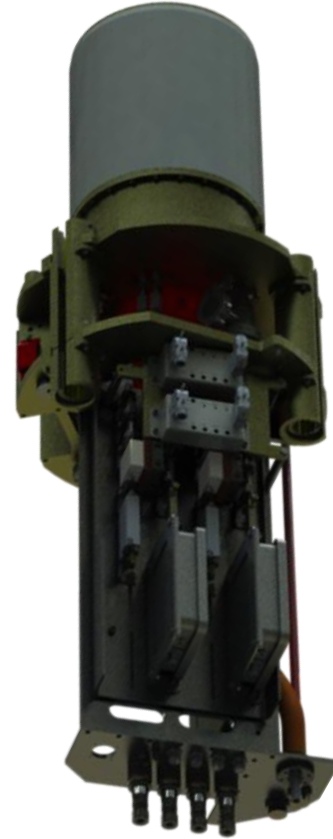


Frontend Block Diagram



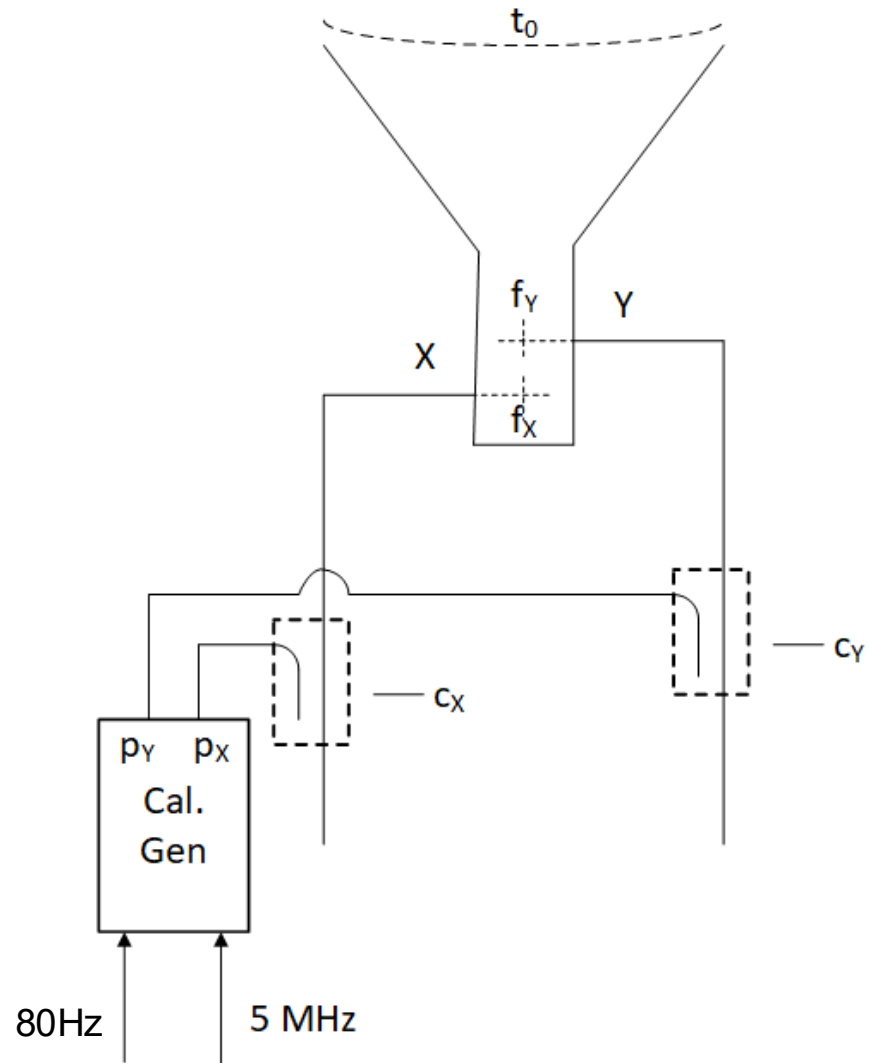
Receiver Payload

- 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



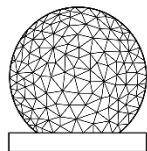
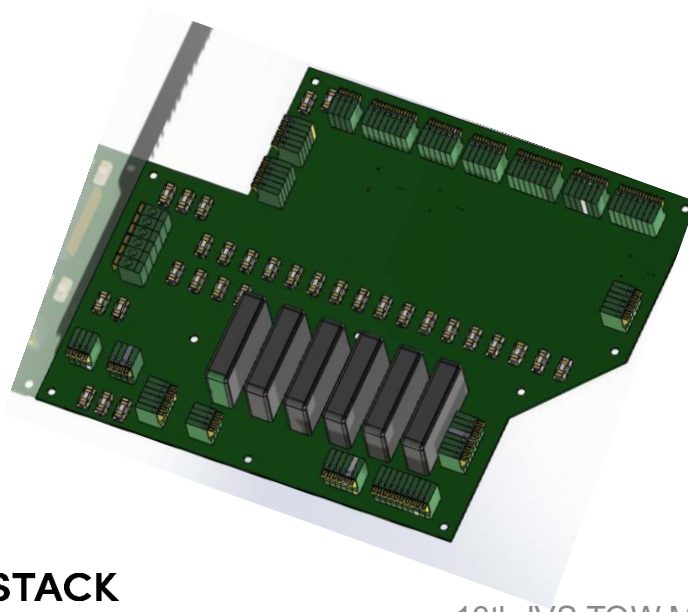
Signal Chain Calibration Subsystem

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



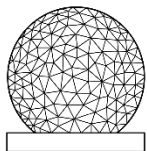
Frontend Payload Power Distribution Subsystem

- DC Breakout Board DCCB
 - 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



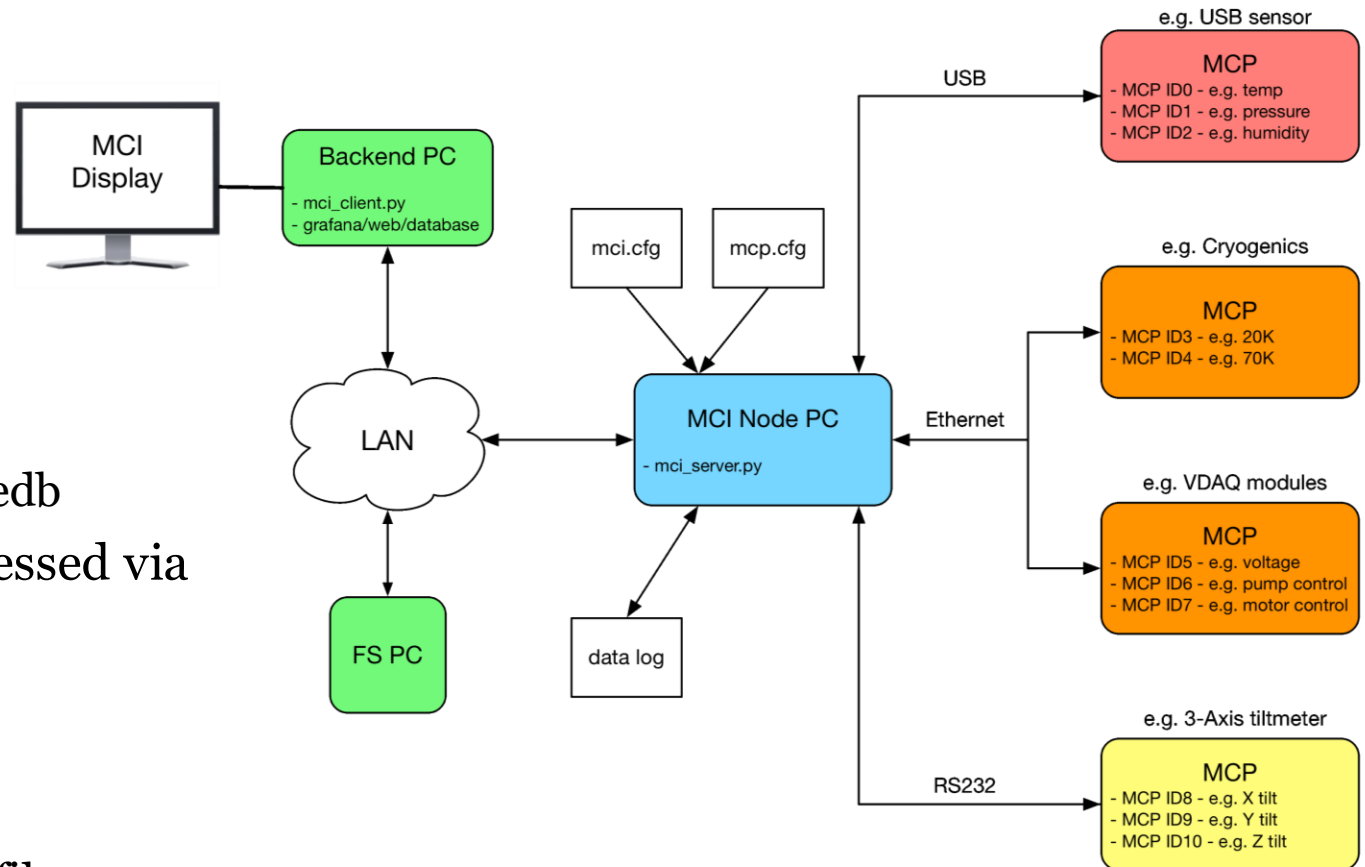
Monitor and Control Subsystem

- 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)

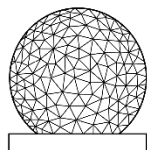
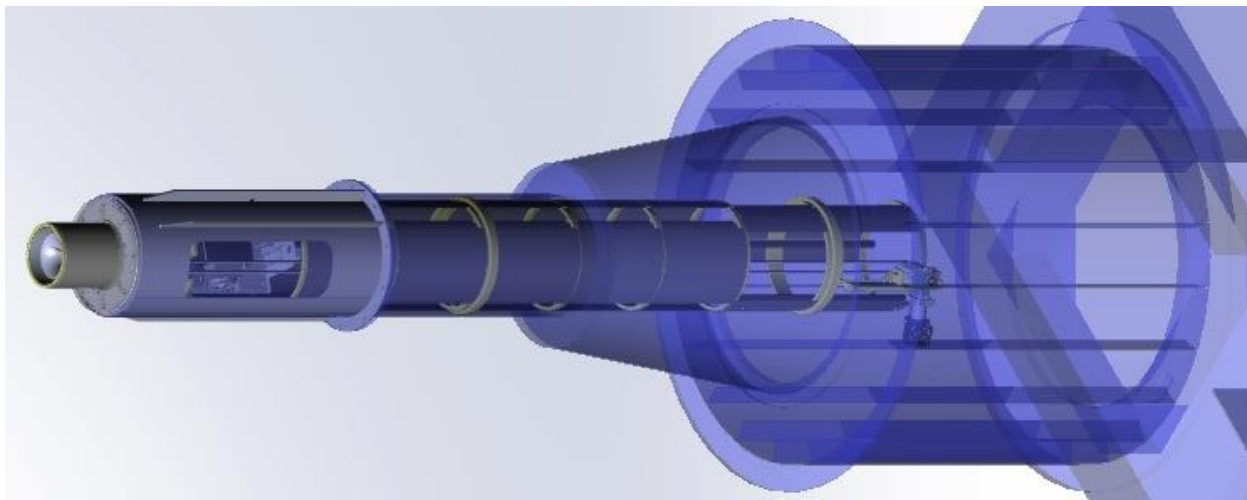


Monitor and Control Architecture

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



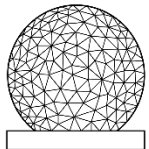
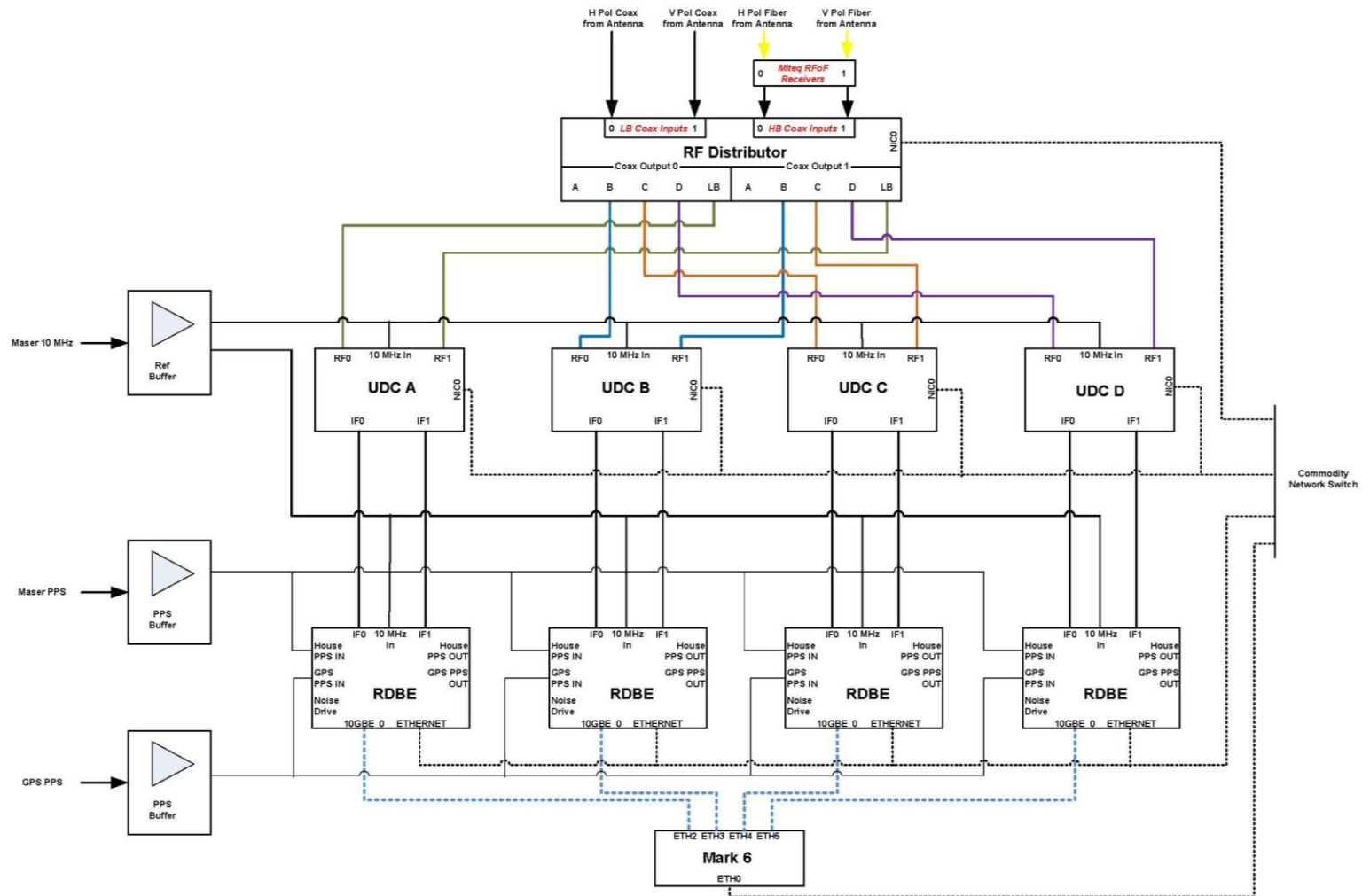
Frontend System



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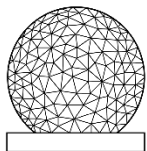
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Backend Block Diagram



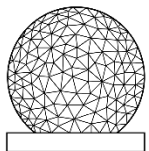
UpDown Converter (UDC)

- UDC's converts Radio Frequency (RF) 2-14GHz to an Intermediate Frequency (IF) of 512 MHz or 1024 MHz
- Two versions exist:
 - 2.0 with KPGO/MGO
 - IF Output 512MHz
 - Tuning range 2-12 GHz. 400 kHz resolution
 - 2.1 at Wf / FGO
 - IF output 512-1536MHz
 - tuning range 2-16 GHz. 40 Hz resolution
 - Upgrade plan for NASA stations 2025
- 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



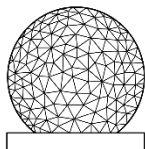
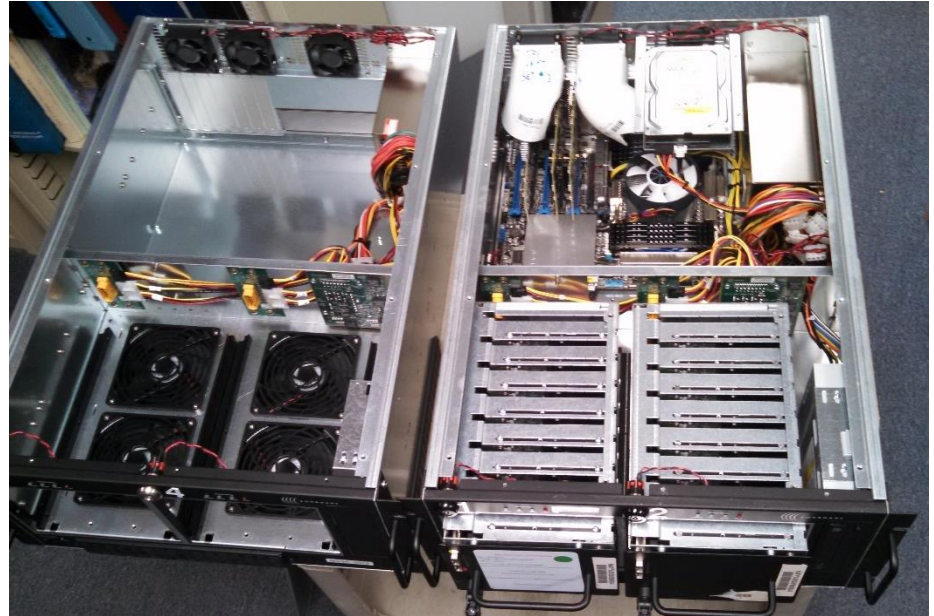
DBEv3/v4 - Roach Digital Backend (RDBE / R2DBE)

- 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 GGAO / 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, Yj and FGO
 - 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 2025
- Outputs 10-100 MHz diode control for Noise calibration system
- Require 4 DBEs for VGOS signal chain

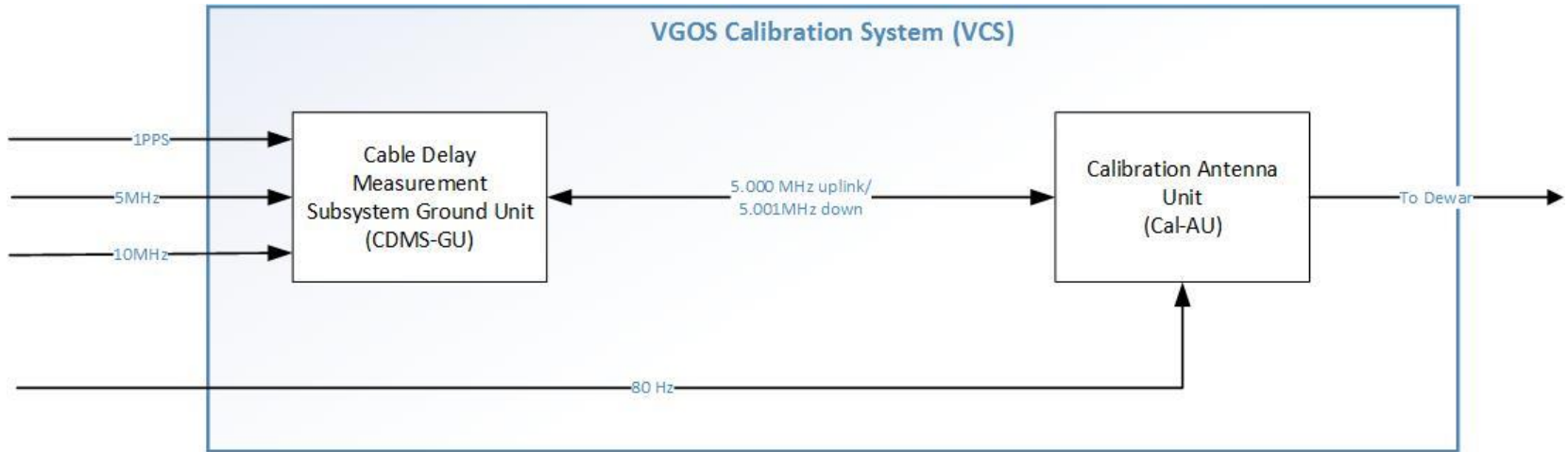


Mark6 / Mark6+ Data Recorder

- 16Gbps (2013) / 32 Gbps (2024)
 - 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 (EoL)
 - CentOS 7 (EoL)
 - Ubuntu (under development)

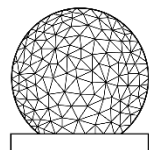
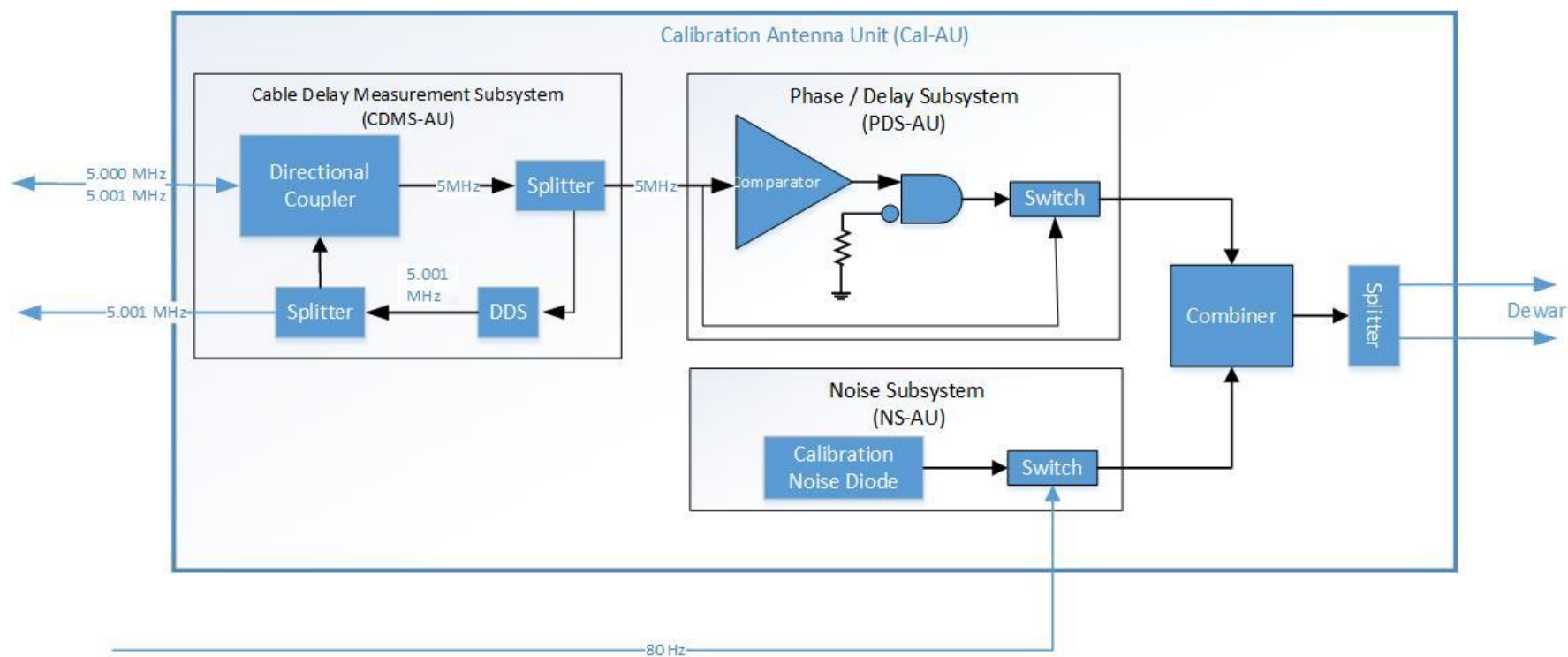


VGOS Calibration System

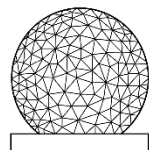
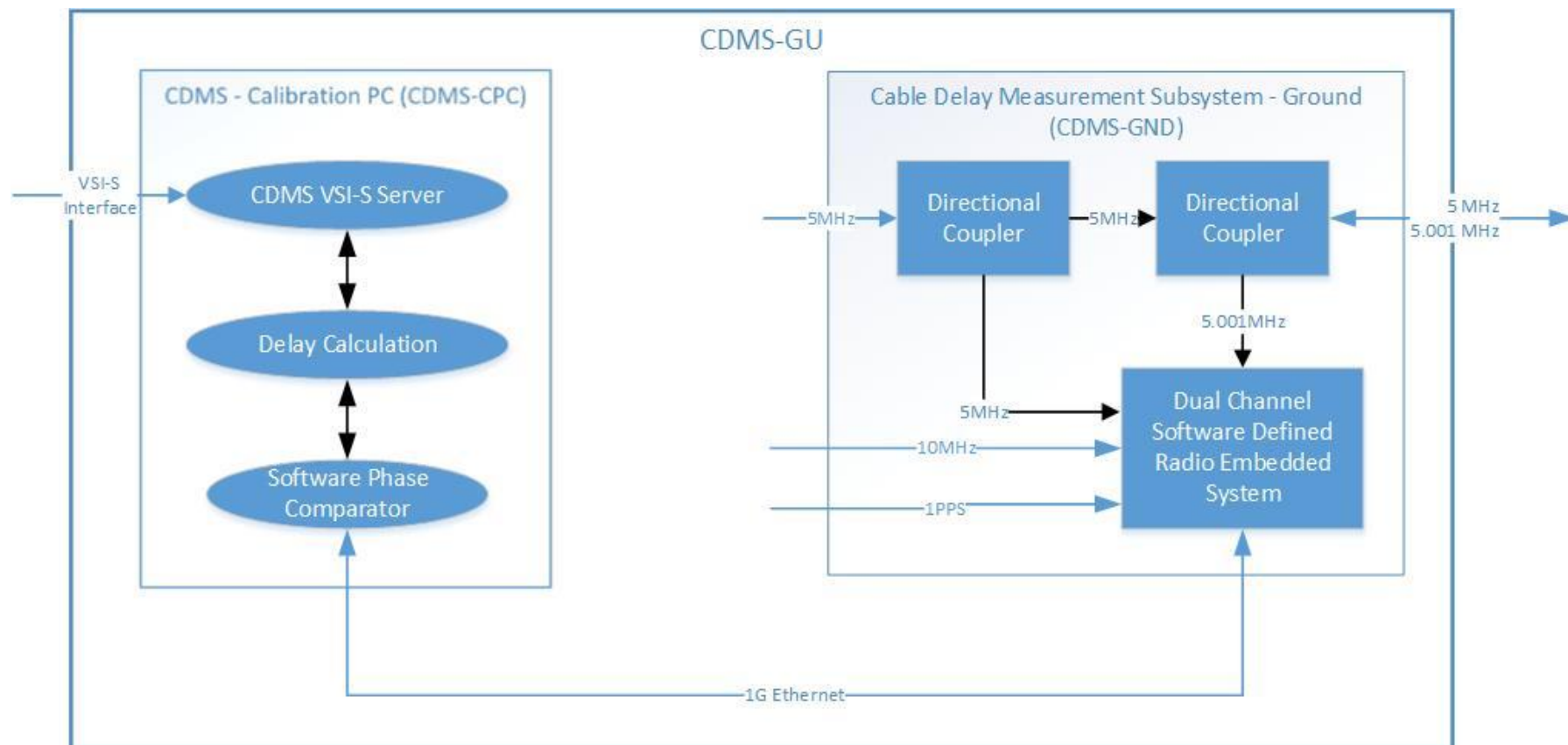


- Calibration Antenna Unit
 - Phase calibration injection
 - Noise calibration injection (sourced from one RDBE-G Unit – 10-100MHz)
 - Cable Delay Measurement System - AU
- CDMS Ground Unit
 - Cable Delay Measurement System – Gnd
 - Calibration PC - recorder

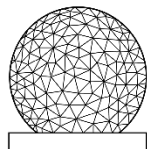
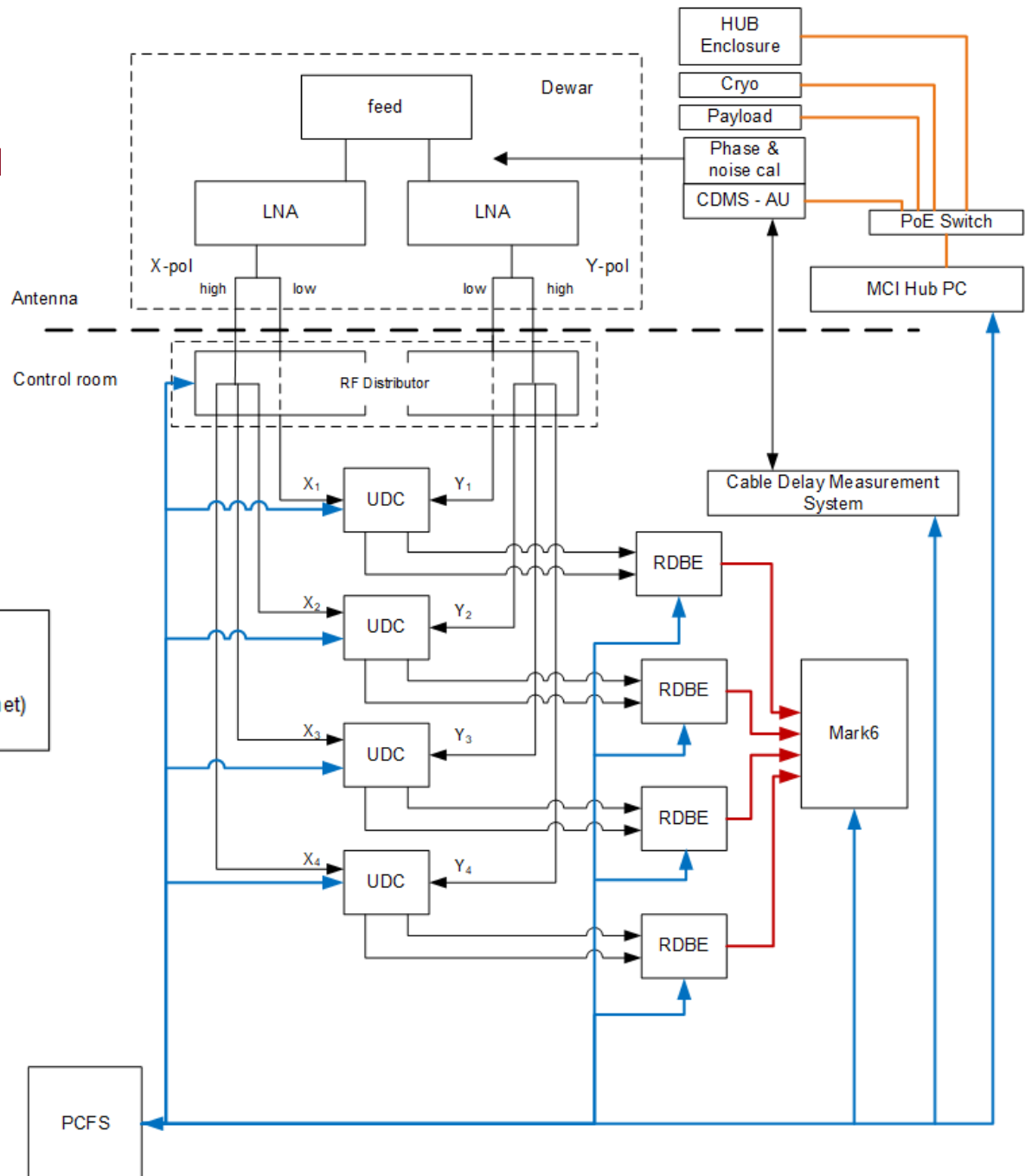
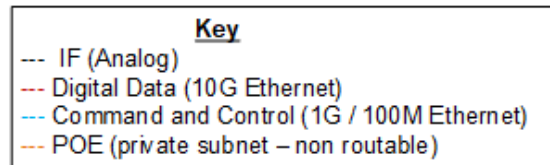
Calibration Antenna Unit



CDMS Ground Unit



Command and Control: PC Field System

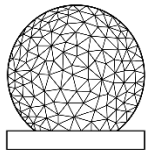


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Documentation

- 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?



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