



VNDA:VLBA New Digital Architecture

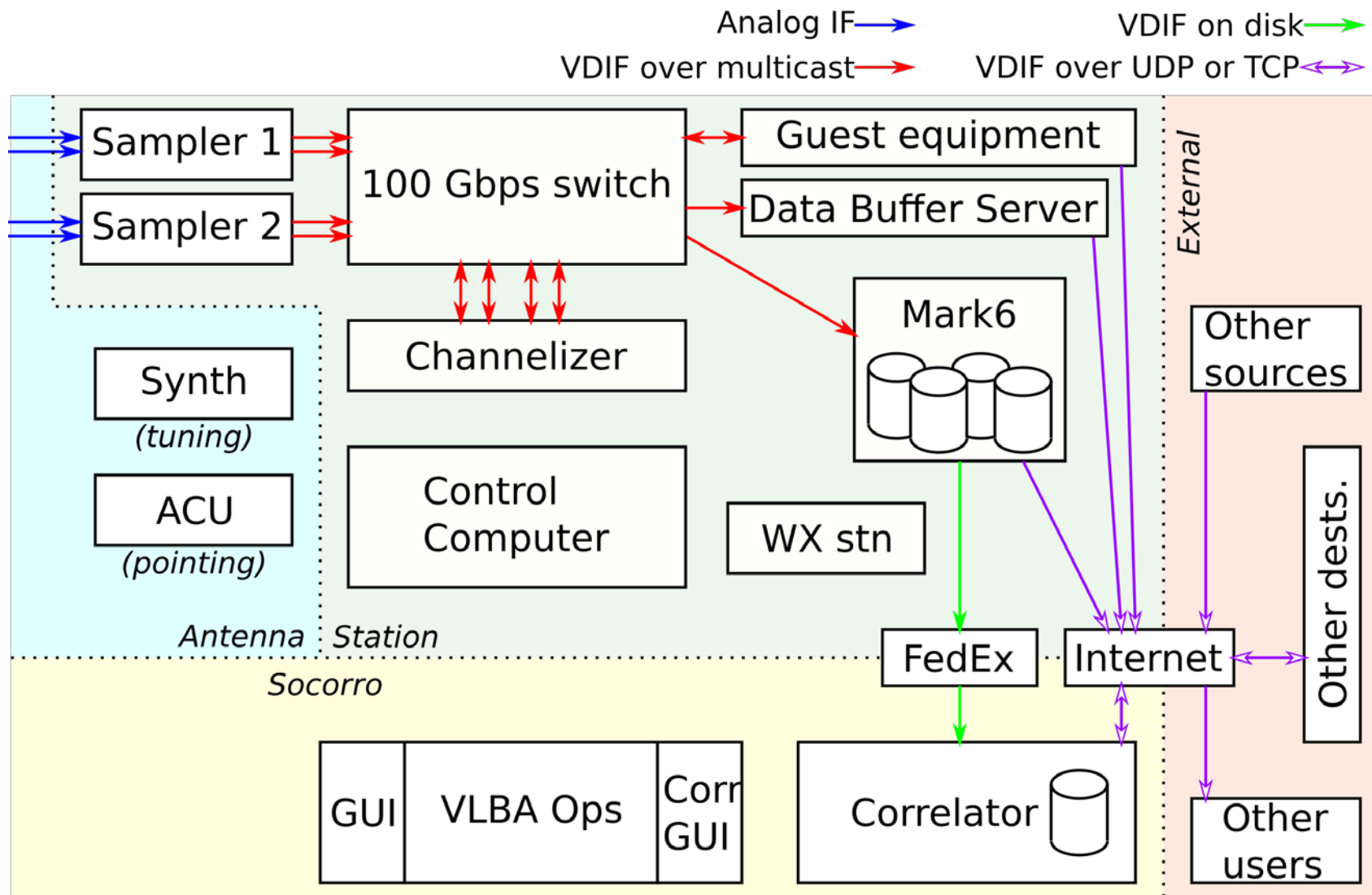
Walter Briskin & Lucas Hunt



VLBA New Digital Architecture

- Replace aging RDBEs with new, extensible architecture
 - RDBEs are becoming difficult to maintain
 - They have some design deficiencies that impact science and operations
- Driving VNDA requirements:
 - Sample at > 8 bits per sample
 - Avoid sampler resets to improve delay stability
 - No user-visible tuning restrictions within bands
 - One personality supporting all PFB & DDC modes
 - To be fully backward compatible with RDBEs
 - Use of commercially available equipment to degree possible
 - Use standard interfaces wherever possible
 - Extensible: support user-provided guest equipment
 - E.g., spectrometer, pulsar backend, transient detector, ...

VLBA New Digital Architecture (VNDA)



Initial approach (2018-2022)

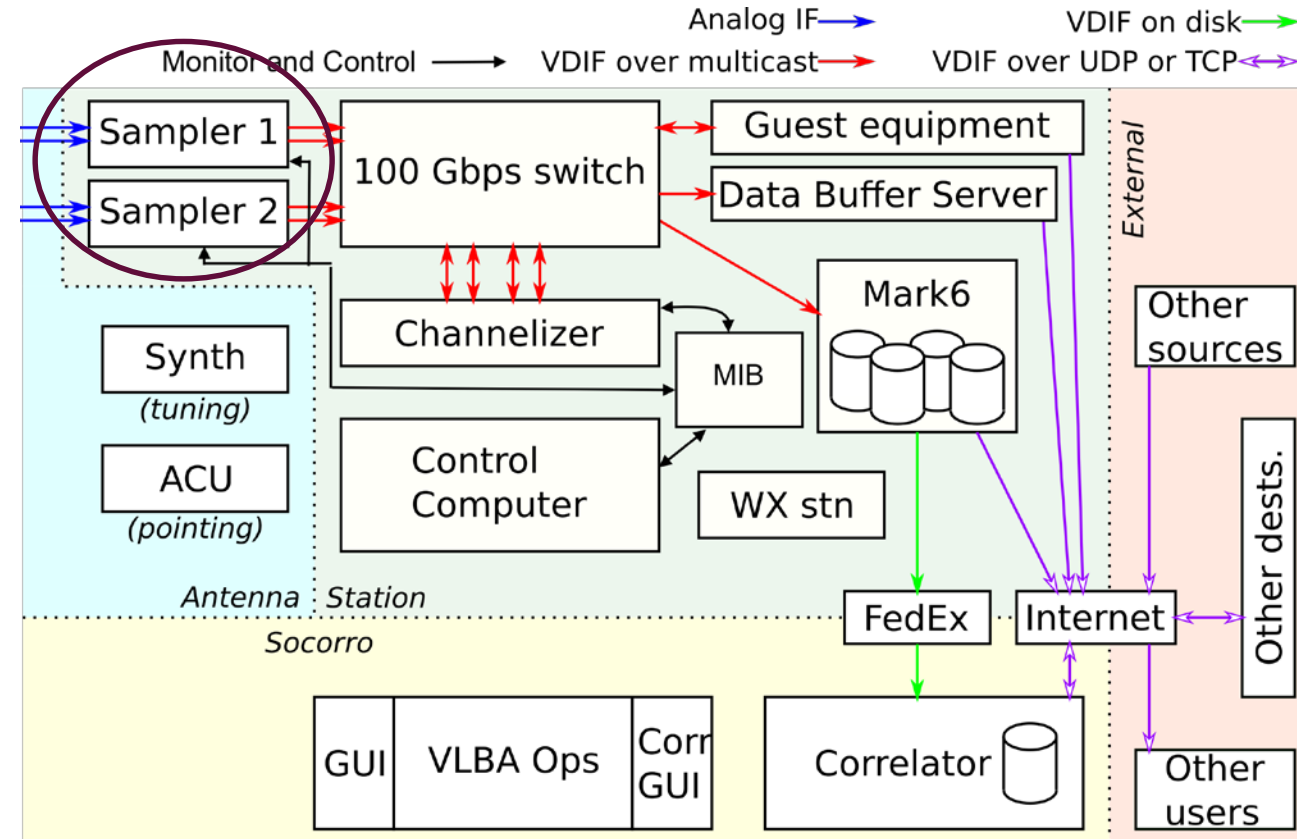
- A first, ambitious, attempt ran into multiple problems
- Producer: Samplers connected via FMC to Vadatech FPGA PCIe board inside server
- Consumer: Vadatech FPGA board inside server
- Lessons learned
 - Don't try to reinvent a full UDP stack in FPGA
 - Data movement across PCIe at near maximum rate is challenging
 - An isolated development group is less effective at solving major problems

VNDA project reboot, 2023

- Look to use external experts
- Lean on successful projects using similar hardware

Producer

- Accepts 4 analog IF inputs
- Produce 4 digital IF outputs
- Sends to switch using multicast UDP
- Idea is that producer will run continuously without interruption. The configuration will be unchanged
 - Ability to reset timing as necessary, should maintenance efforts disturb the 5 MHz clock
- Developed by Digital Radiometer Systems



Producer Digitization and data broadcasting

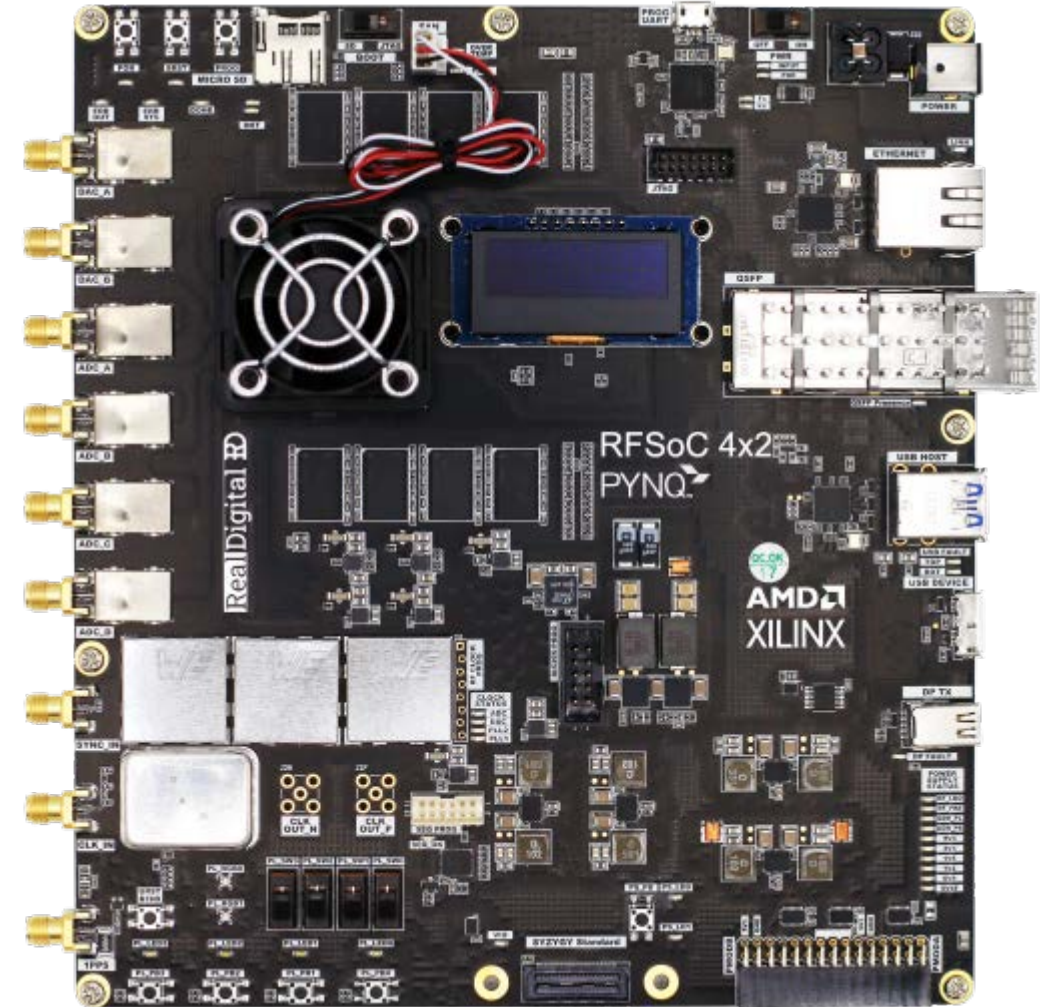
- 2048 Msps output rate
- 14 bits per sample; packed into 16 bit words
- VDIF formatted data output, following VDIF Spec
- Each IF in its own VDIF stream
- No signal processing, only sample, time-tag, format, and broadcast
 - Keep sample clock as stable as possible over long time periods
- Data broadcast using multicast UDP

Timing and Monitor & control

- Reference Signal at 5 MHz
 - Creates internal clock and 1PPS from this
- 1 PPS signal to set absolute timing of the system
- Monitor points
 - 1PPS difference (difference between Internal 1PPS and provided 1PPS signal)
 - Loss of timing signal
 - Other monitor points that follow from development
- Control
 - Ability to trigger timing reset

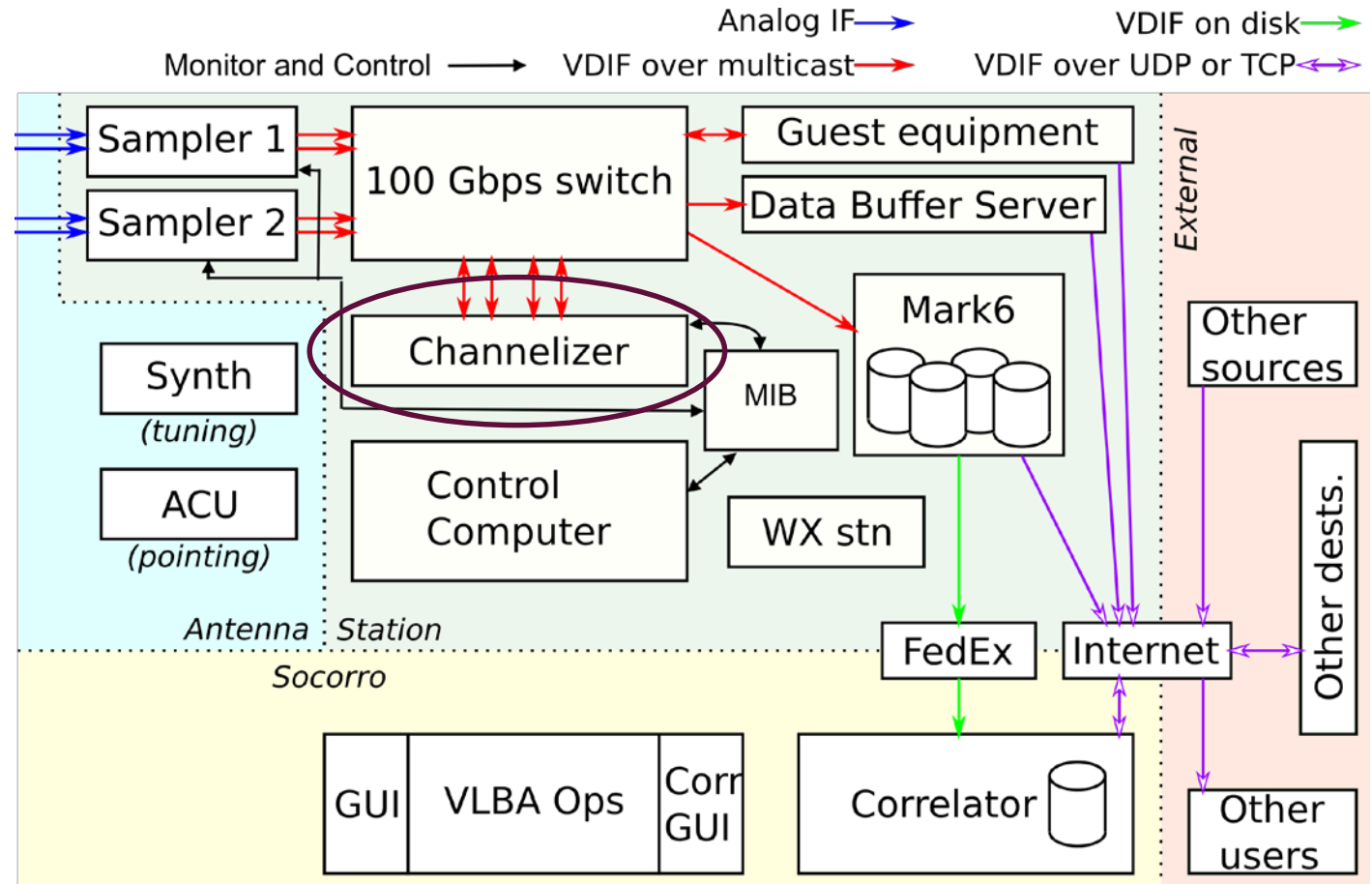
Hardware

- RFSoc 4x2 Manufactured by Real Digital, Recommended by Digital Radiometer Systems
- Entered production May, 2022
- Developed with input from Xilinx, and end users like CASPER
- Board is open source, board schematics, bill of materials, PCB Gerber files all available
- More information on specs available online



Channelizer (or Consumer)

- Accepts 4 digital IF inputs
 - Multicast UDP+VDIF packets from Producer through 100Gbps switch
- Digital signal processing, configured based on observing project setup
- Sends processed data back into switch using multicast UDP
- Development done by Fourier Space



Digital Signal Processing

- Output selectable from any of the IF inputs
- Upper or lower sideband
- Bit depth selectable from 1, 2, 4 or 8 bits per sample.
 - Choose bit depth for each channel
- Up to 32 output channels across all IFs, bandwidths from 1 to 1024 MHz
 - Up to 16 output channels from any one IF
 - Limited to 32 Gbps output
- Each channel tunable to arbitrary setpoint that is a multiple of 10 kHz from the input IF edge

Monitor and Control

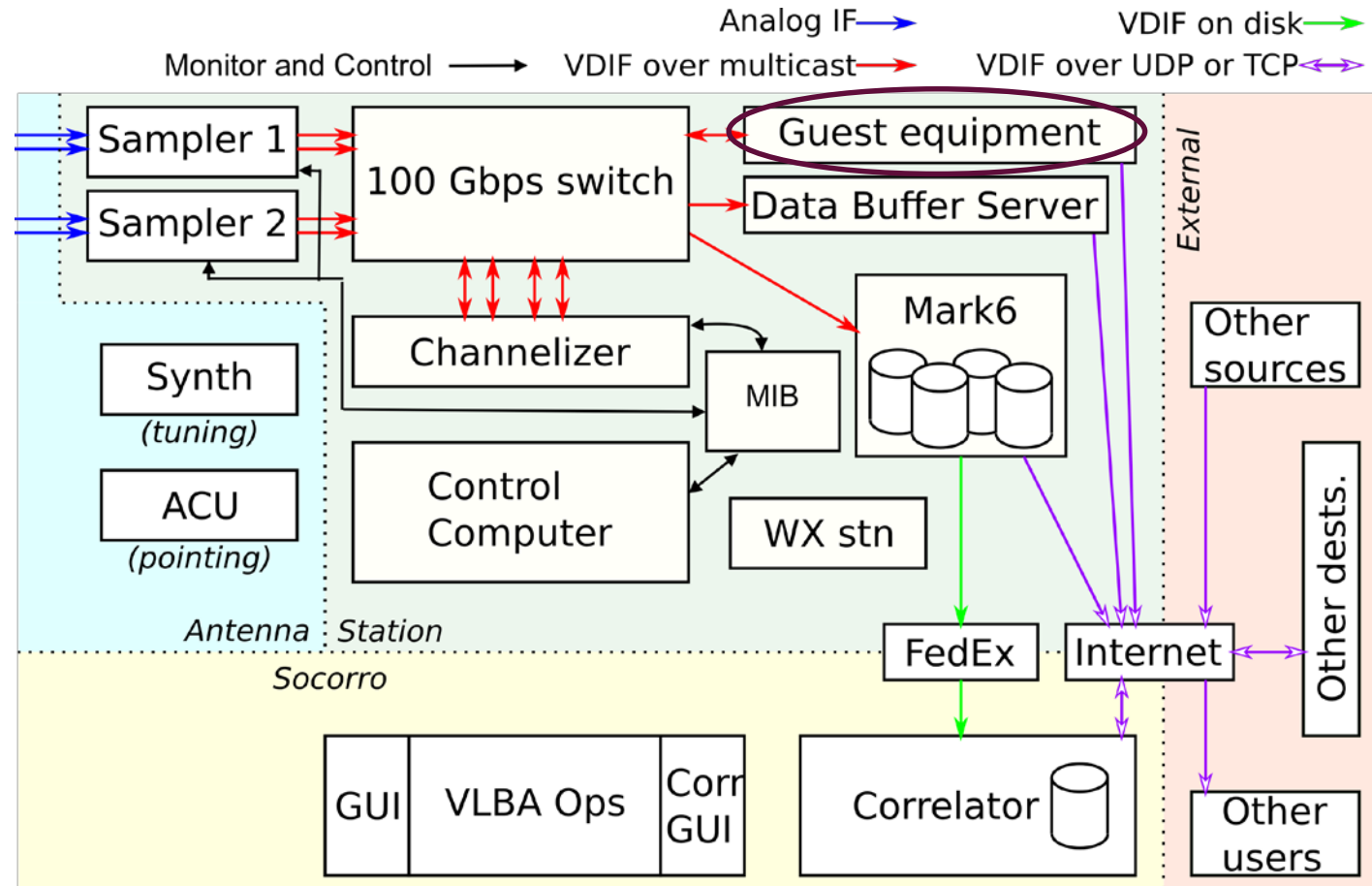
- Configure commands allow change of all or individual configuration parameters
- Validation command checks if configuration parameter set is valid
- Parameters can remain through entire observation or change from scan to scan.
- Monitor data available for
 - Data acquisition performance
 - Input and output ring buffer capacity/utilization
 - Statistics of input and output time-series for each IF stream
 - Information on DSP performance, power integration measurements
 - Switched power measurements

Hardware

- One rack-mount server hosting 2+ GPUs
- Currently using supermicro server
 - Hosts 2 high speed NICs for data receive and send
 - Current hardware hosts 4 NVIDIA RTX A4000 GPUs
 - COTS hardware is flexible, and this will likely change for deployment
 - Hardware updates will be easier as GPUs become more powerful

Guest Equipment

- Multicast data passed through switch to guest equipment
 - Guest equipment can subscribe to Sampler data or Channelizer data
- Ability to process data in real time and send relevant information over the internet
- Requirements
 - Equipment to pass RFI testing
 - NRAO need to safely shut down equipment for maintenance
- Subject to proposal and PM process

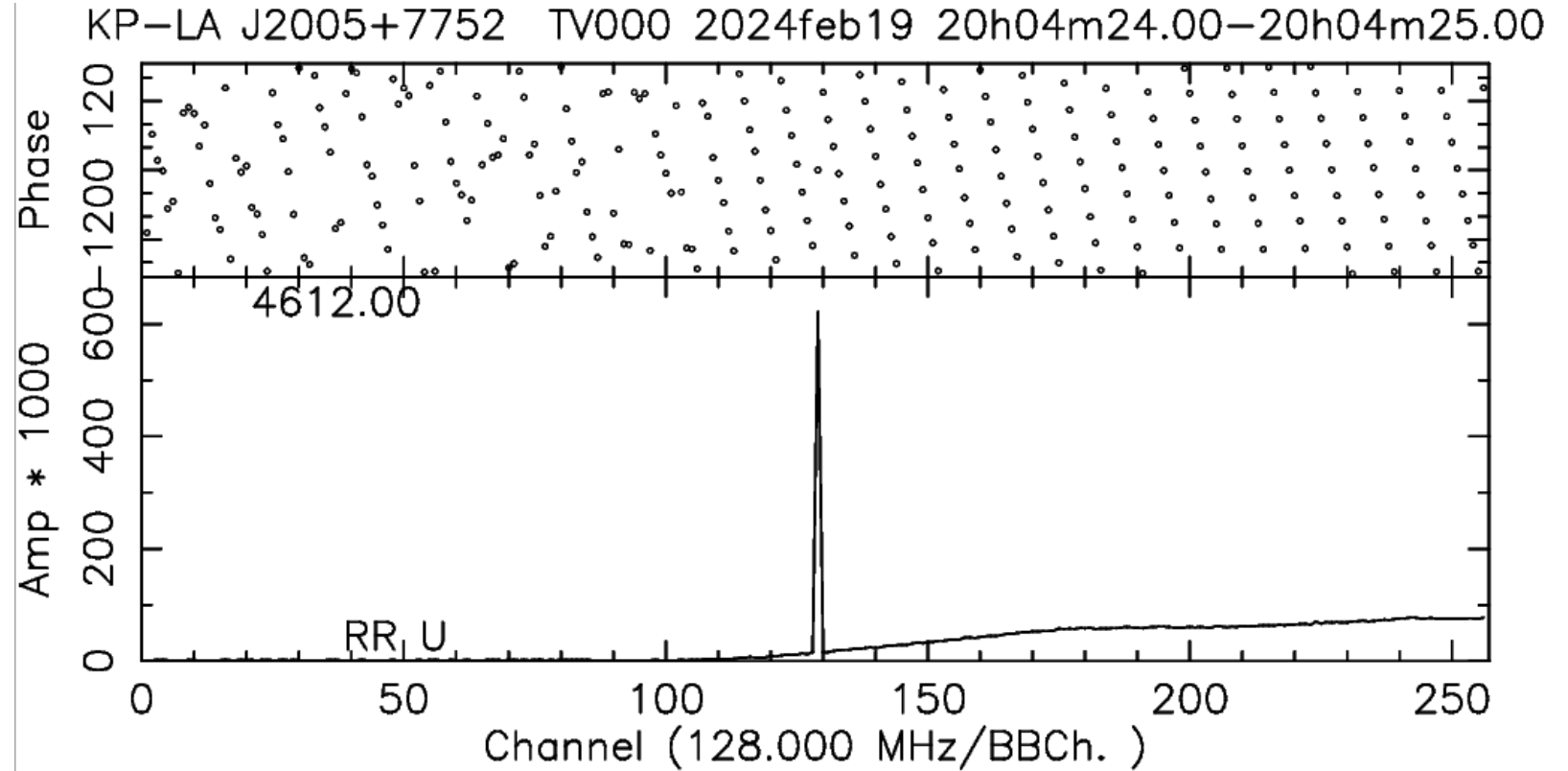


Guest Equipment

- Commensal Observations
 - A lot of guest equipment will likely be commensal instruments
 - They will observe while other projects are observing
 - NRAO will maintain the ability to turn off data flow to any desired guest equipment
- Current unknowns
 - Rack space, power, and cooling are currently limited, resources for guest equipment hardware is currently unknown (or likely unavailable)
 - Options for GE location: On site, Centralized rack at DSOC, Guest equipment owners site
 - Tradeoffs for availability of data streams, Rackspace and power consumption issues

Lab Testing Results

- Zero Baseline Test
 - Send signal to RDBE and VNDA
 - Correlate Signal
- See fringes!
- Everything worked as expected, moving to On The Sky testing



Key VNDA Dates

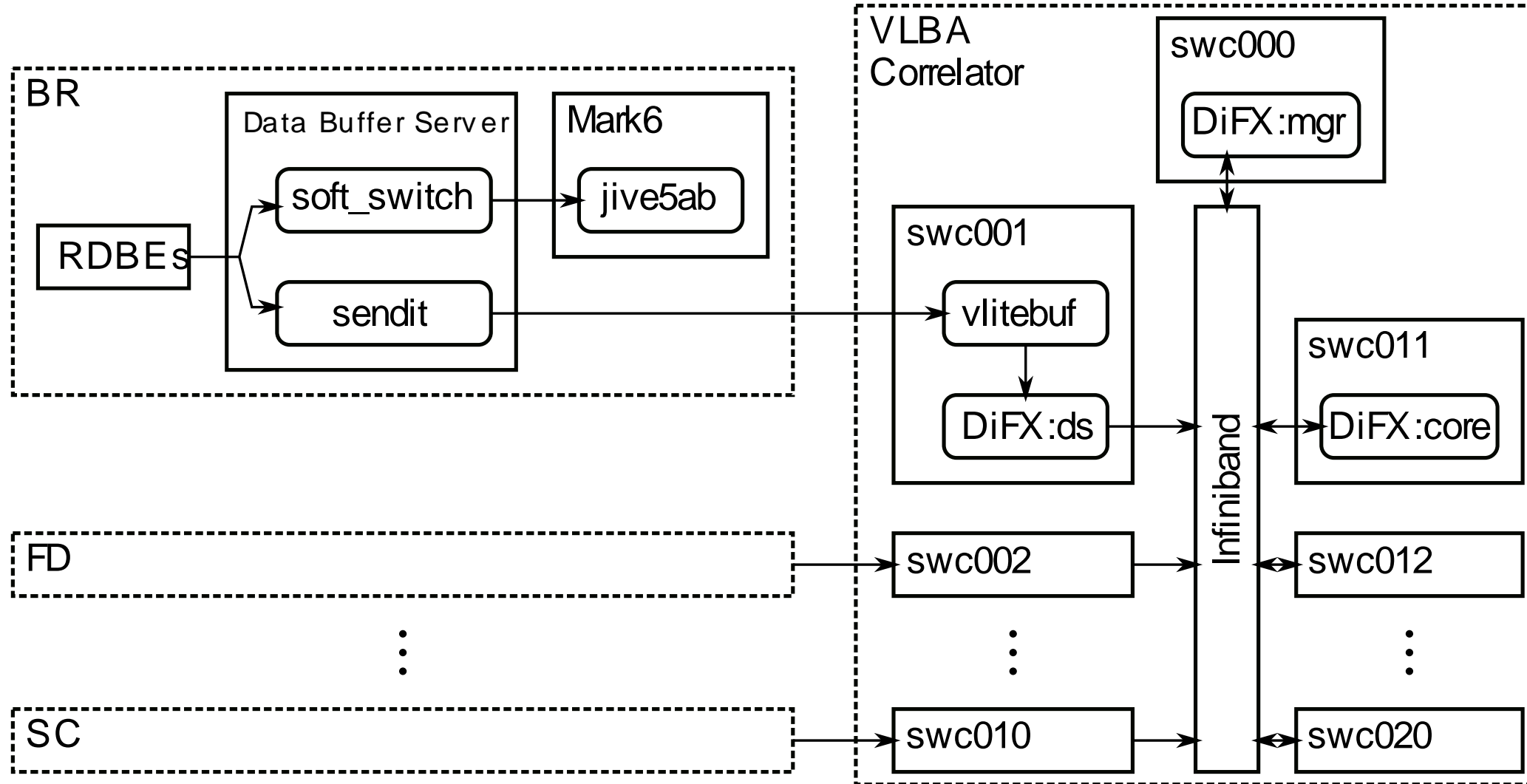
- Phase 2
 - Pass Preliminary Design Review
- Phase 3
 - On the Sky testing
 - Final design review
- Phase 4
 - Instrument Commissioning
- On track to meet these dates currently

| Milestone | Rough Date |
|------------------------------------|------------|
| Preliminary Design Review Complete | 08/24 |
| On the Sky testing complete | 12/24 |
| Final design Review | 08/25 |
| Commissioning | 12/25 |
| Project closeout | 3/26 |

VNDA adjacent developments

- Real-time data transmission
 - Goal: real-time correlation at 8 Gbps
 - Intermediate steps:
 - Real-time correlation at lower rates (currently 128 Mbps)
 - Remote record of 1+ VLBA sites in Socorro
- Research-grade GNSS receivers
 - In collaboration with ARL:UT
 - Multi-band receive of all GNSS satellites
 - Combined data to provide much improved “GPS minus maser” results
 - Separate lines of site to provide direction-dependent calibration
 - Direct correlation between GNSS and VLBI for frame tie (c.f., J. Skeens & J. York)

Real-time correlation with the VLBA



GNSS antenna at VLBA OV



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Server Rack Space and Power Usage

- G-Rack has 30U of space available, PDU has ~1900W available (20A, 120V)
 - Includes VNDA and VBER modules
 - VNDA
 - Producer – 2U, 130W
 - Consumer – 4U, 700W
 - Switches – 2U, 270W
 - Timing and Reference Distribution
 - IPPS and 5 MHz signals each take up 1.5U, allocate 4U, 120W
 - Data Buffer Server
 - Allocated 2U space, 200W
 - **Estimated available space and power – 16U, 500W**
- Option for 1900W new circuit, not on building UPS
 - Some retrofit costs to be expected if this is to be exercised