BLADE

Allen Telescope Array GPU accelerated beamformer backend

Luigi Cruz, Wael Farah, Alexander Pollak

AAS 241 - Seattle, WA

The Equipment

- Designed primarily for SETI purposes.

- Composed of 42 antennas each with 6.1 meters in diameter.

- Randomly scattered and have a maximum baseline of 300 meters.

- Sensitive to a wide and continuous range of frequencies ranging from 900 MHz to 12 GHz.

- Maximum bandwidth is around 1.5 GHz per antenna for each polarization.

- The GPU compute cluster receive digitized data via a 100 Gbps network.

- More details will be covered by a presentation from our Chief Astronomer, Wael Farah, on Thursday (Session 451).

Digital Signal Processing

- Always looking at ways to expand its capabilities.

- Development cycles where the target is set, the code and tests are written, and the new pipeline is tested on sky.

- Brand-new processing framework called BLADE the "Breakthrough Listen Accelerated DSP Engine".

- Compute cluster composed of 8 dual-socket EPYC servers with two NVIDIA RTX 3090 class graphics cards.

- Processing performed by the GPU.

- Composed of modules inside pipelines organized with runners.

- Modular design allows development without affecting the stability of production sections.
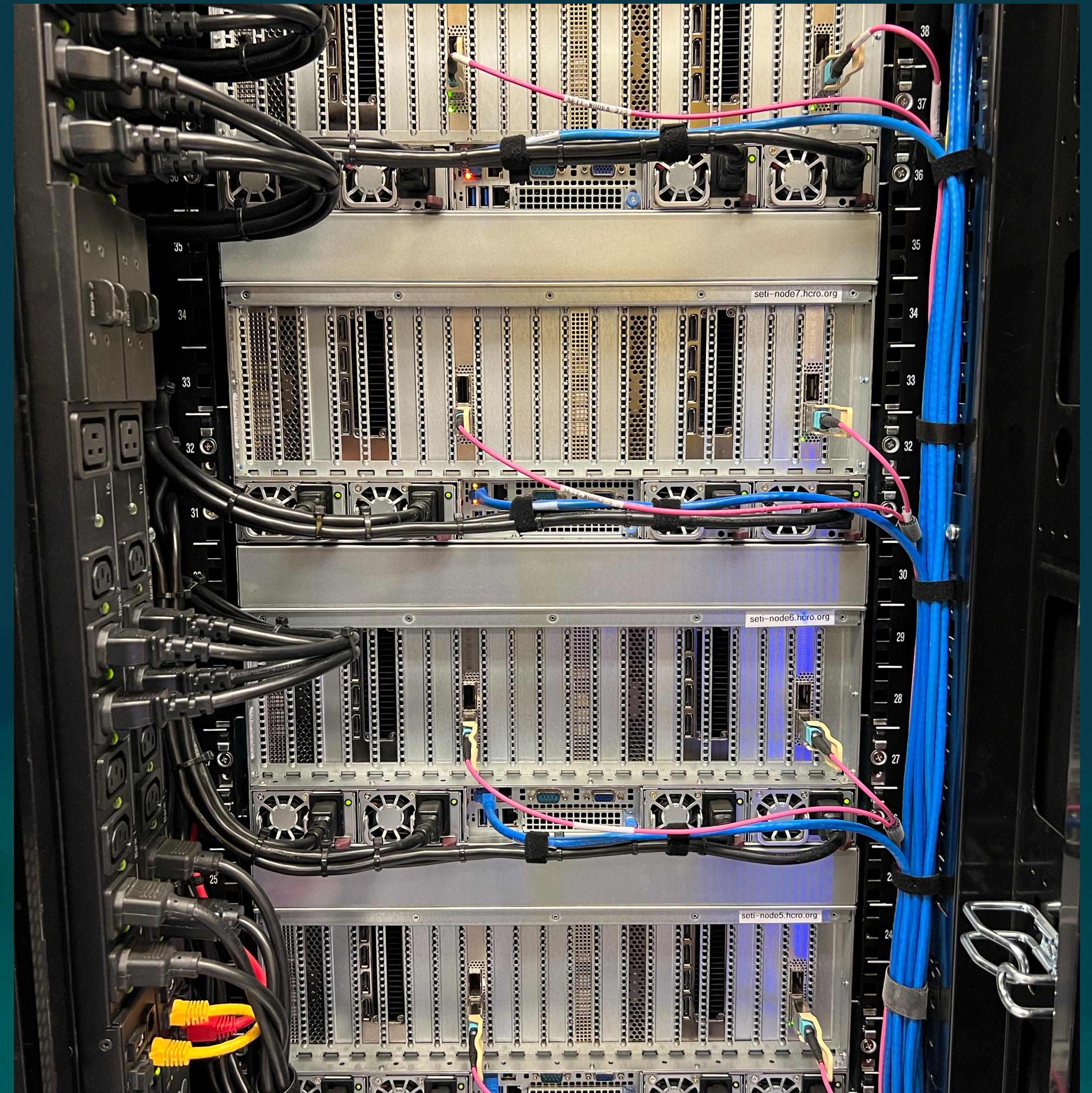
Beamformer
BLADE Processing Pipeline

- First to be developed.
- Combines the signal received by individual antennas into a single larger disk.
- Accomplished by delaying the signal slightly using a phasor.
- Supports electronic steering and multiple beam generation.
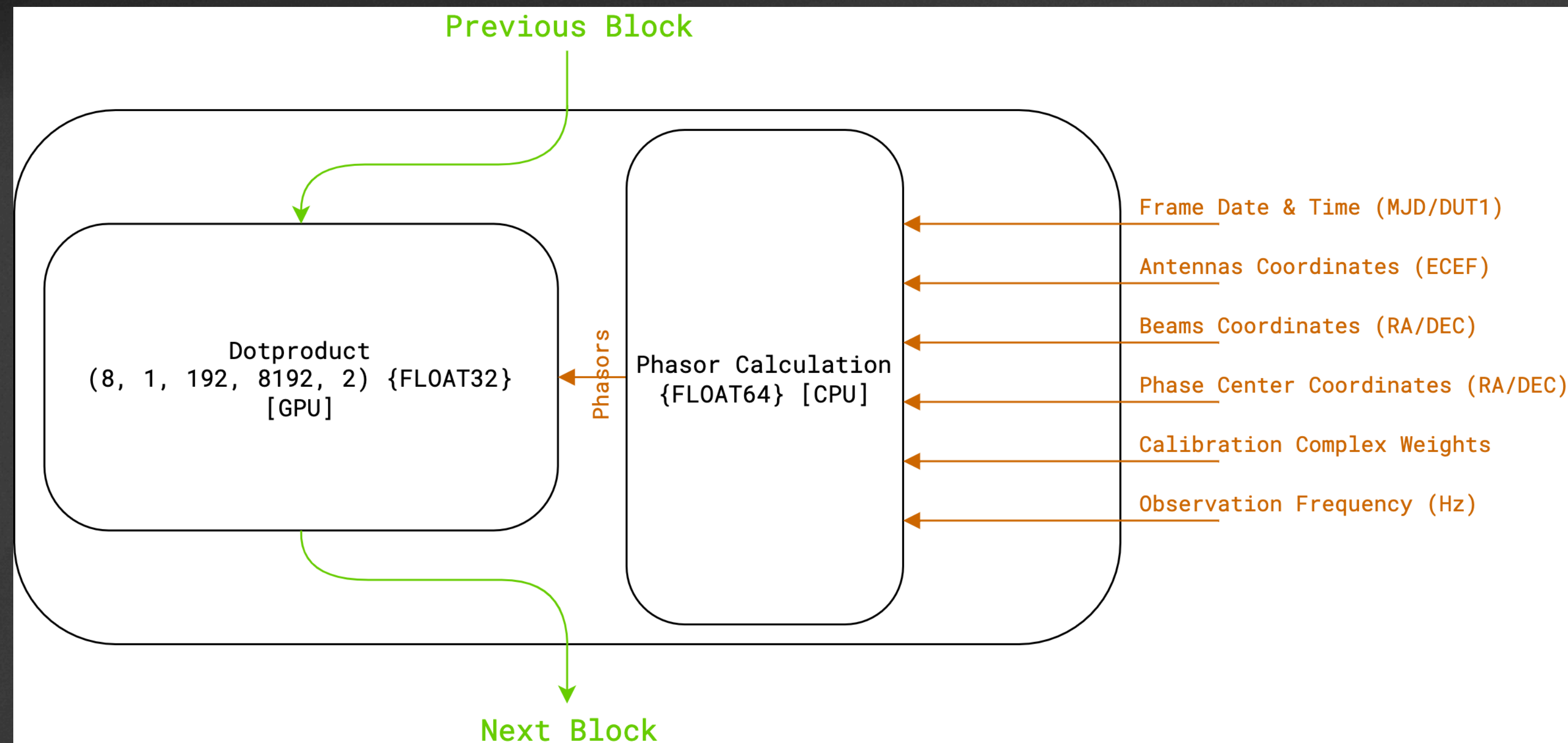
High-Resolution Spectrogram
BLADE Processing Pipeline

- Received data is pre-channelized down to 500 kHz in resolution.
- The ideal channelization resolution is around 1 Hz for SETI search.
- Module further channelizes the data using FFT.
- Total of 1.5 million bins FFT of a time-domain vector for each polarization.
- Translates into a 3 million bins (3 GHz) FFT done every second.

Detection
BLADE Processing Pipeline

- Calculates the Stokes-I.
- Integrates the signal in real-time.
- Integration does not require writing data to disk.
- Continuous operation until overflow.

Circular Polarization
BLADE Processing Pipeline

- Data produced by the telescope have Vertical and Horizontal polarizations.
- Generates the RHCP and LHCP.
- Necessary calibration done internally by the pipeline.
- Useful for telecom purposes and some science.
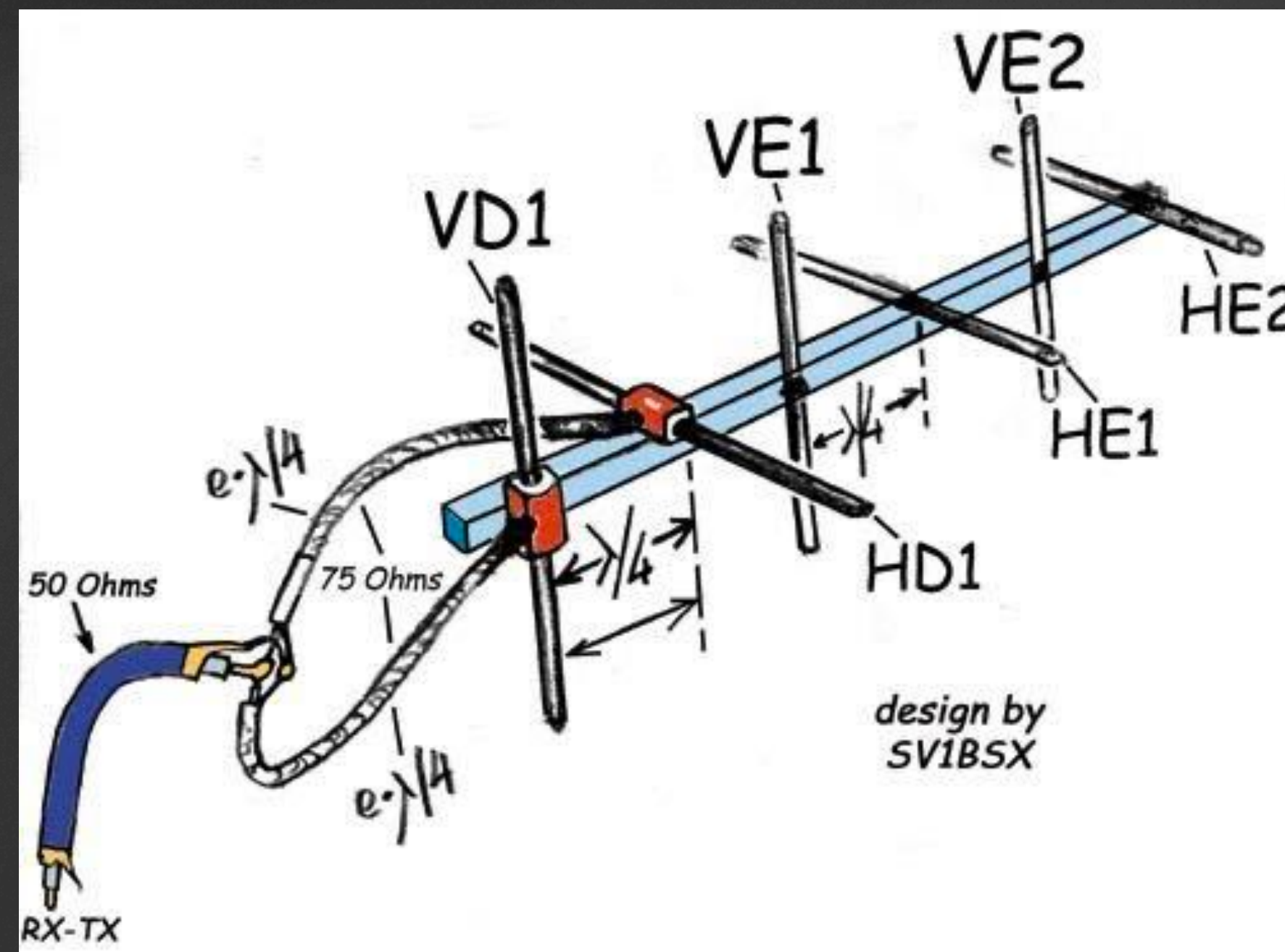
Future Modules
BLADE Processing Pipeline

- Coherent de-dispersion (pulsars and drift-search).
- Active RFI mitigation using the beamformer.
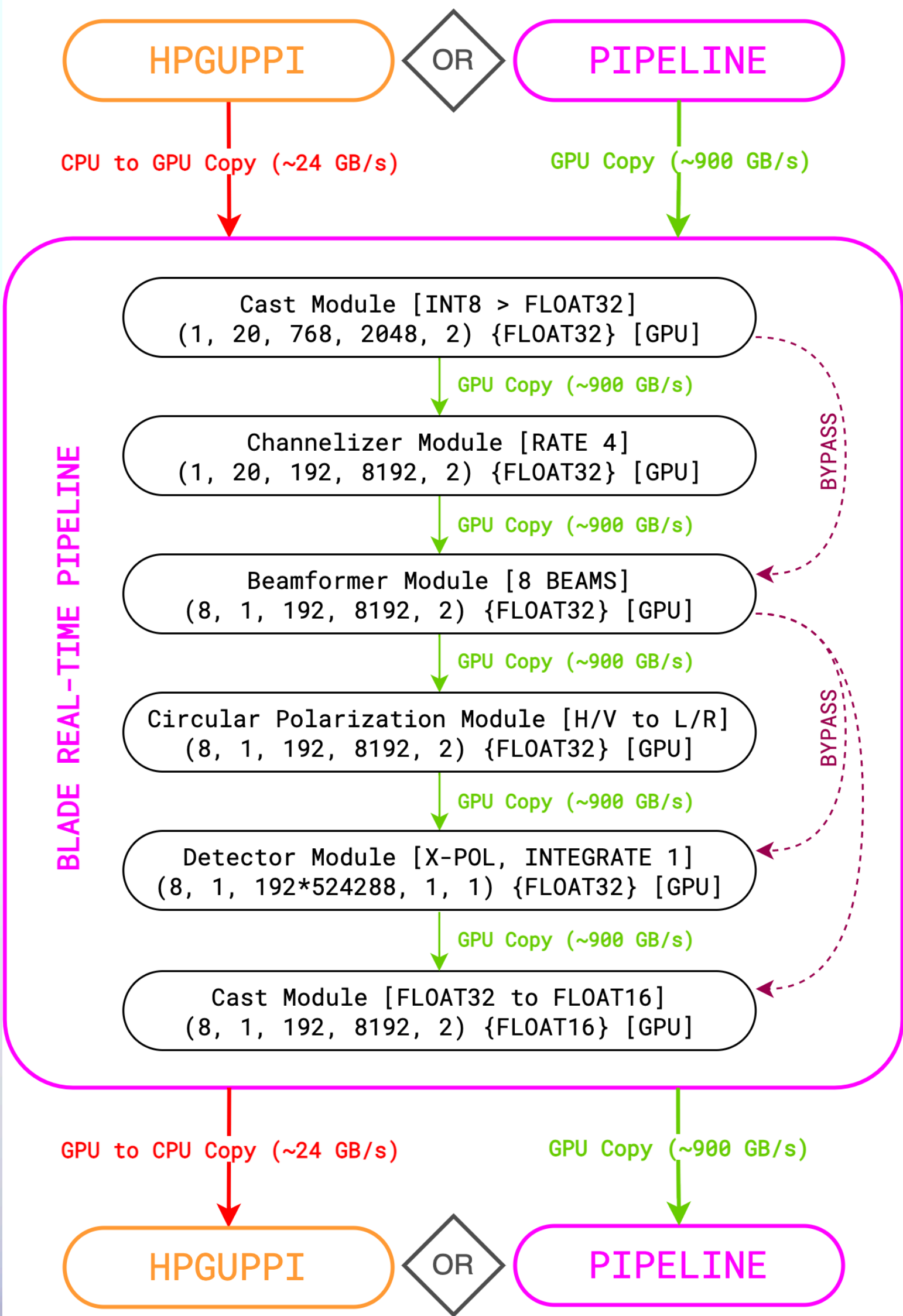- Correlation.

Takeaways

- The Allen Telescope Array is a good example of an instrument primarily created for SETI being used for other scientific purposes.

- Fundamental to design the instrument to accommodate incremental changes without impacting on-sky time.

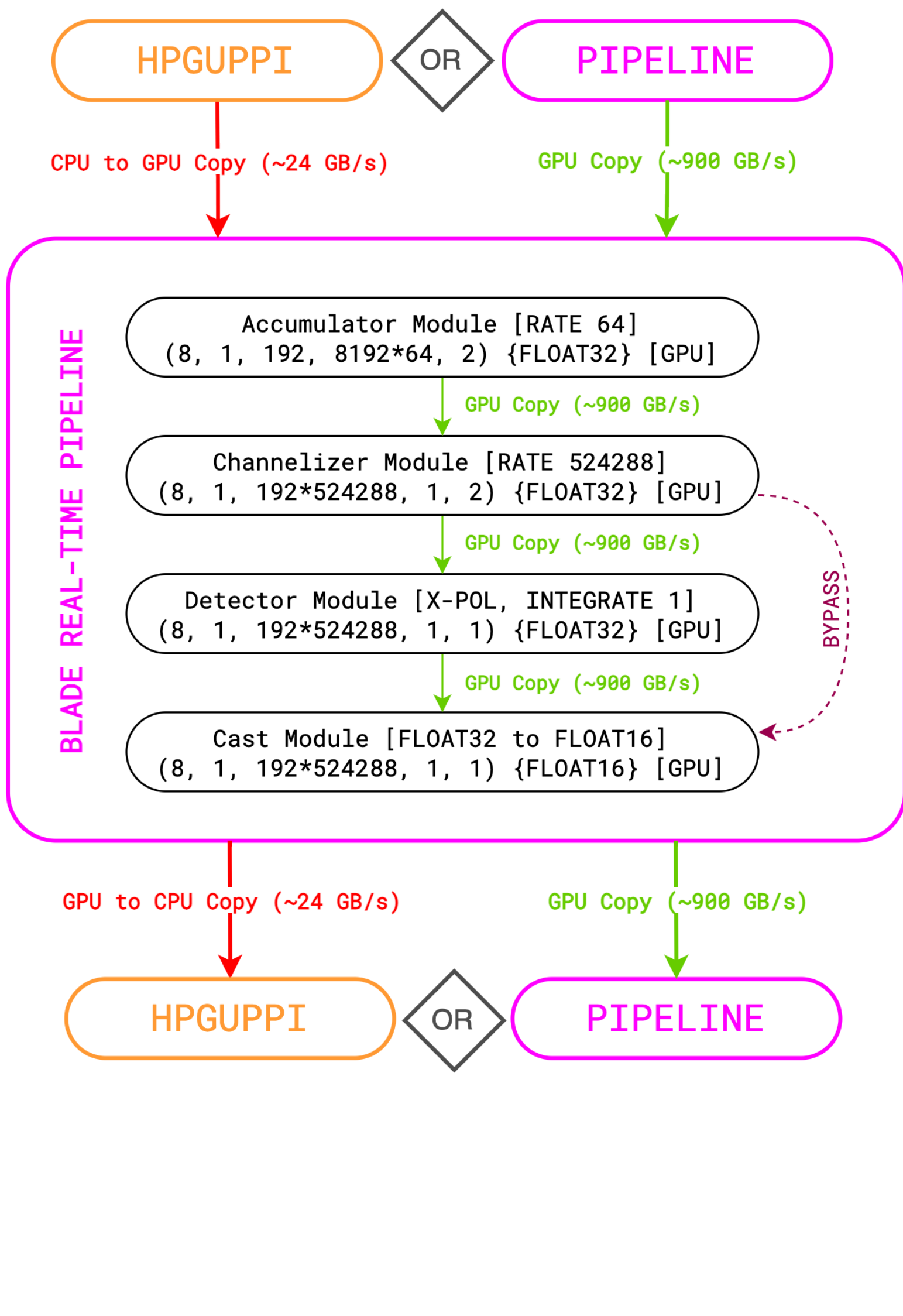- Real-time processing pipelines increase efficiency.

Pipelines

ATA PIPELINE - MODE-B
Beamforming/Detection

HPGUPPI **OR** PIPELINE

CPU to GPU Copy (~24 GB/s) | GPU Copy (~900 GB/s)

BLADE REAL-TIME PIPELINE

Cast Module [INT8 > FLOAT32]
(1, 20, 768, 2048, 2) {FLOAT32} [GPU]

GPU Copy (~900 GB/s)

Channelizer Module [RATE 4]
(1, 20, 192, 8192, 2) {FLOAT32} [GPU]

GPU Copy (~900 GB/s)

BYPASS

Beamformer Module [8 BEAMS]
(8, 1, 192, 8192, 2) {FLOAT32} [GPU]

GPU Copy (~900 GB/s)

Circular Polarization Module [H/V to L/R]
(8, 1, 192, 8192, 2) {FLOAT32} [GPU]

GPU Copy (~900 GB/s)

BYPASS

Detector Module [X-POL, INTEGRATE 1]
(8, 1, 192*524288, 1, 1) {FLOAT32} [GPU]

GPU Copy (~900 GB/s)

Cast Module [FLOAT32 to FLOAT16]
(8, 1, 192, 8192, 2) {FLOAT16} [GPU]

GPU to CPU Copy (~24 GB/s) | GPU Copy (~900 GB/s)

HPGUPPI **OR** PIPELINE

GENERIC PIPELINE - MODE-H
High Resolution Channelization (<1Hz/bin resolution)

HPGUPPI **OR** PIPELINE

CPU to GPU Copy (~24 GB/s) | GPU Copy (~900 GB/s)

BLADE REAL-TIME PIPELINE

Accumulator Module [RATE 64]
(8, 1, 192, 8192*64, 2) {FLOAT32} [GPU]

GPU Copy (~900 GB/s)

Channelizer Module [RATE 524288]
(8, 1, 192*524288, 1, 2) {FLOAT32} [GPU]

GPU Copy (~900 GB/s)

BYPASS

Detector Module [X-POL, INTEGRATE 1]
(8, 1, 192*524288, 1, 1) {FLOAT32} [GPU]

GPU Copy (~900 GB/s)

Cast Module [FLOAT32 to FLOAT16]
(8, 1, 192*524288, 1, 1) {FLOAT16} [GPU]

GPU to CPU Copy (~24 GB/s) | GPU Copy (~900 GB/s)

HPGUPPI **OR** PIPELINE

Thanks for listening!

https://github.com/luigifcruz/blade

Questions?

Contact me!

https://luigi.ltd/contact/