

ACCELERATING SETI

ALLEN TELESCOPE ARRAY NEXT-GEN DSP PIPELINE

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What is SETI?

Search for Extraterrestrial Intelligence

The Quest

- Exploring the possibility of **intelligent life** beyond Earth.
- Utilizing **advanced technology** to listen for signals from distant civilizations.

The Mission

- A worldwide effort involving telescopes, scientists, and engineers.
- Answering "Are we alone?".

The Challenge

- Distinguishing the civilizational whispers from the cosmic noise.
- $$N = R_* \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$

Allen Telescope Array

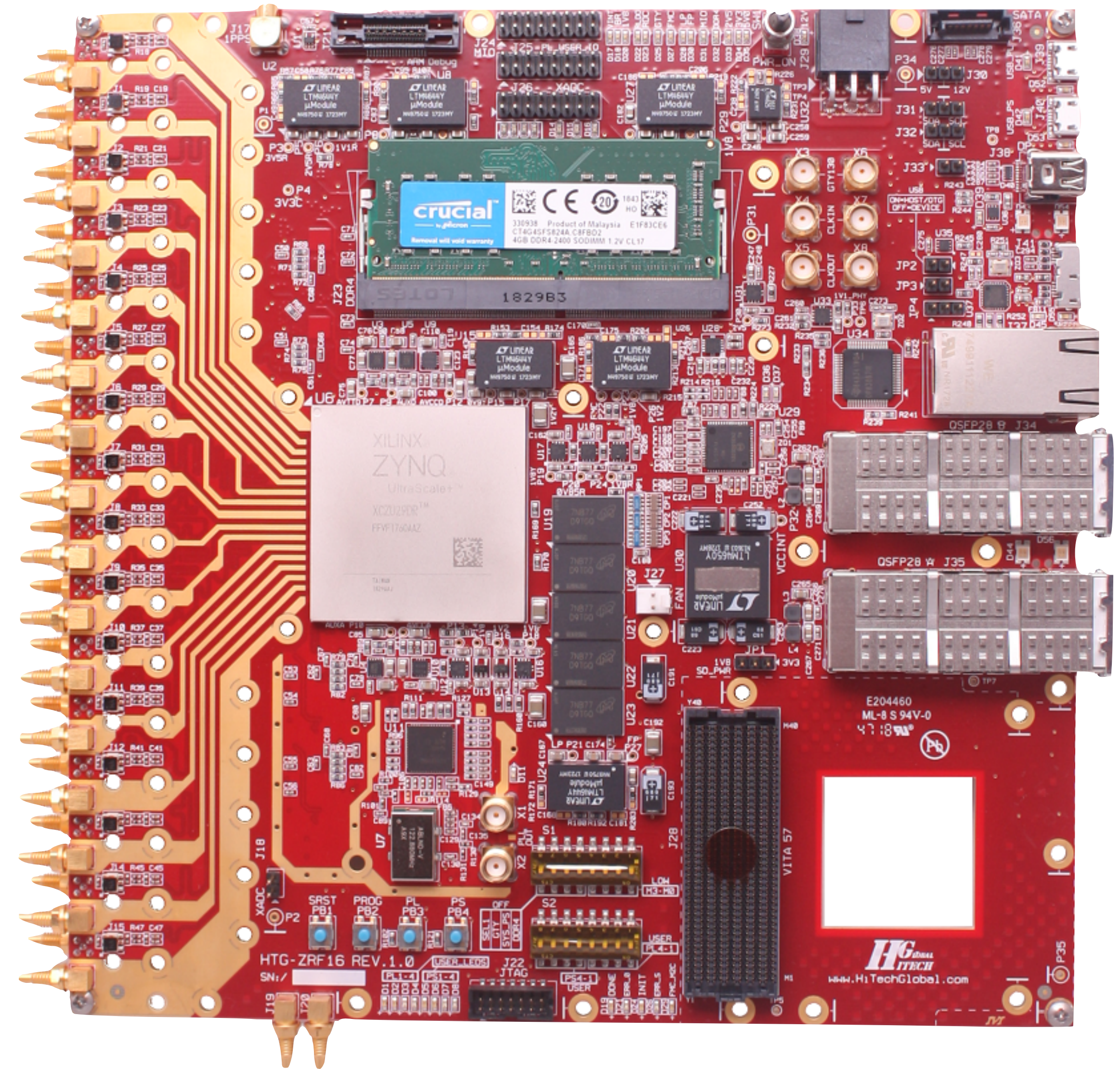
Offset Gregorian Dish

- Each of the 42 antennas has 20 feet (6.1 m) in diameter.
- Produces ~ 1.5 GHz of bandwidth for each polarization (~ 3.0 GHz in total).
- The entire telescope equates to ~ 84 GHz or ~ 1.4 Tbps at 8 bits per sample.
- Connected to the DSP Room via RF over fiber.
- Ultra-wideband reception.



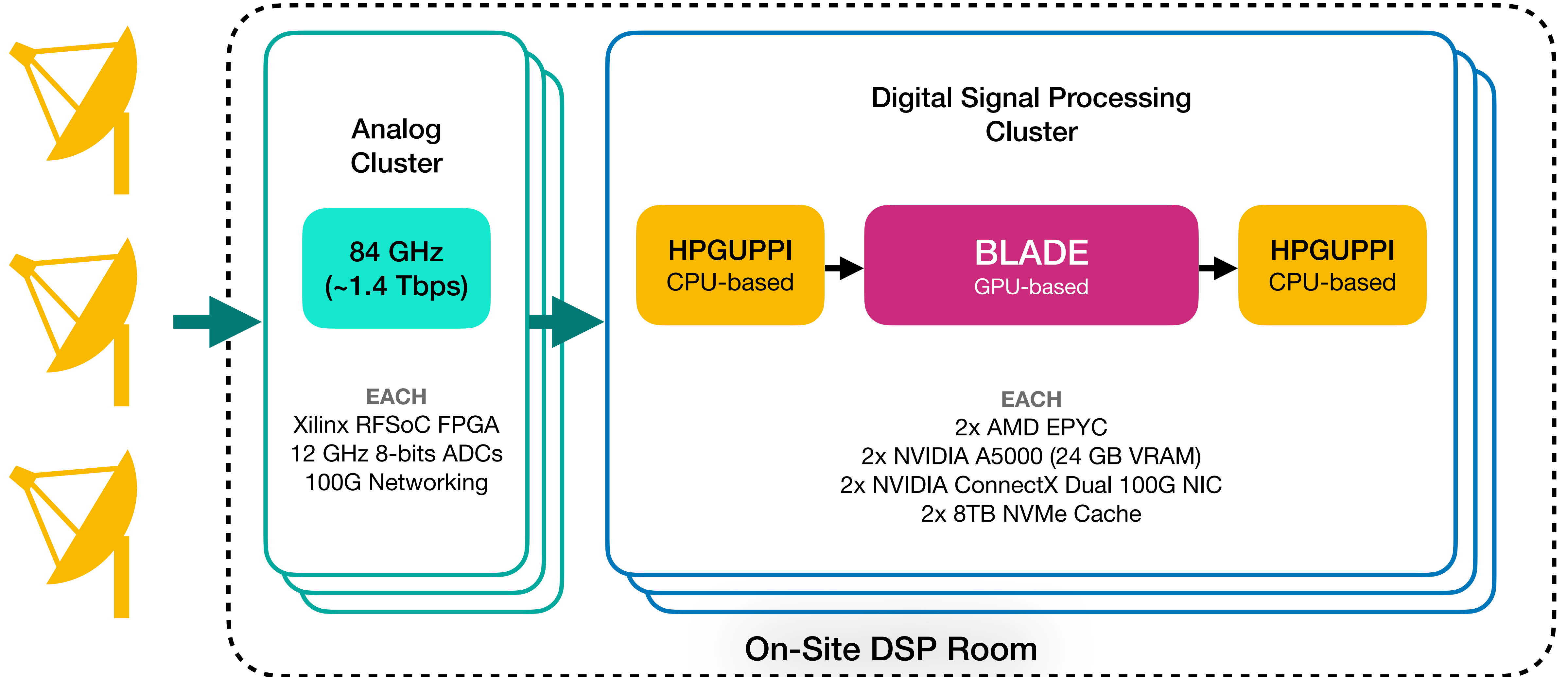
Allen Telescope Array Data Acquisition

- Received radio signal is transmitted to the DSP room via RF over fiber.
- Signal is converted back to copper, pre-amplified, mixed, and distributed to the data-acquisition boards.
- Signal is digitized using RFSoc FPGA boards where it is pre-channelized, packetized, and sent over the network via 100G fiber.
- Data is received in the processing nodes.



Data Processing

Current Pipeline



BLADE



BLADE

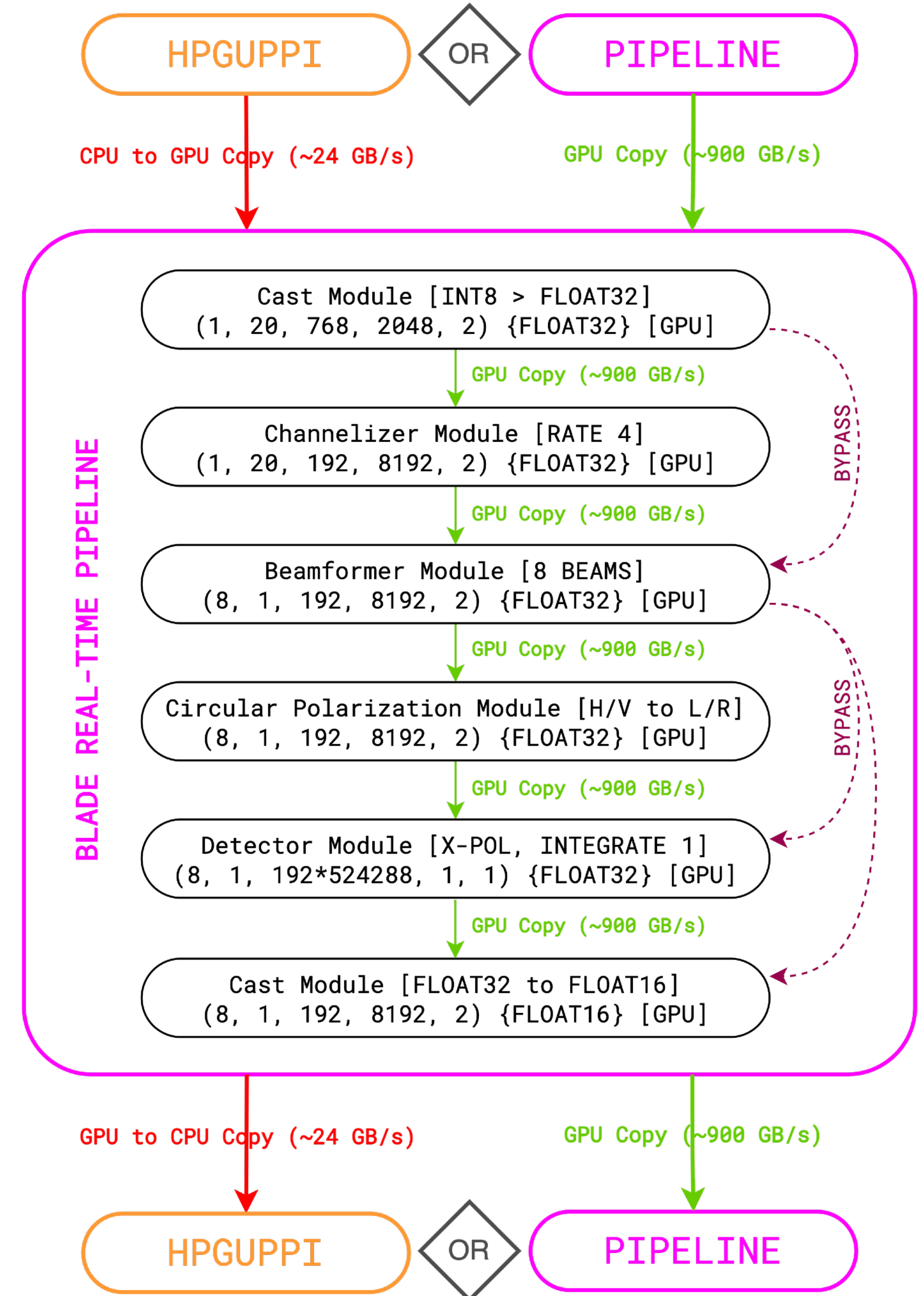
Breakthrough Listen Accelerated DSP Engine

- Responsible for most of the Digital Signal Processing of the ATA.
- Currently processing data incoming from 28 antennas with more soon!
- Each antenna represents ~3.0 GHz of bandwidth in 8 bits samples.
- Equates to an aggregated ~1.4 Tbps in 16 instances (~90 Gbps/instance).
- Currently implements 9 processing modules (beamforming, correlator, etc).
- Design:
 - Common interface between astronomy oriented DSP modules.
 - Just-in-time compilation of CUDA kernels.
 - Performant while hackable.

BLADE

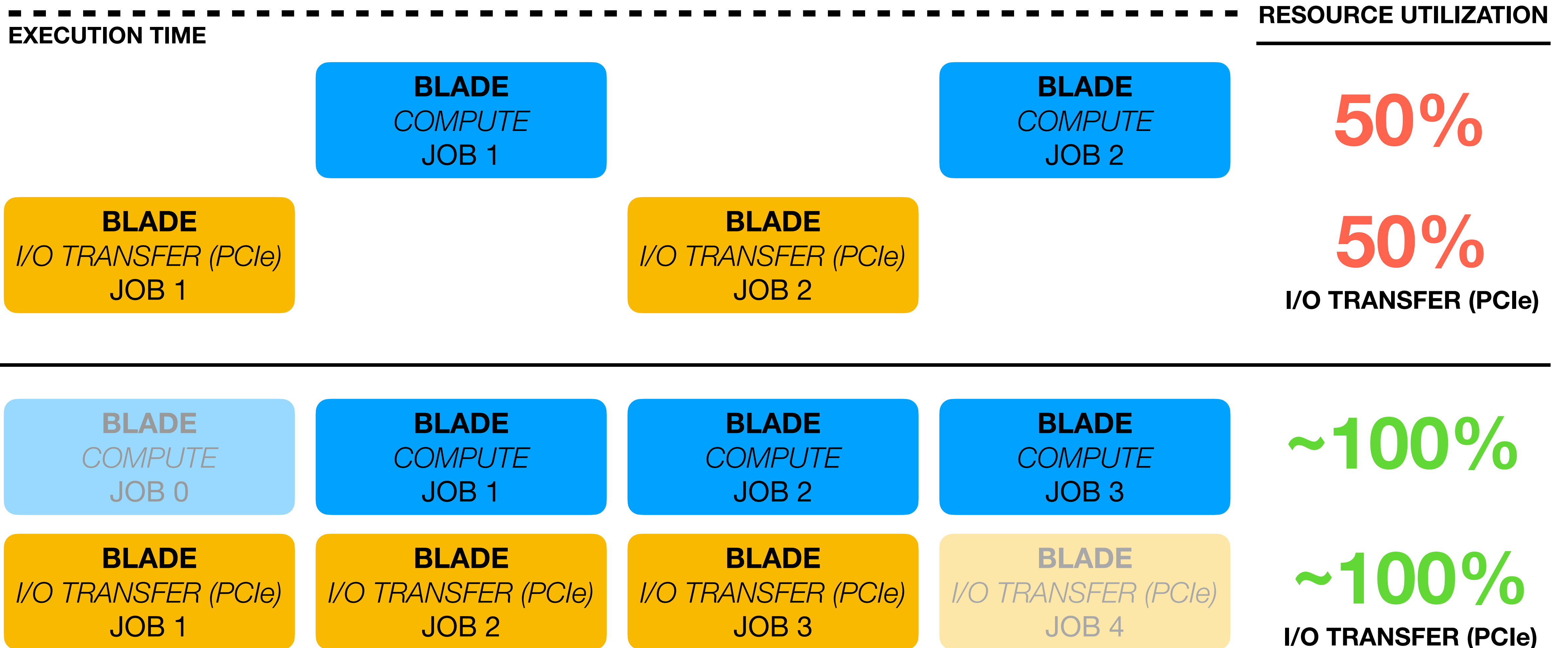
Overall Architecture

- Each module represents a compute operation (cast, beamforming, channelization, polarization, etc).
- A sequence of modules is contained inside a pipeline. It's also responsible to interface with the host device and hold staging buffers.
- Runner holds two pipelines streams running asynchronously. The runner will schedule the execution optimizing for maximum parallelization.



Concurrent Execution

Asynchronous Worker Pool





HOLOSCAN

Holoscan

NVIDIA's Streaming Sensor Platform

What is Holoscan?

- High-performance platform for sensor data processing and AI inferencing.
- Leverages the power of NVIDIA GPUs for efficient data movement and computation.

Benefits

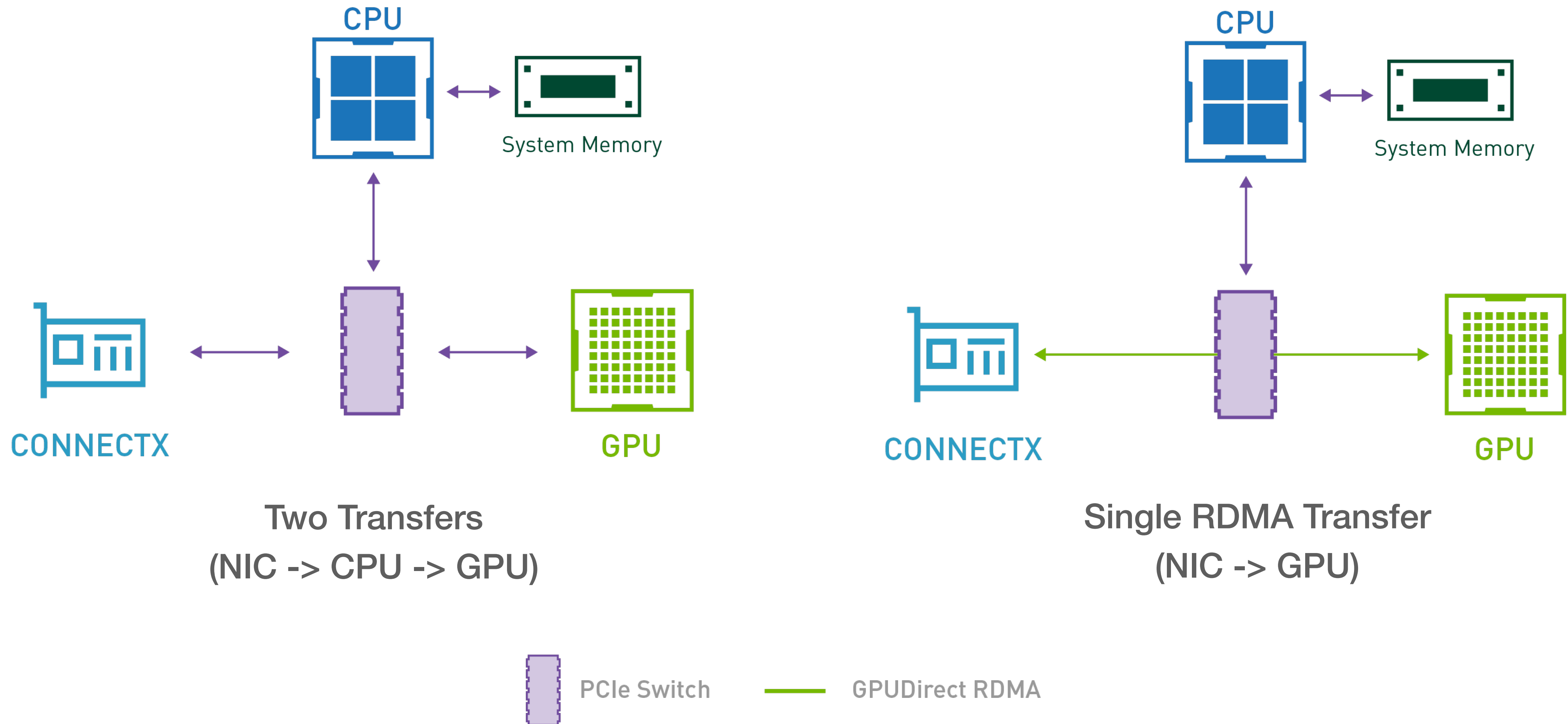
- Scalability: Handles high data volumes and scales with additional hardware.
- Simplicity: Easier to build and deploy sensor processing applications.

Advanced Network Operator (ANO):

- Abstracts system tuning and GPUDirect RDMA implementation.
- Enables data to bypass CPU and directly reach GPUs for faster processing.

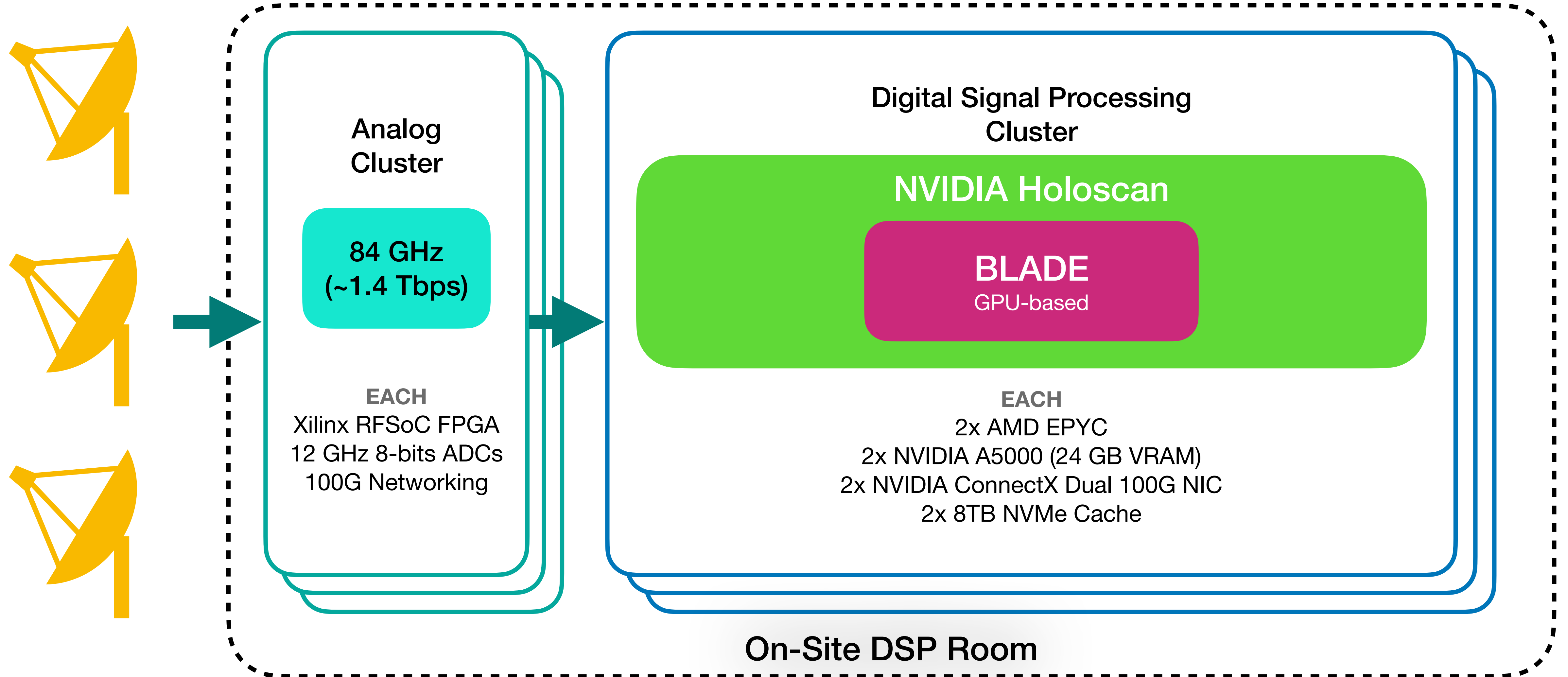
Holoscans

Advanced Network Operator (ANO)

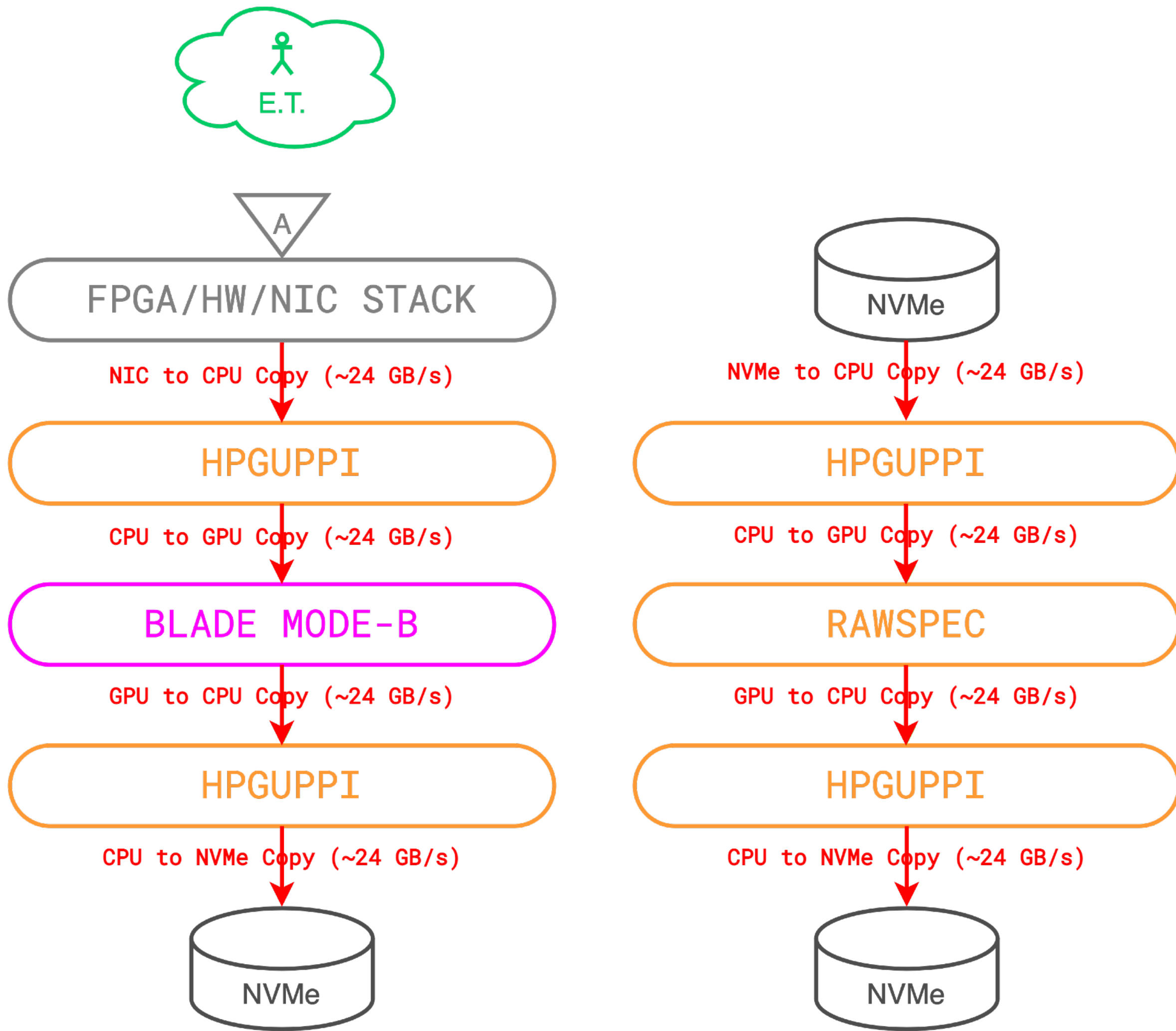


Data Processing

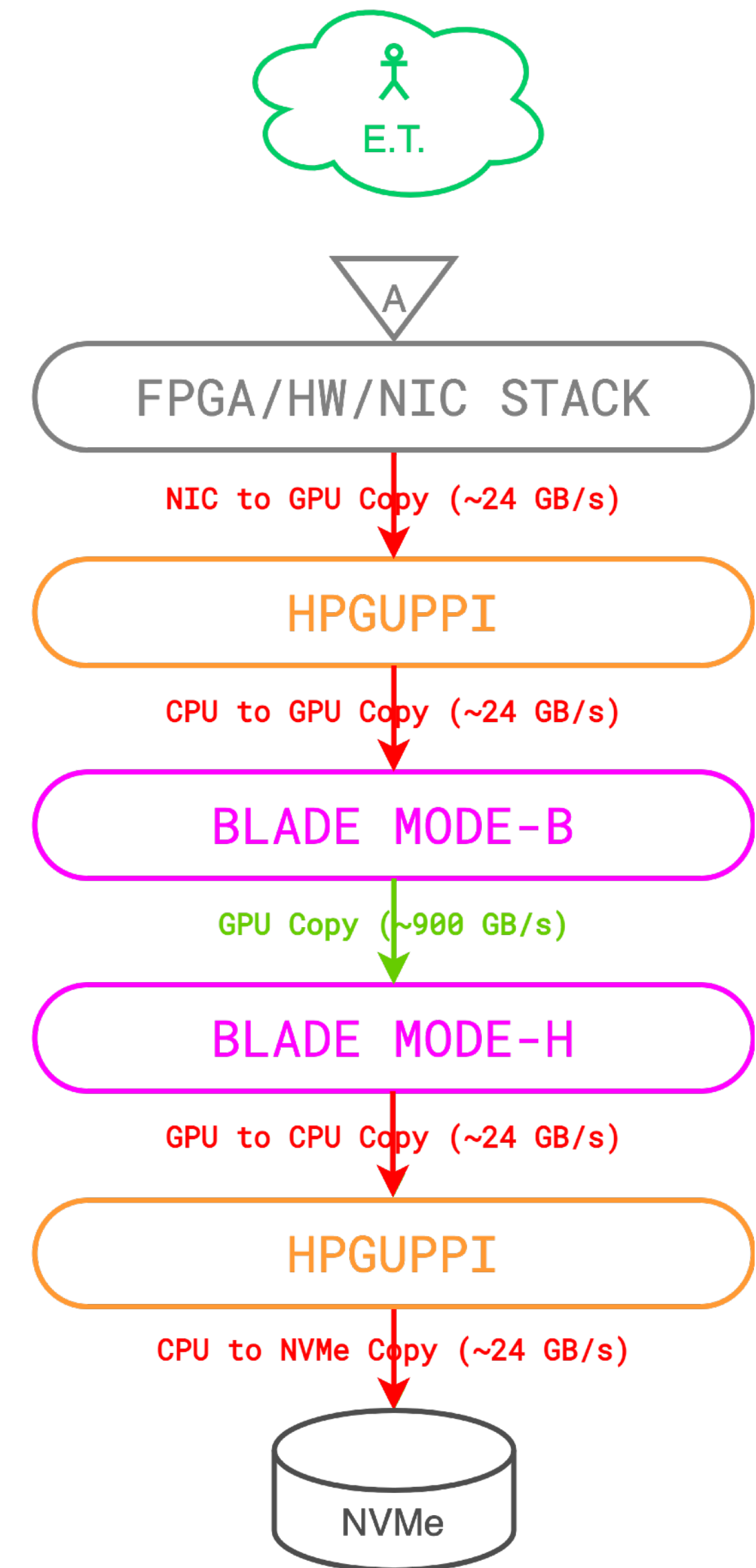
Future Pipeline



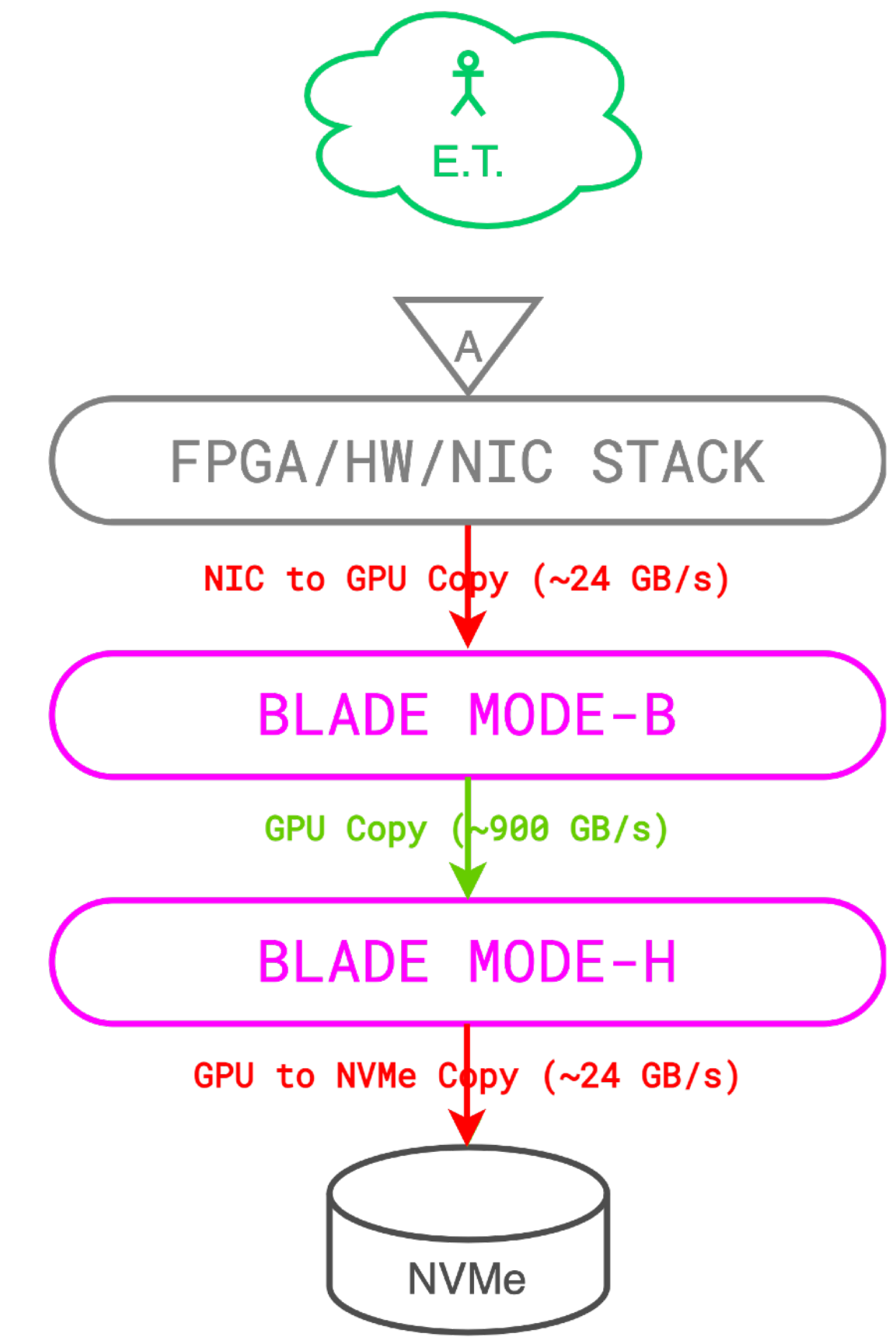
BLADE v0.6.5 - 8x PCIe 4.0 Hops
 - 2x NVMe Writes
 PREVIOUS PRODUCTION - 1x NVMe Reads



BLADE v0.7.0 - 4x PCIe 4.0 Hops
 CURRENT PRODUCTION - 1x NVMe Writes



BLADE - 2x PCIe 4.0 Hops
 NEXT - 1x NVMe Writes



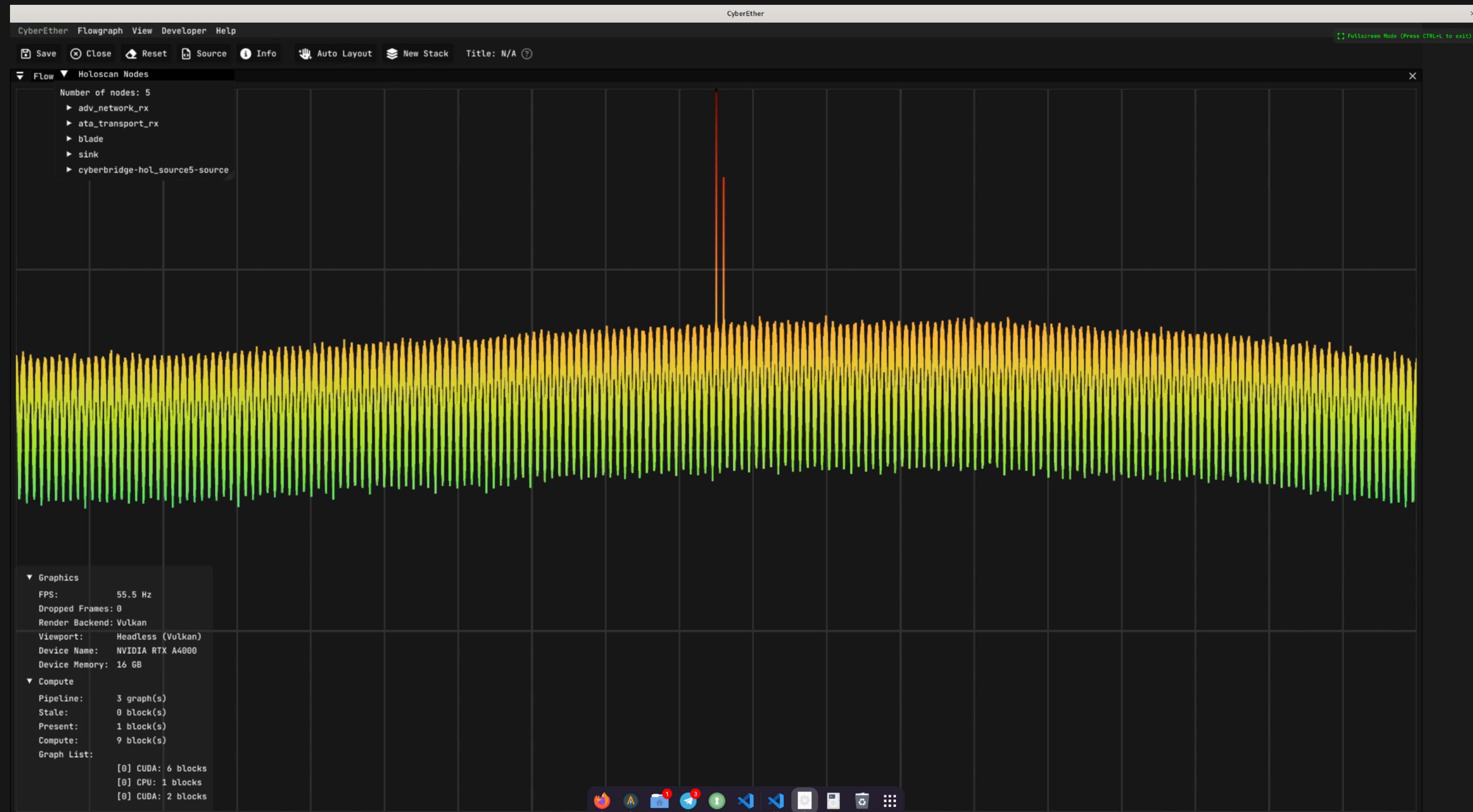
CPU
 BLADE
 NOT COMPUTER



TESTING

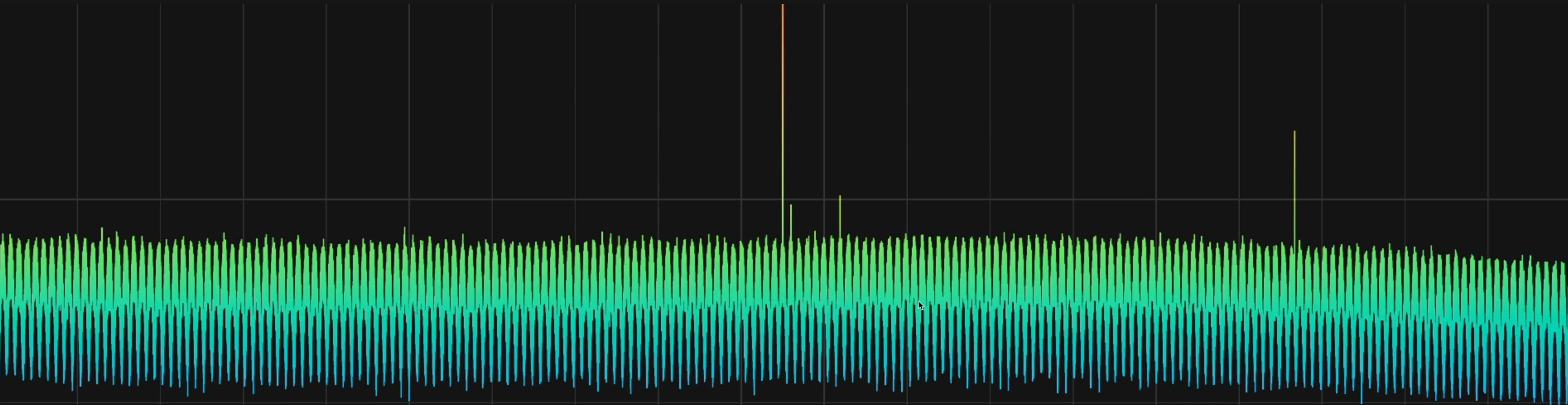
Data Processing

Holoscan + CyberEther Pipeline



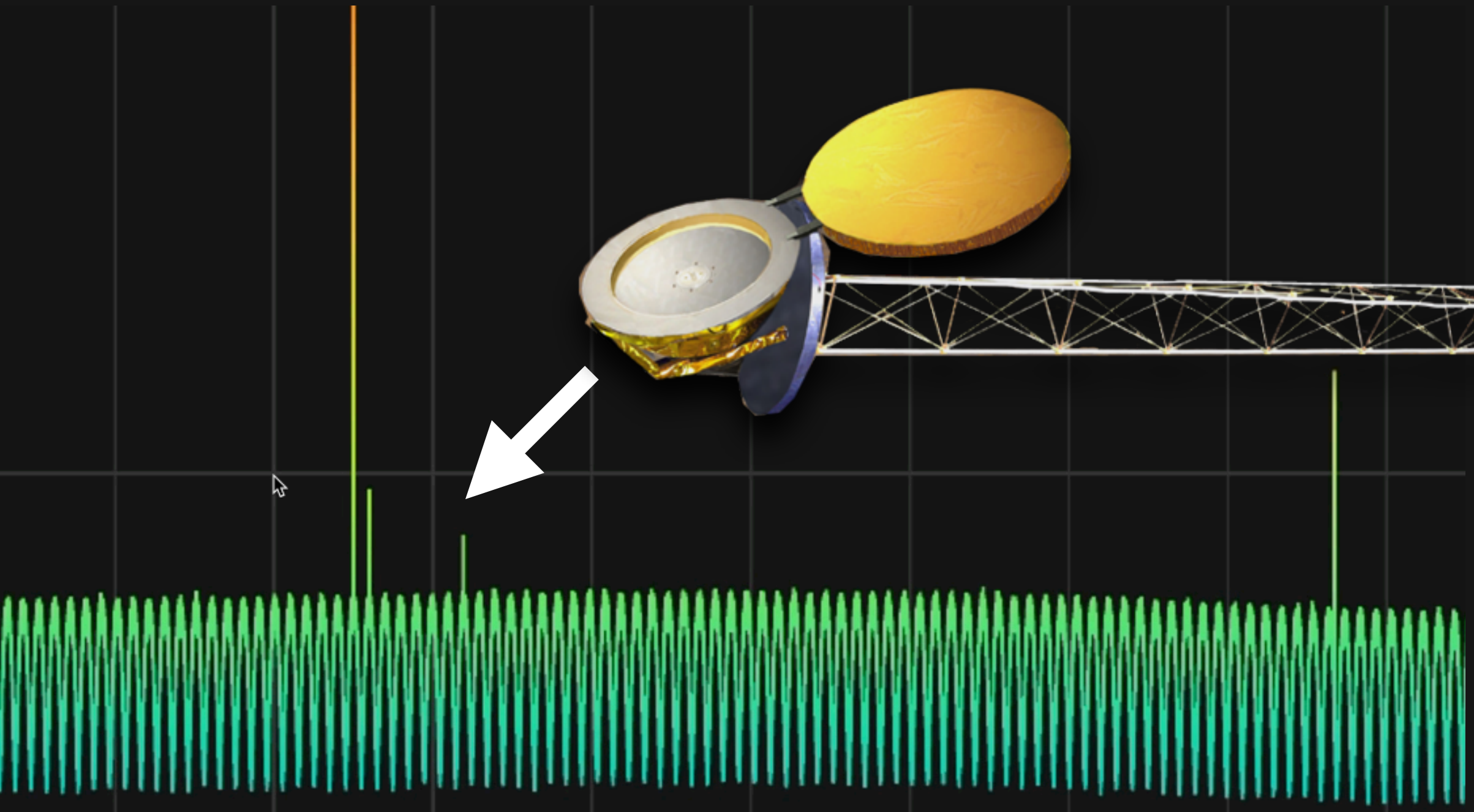
Deep Space Demonstration

Allen Telescope Array Holoscan Pipeline



Deep Space Demonstration

Allen Telescope Array Holoscan Pipeline



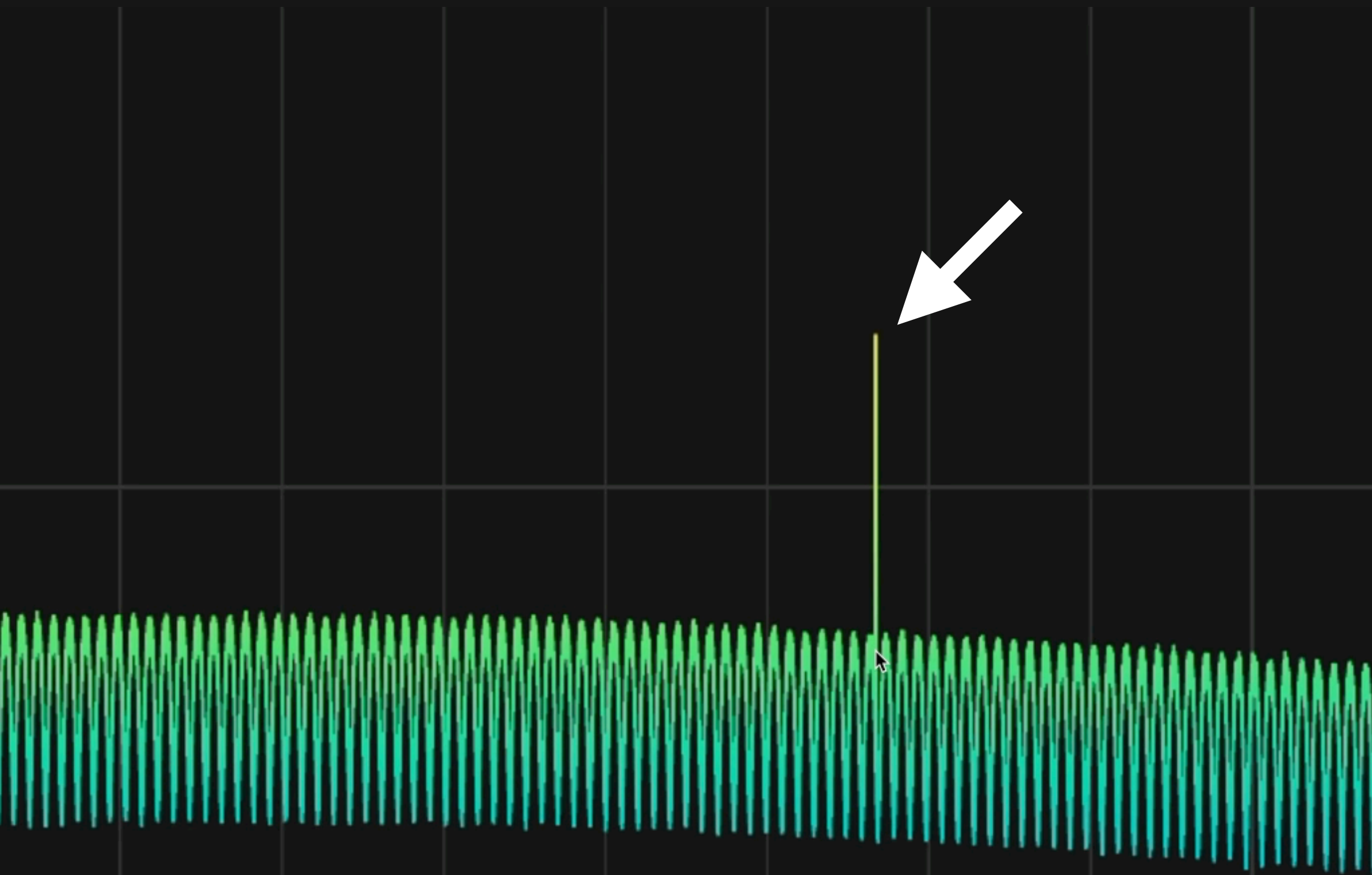
~8406 MHz



Mars Odyssey

Deep Space Demonstration

Allen Telescope Array Holoscan Pipeline



~8430 MHz

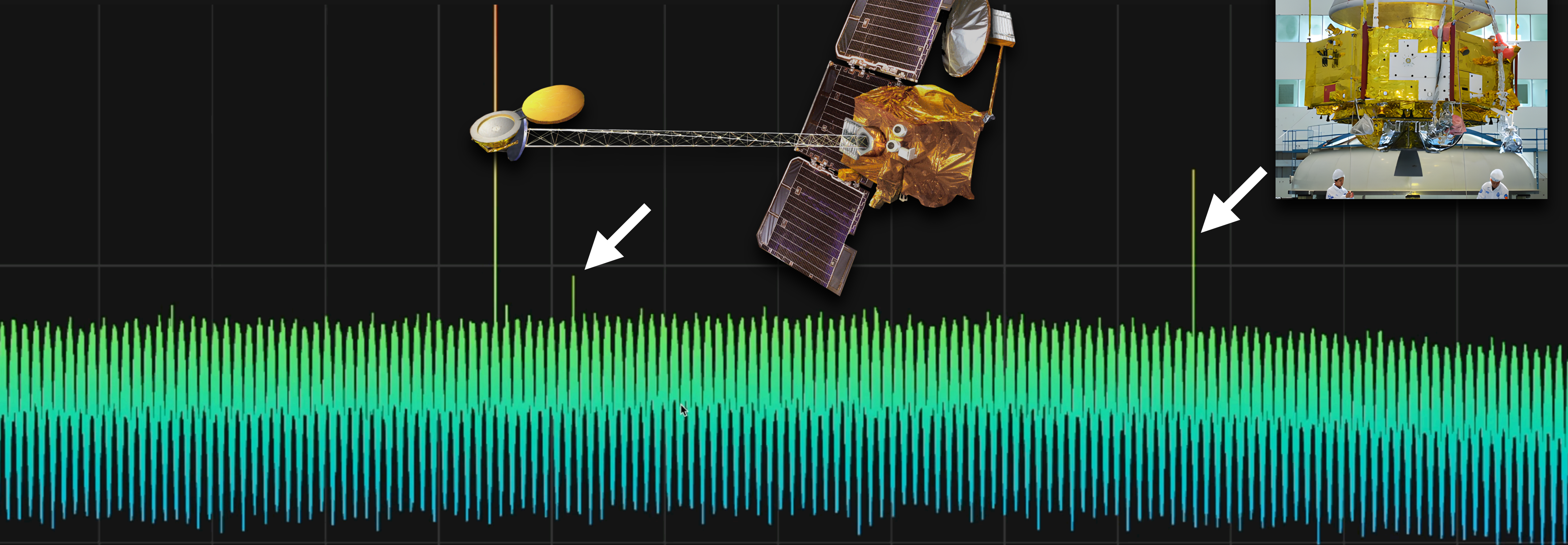
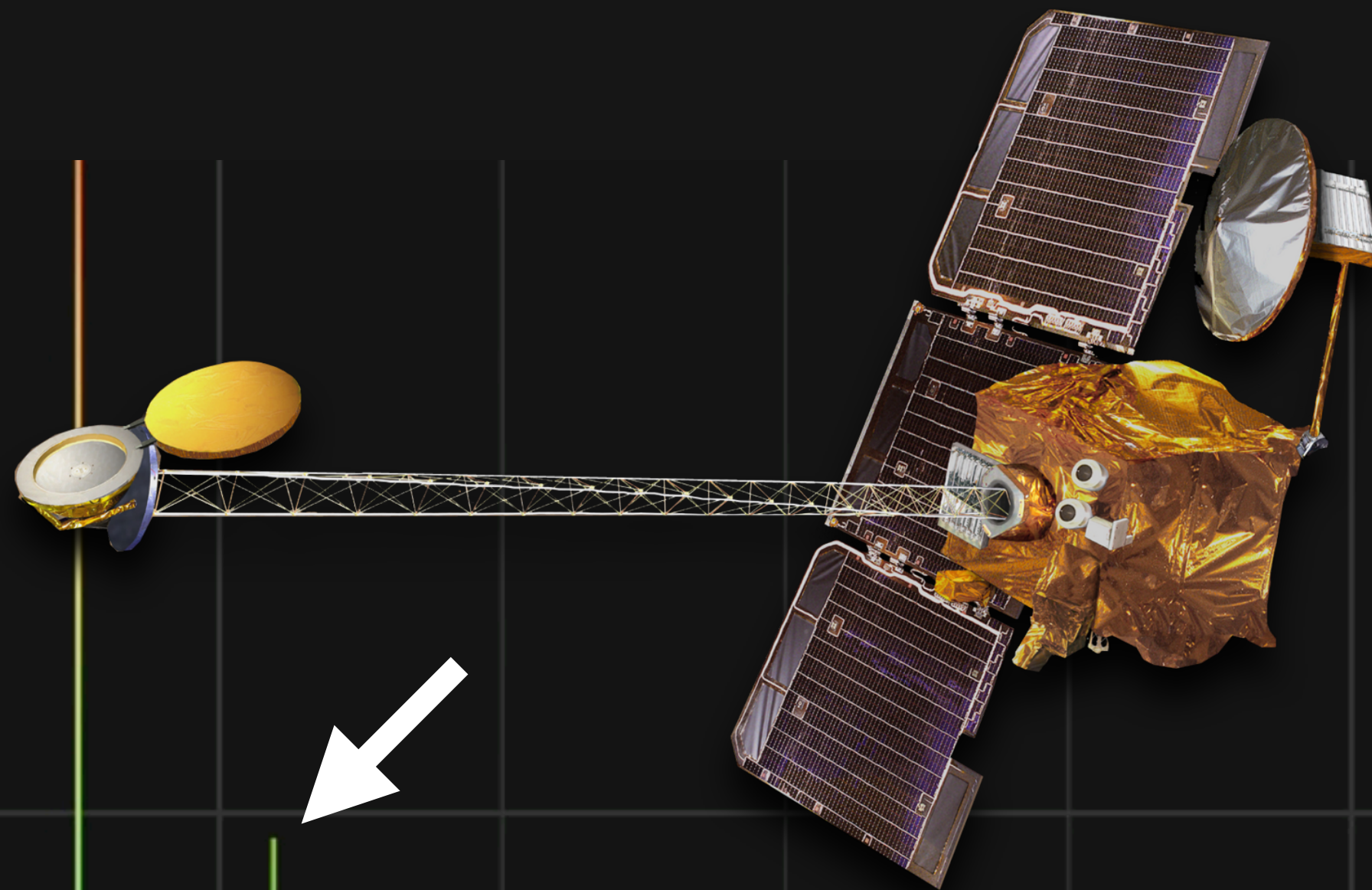


Tianwen

天问一号

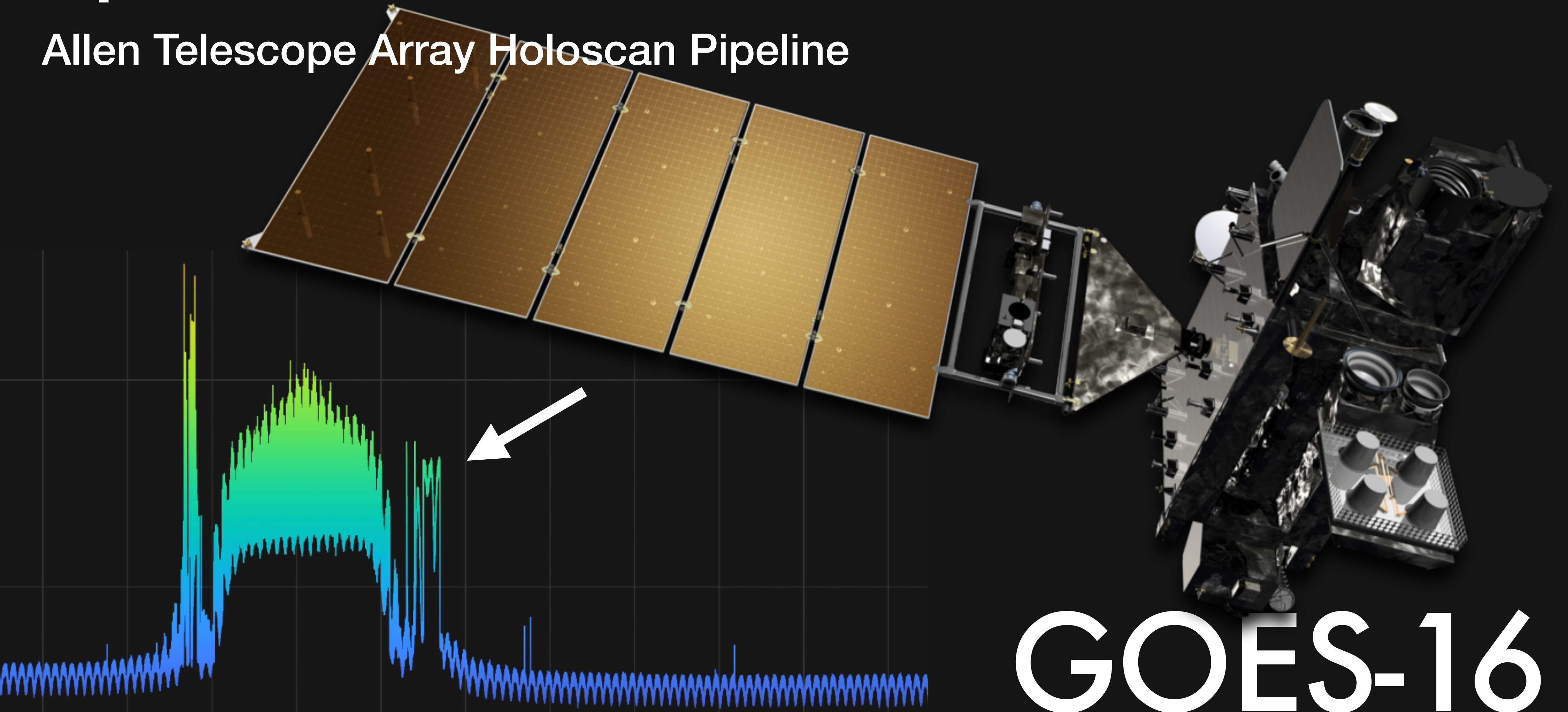
Deep Space Demonstration

Allen Telescope Array Holoscan Pipeline



Space Demonstration

Allen Telescope Array Holoscan Pipeline

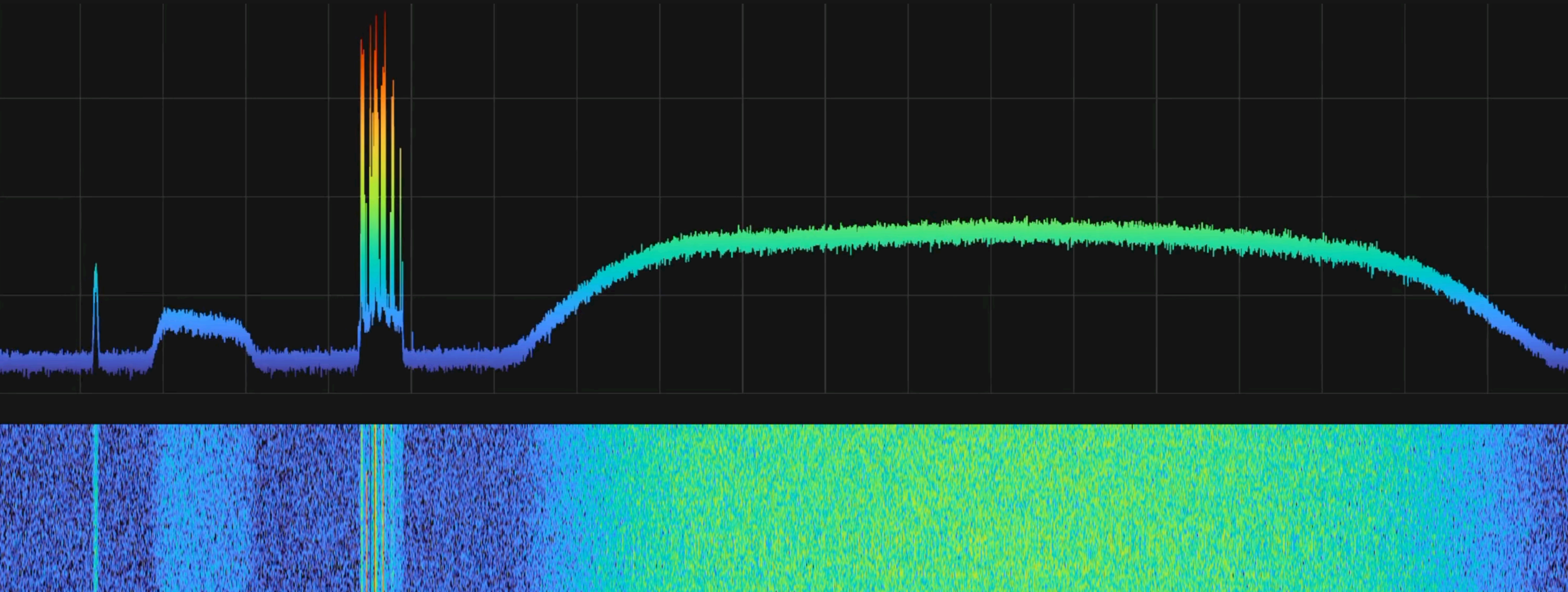


GOES-16

~1694 MHz

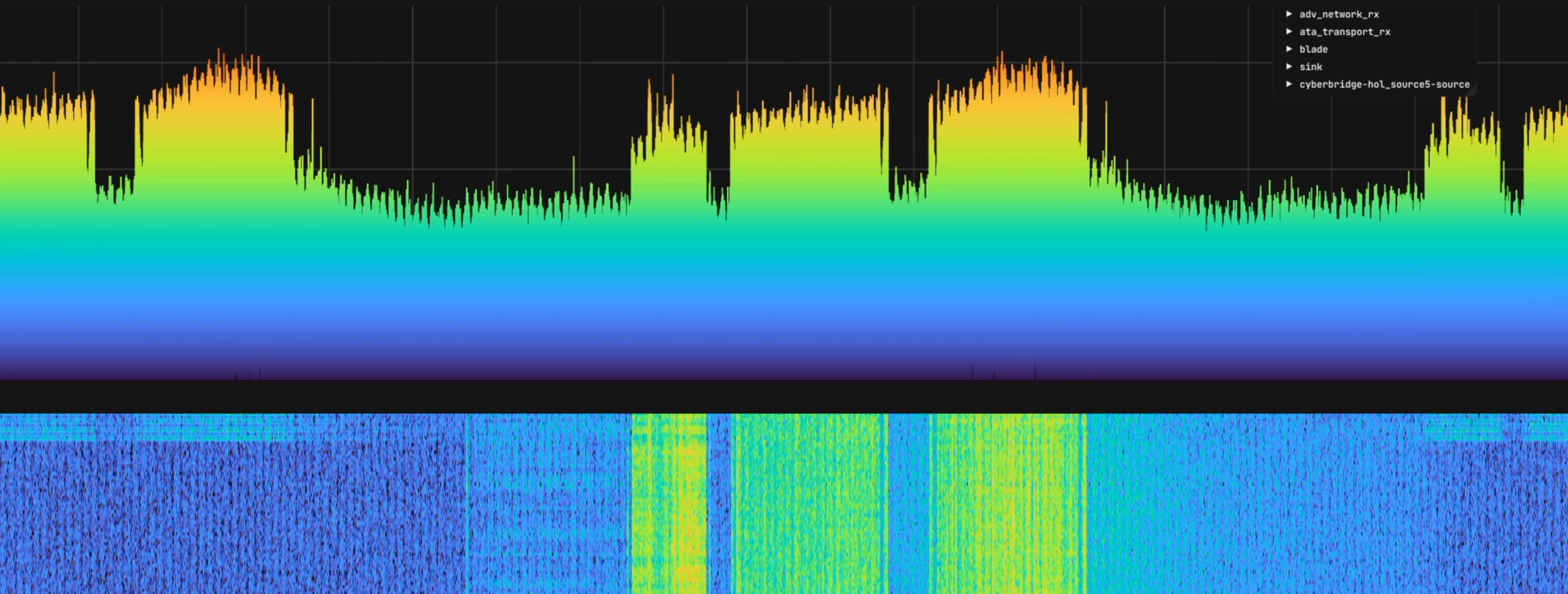
Space Demonstration

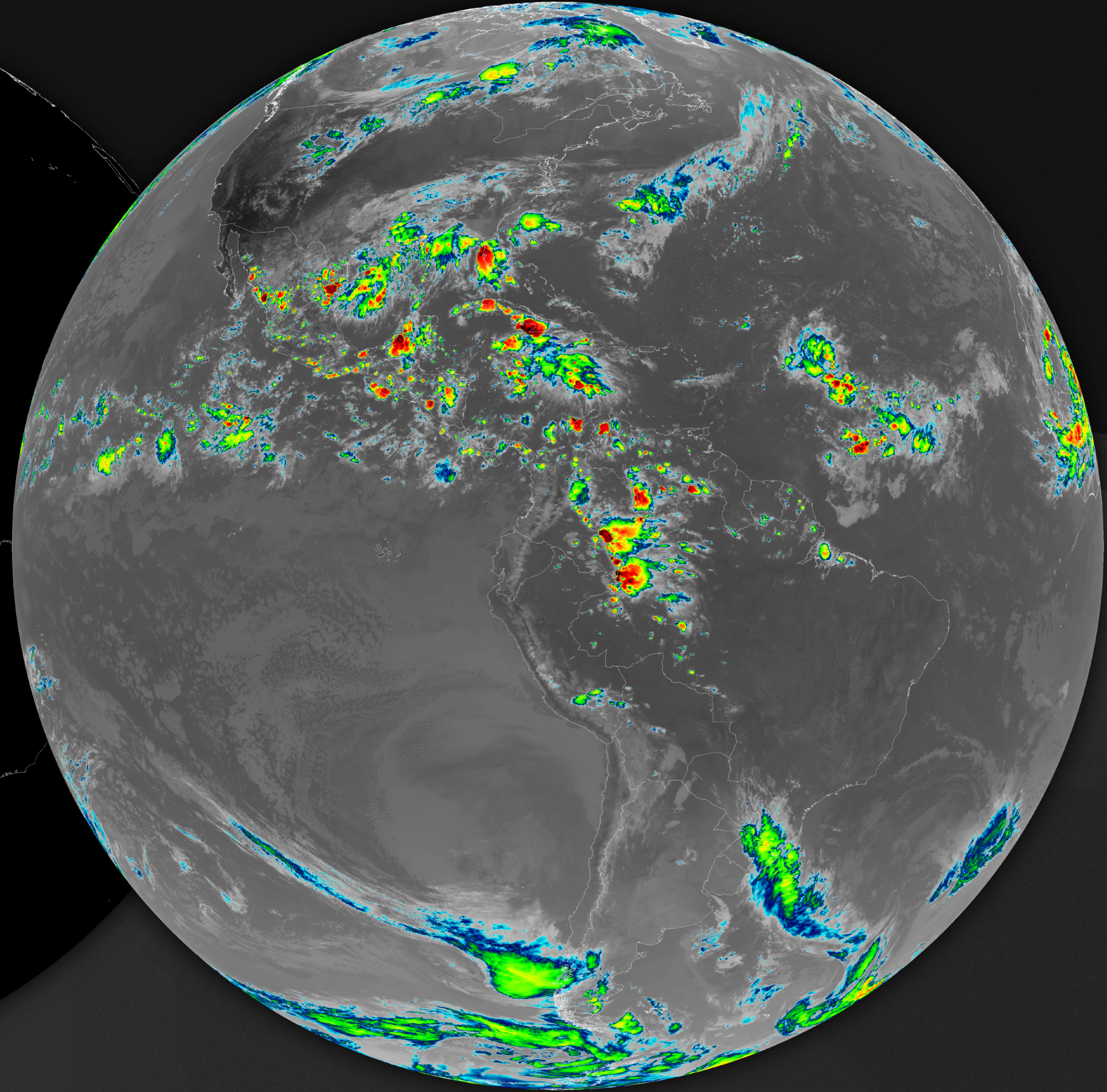
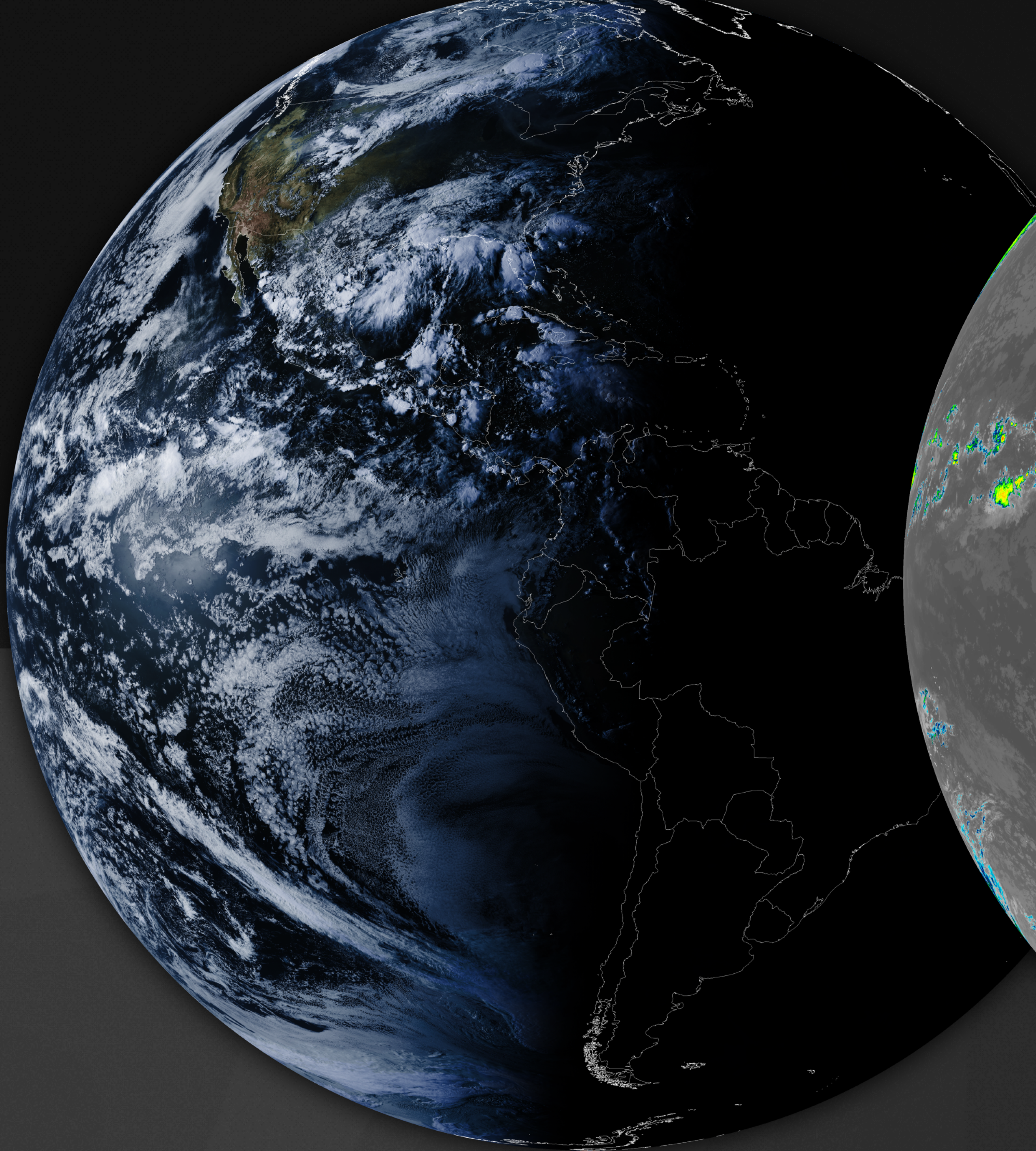
Allen Telescope Array Holoscan Pipeline

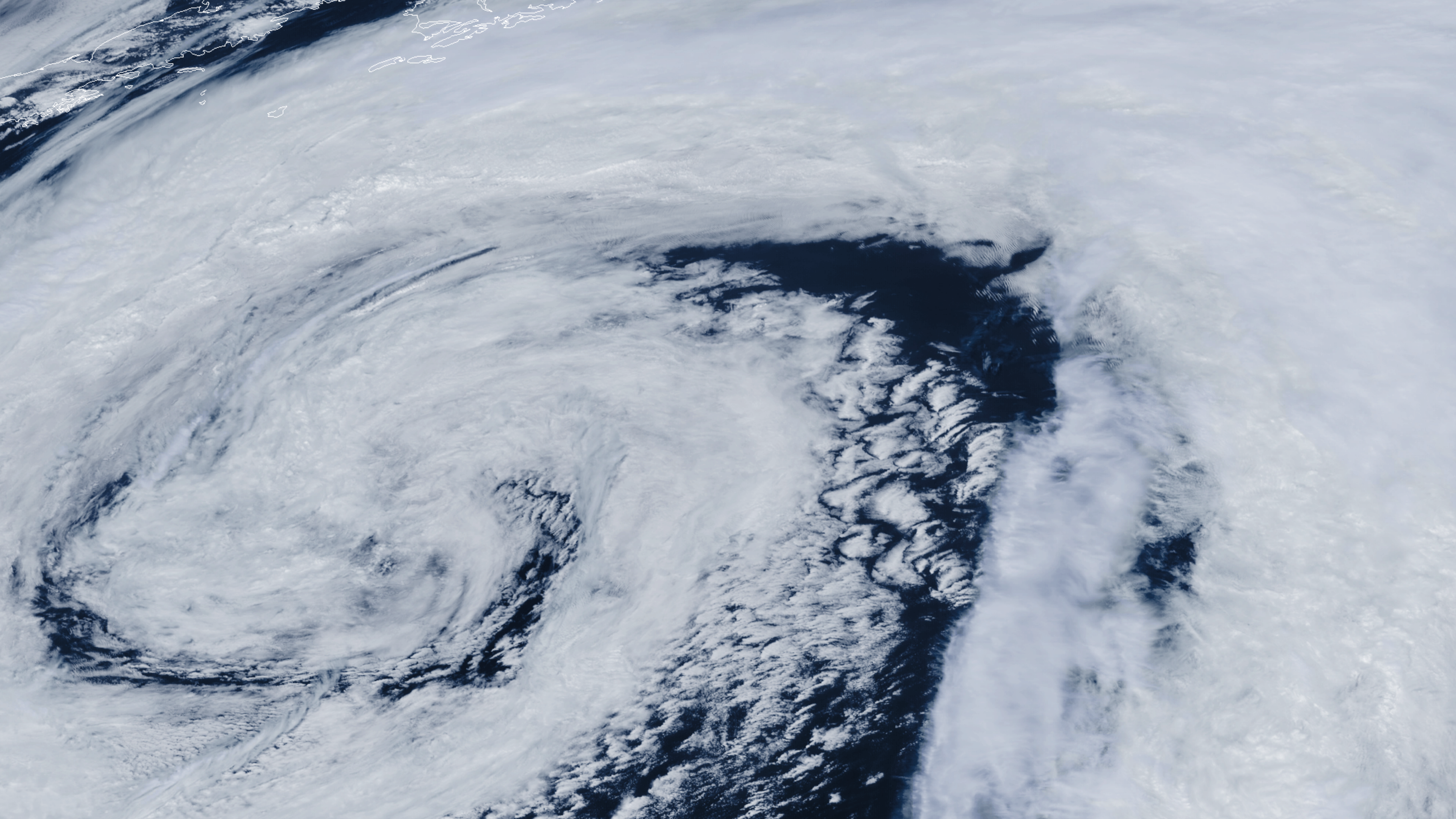


Space Demonstration

Allen Telescope Array Holoscan Pipeline





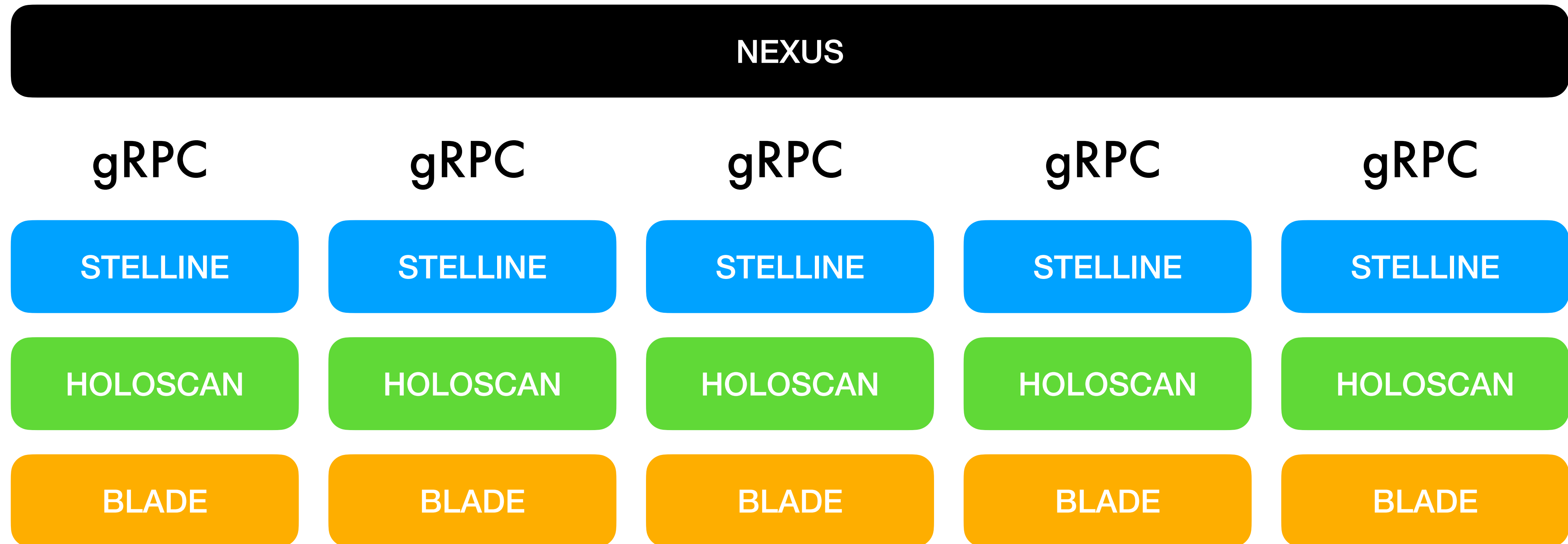




FUTURE

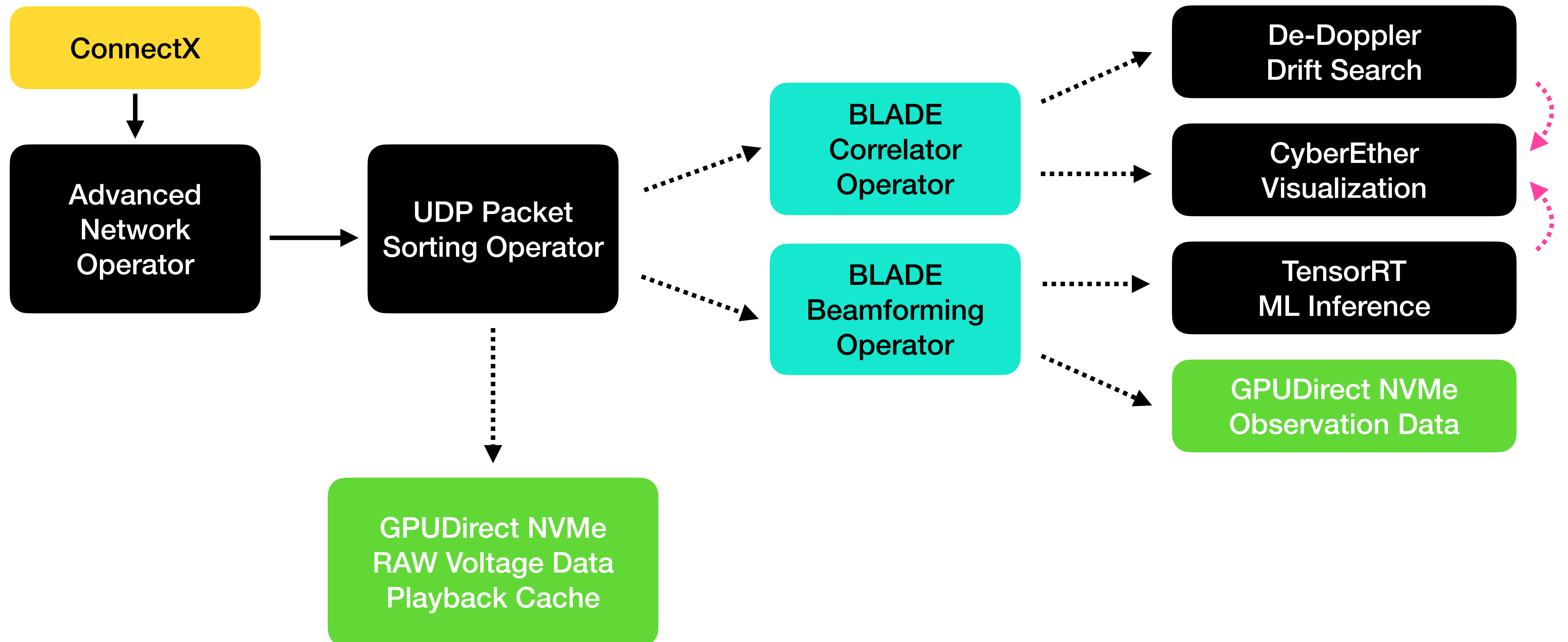
Future

Extending the ATA's Capabilities with Holoscan



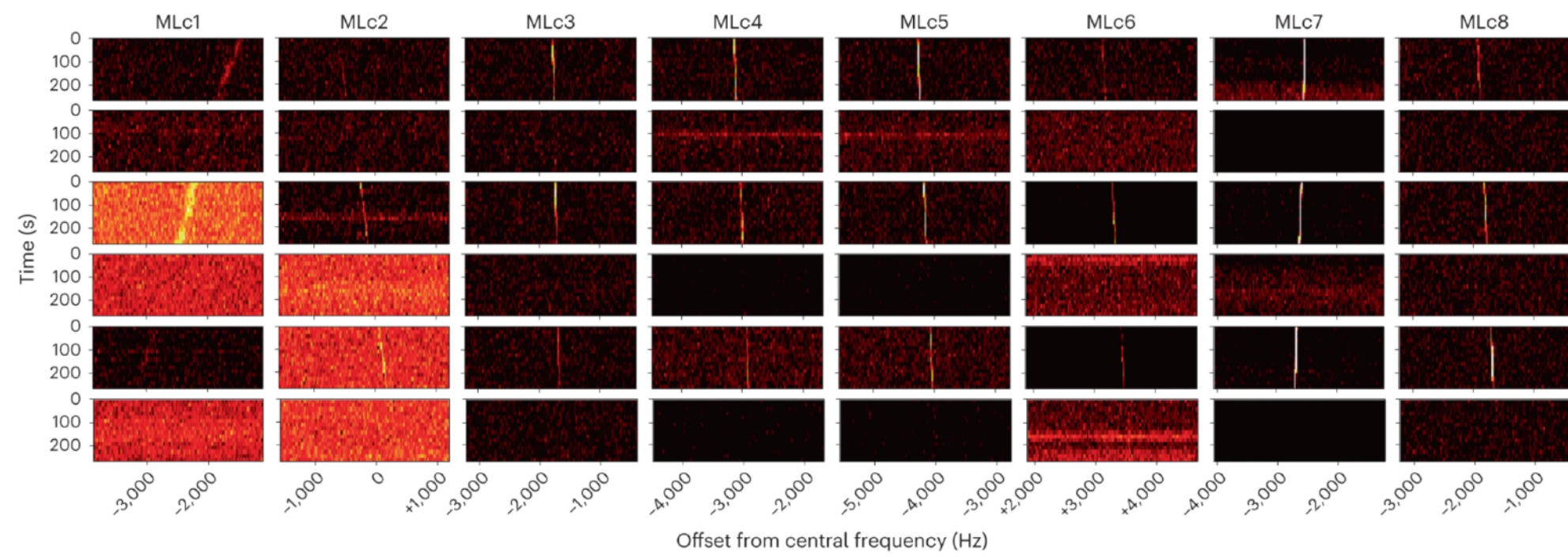
Future

Extending the ATA's Capabilities with Holoscan



Real Time ML for Transient Search

Previous ML for SETI

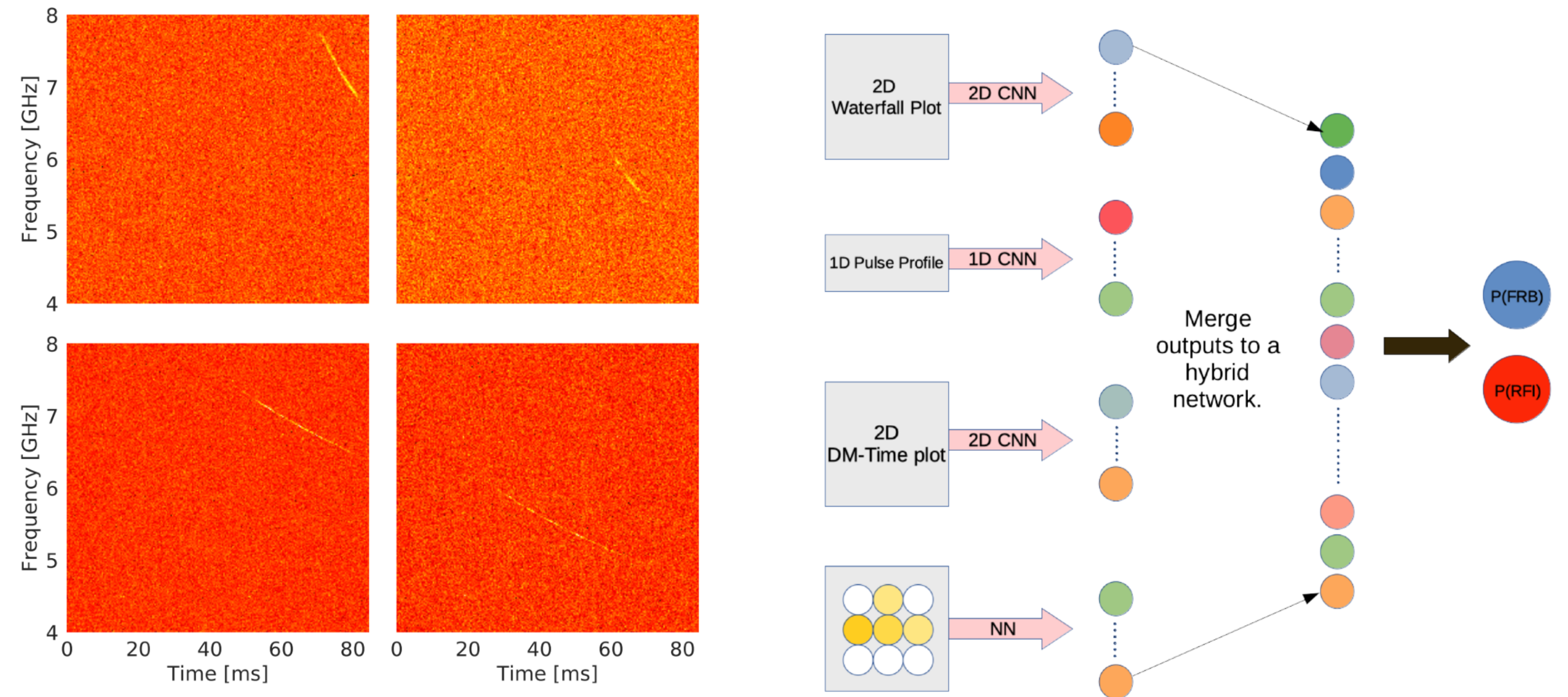


Discovered candidates not found by previous classical techniques

Used B-VAE + Random Forest Class. CNN model (Zhang et al.)

Used 12 Titan Xs
achieved ~ 18min / 30min obs [dom. I/O]

Previous ML for Fast Radio Burst



Hybrid (Connor et al.)

Next Compute Platform Trials

NVIDIA IGX Orin



- 12-core ARM CPU (Cortex-A78)
- NVIDIA ConnectX-7
 - 2x 100 GbE
 - 32-lane PCIe 5.0 Switch
- NVIDIA A6000 Ada
- OpenBMC (Aspeed AST2600)

Thank You!
Questions?

