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.

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$$N = R_* \cdot f_p \cdot n_e \cdot f_1 \cdot f_1 \cdot f_c \cdot L$$

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, preamplified, 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 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.















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.

Holoscan **Advanced Network Operator (ANO)**



Two Transfers (NIC -> CPU -> GPU)





Single RDMA Transfer (NIC -> GPU)

Data Processing Future Pipeline













Data Processing Holoscan + CyberEther Pipeline

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Deep Space Demonstration Allen Telescope Array Holoscan Pipeline



Mars Ocyssey

Deep Space Demonstration Allen Telescope Array Holoscan Pipeline



~8406 MHz



Deep Space Demonstration

Allen Telescope Array Holoscan Pipeline





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Deep Space Demonstration Allen Telescope Array Holoscan Pipeline











Space Demonstration Allen Telescope Array Holoscan Pipeline

~1694 MHz



Space Demonstration Allen Telescope Array Holoscan Pipeline





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Space Demonstration Allen Telescope Array Holoscan Pipeline









Future Extending the ATA's Capabilities with Holoscan



Future Extending the ATA's Capabilities with Holoscan



GPUDirect NVMe RAW Voltage Data Playback Cache



Real Time ML for Transient Search

Previous ML for SETI



Discovered candidates not found by previous classical techniques

Used B-VAE + Random Forest Class.

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

Previous ML for Fast Radio Burst



CNN model (Zhang et al.)

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 PCle 5.0 Switch
- NVIDIA A6000 Ada
- OpenBMC (Aspeed AST2600)

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Thank You! Questions?



