Updates from the OVRO-LWA-352 Upgrade

Marin M. Anderson
(on behalf of the OVRO-LWA collaboration)

LWA Users Meeting
08/16/2021

Caltech LWA Long Wavelength Array NASA Jet Propulsion Laboratory California Institute of Technology NJIT New Jersey Institute of Technology ASU Arizona State University RICE NSF WILF FAMILY FOUNDATIONS SIMONS FOUNDATION

OVRO-LWA-352 Team

Caltech / OVRO / JPL

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Larry D'Addario
Jack Hickish
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UNM

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Jayce Dowell

NJIT

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Sherry Chhabra (NRL)
Gelu Nita
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Surajit Mondal

NUIG

Aaron Golden
Dúalta Ó Fionnagáin

ASU

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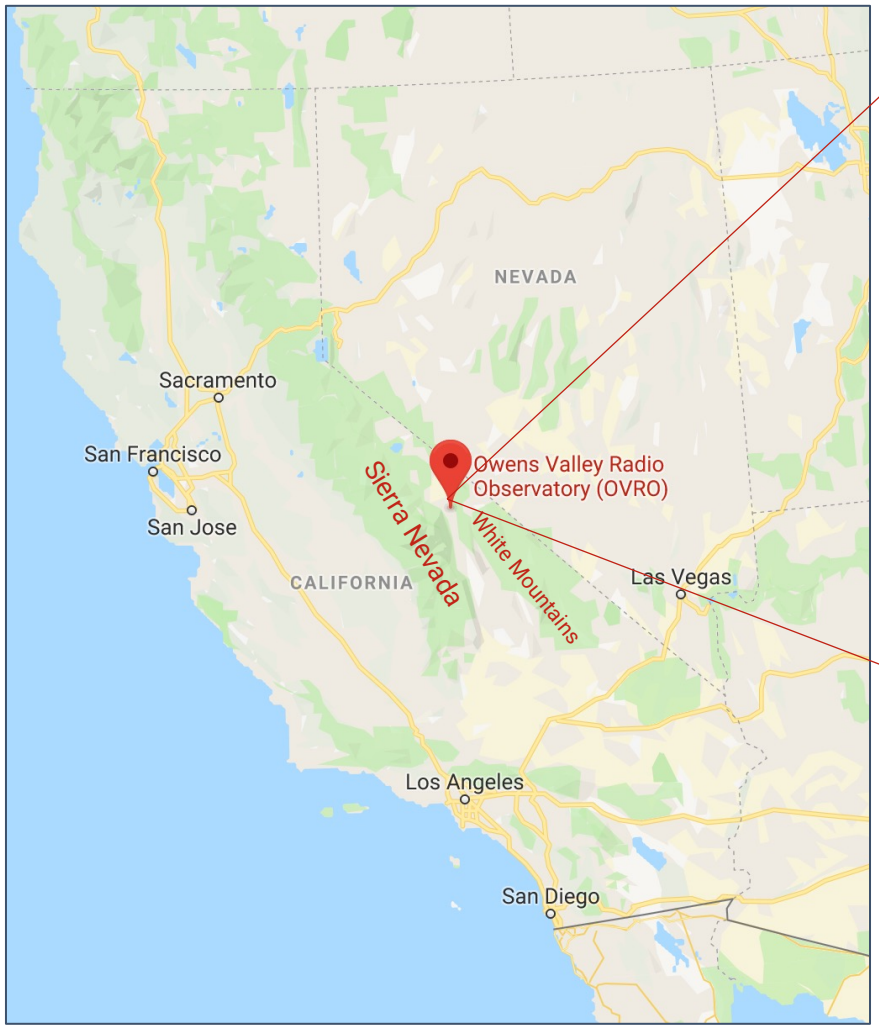
Danny Jacobs
Bharat Gehlot
Katherine Elder

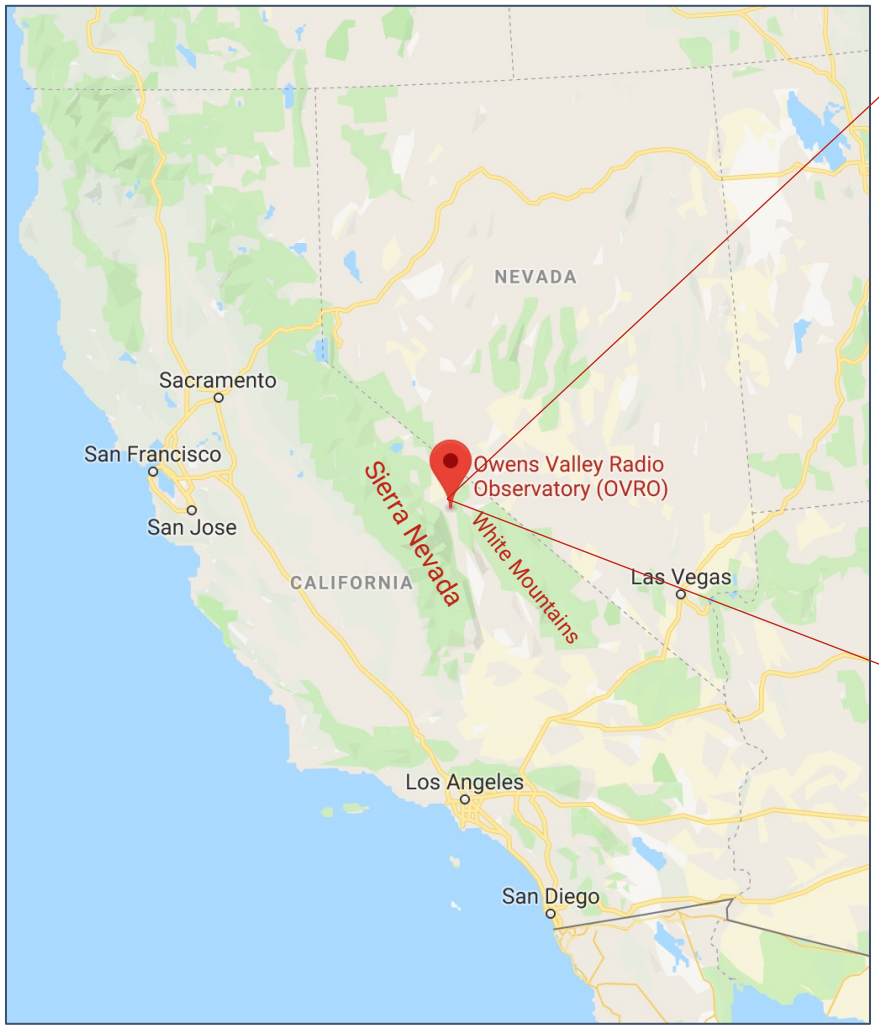
Rice

Andrea Isella **Co-PI**
Jason Ling

Owens Valley Radio Observatory Long Wavelength Array (OVRO-LWA)



Owens Valley Radio Observatory Long Wavelength Array (OVRO-LWA)



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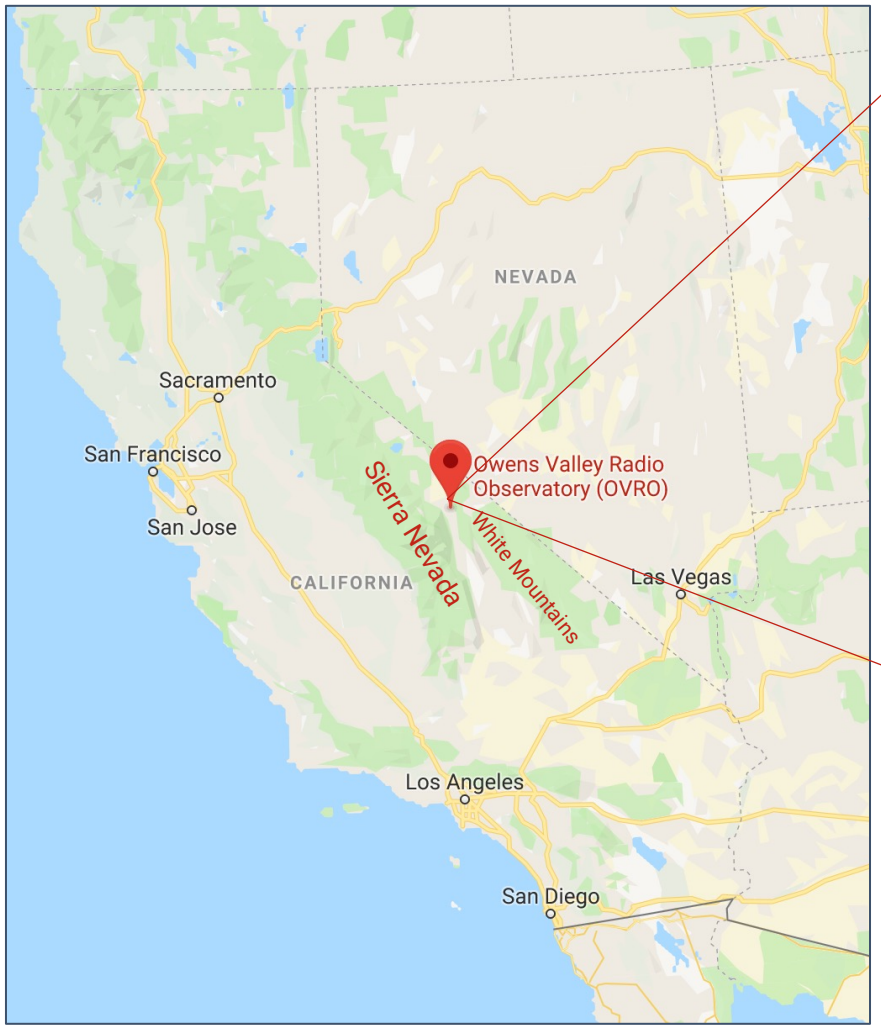
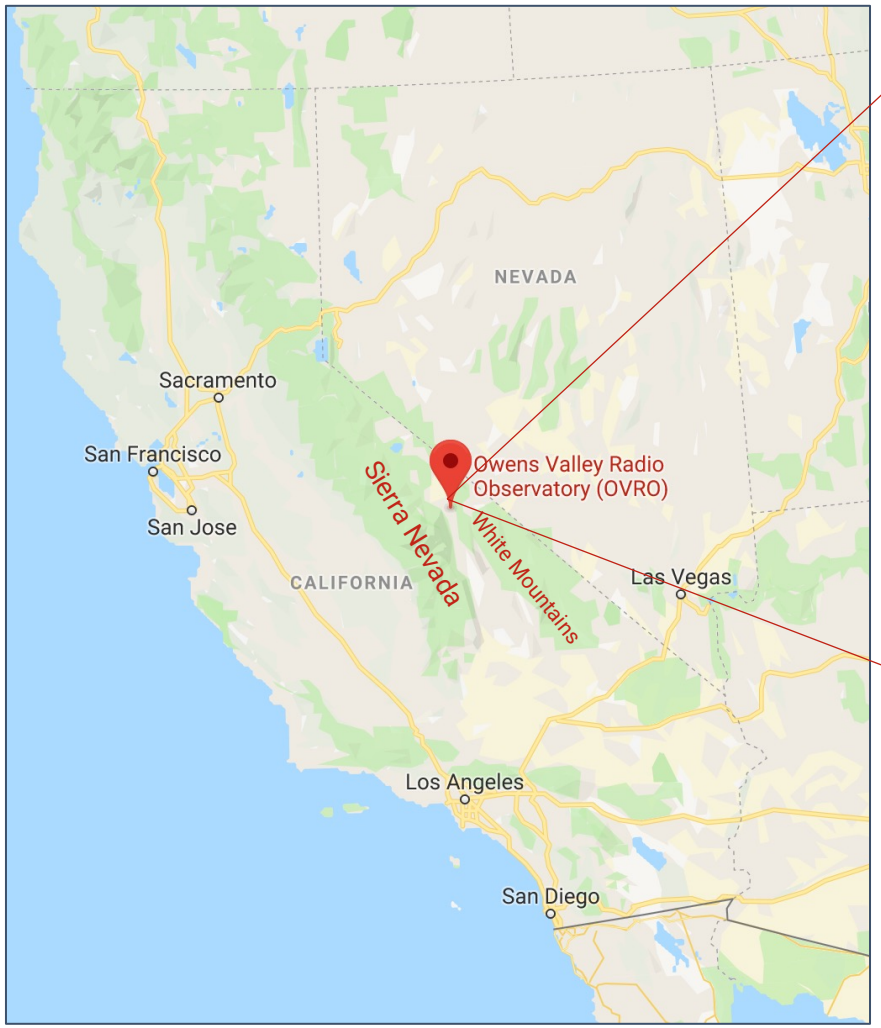


Owens Valley Radio Observatory Long Wavelength Array (OVRO-LWA)



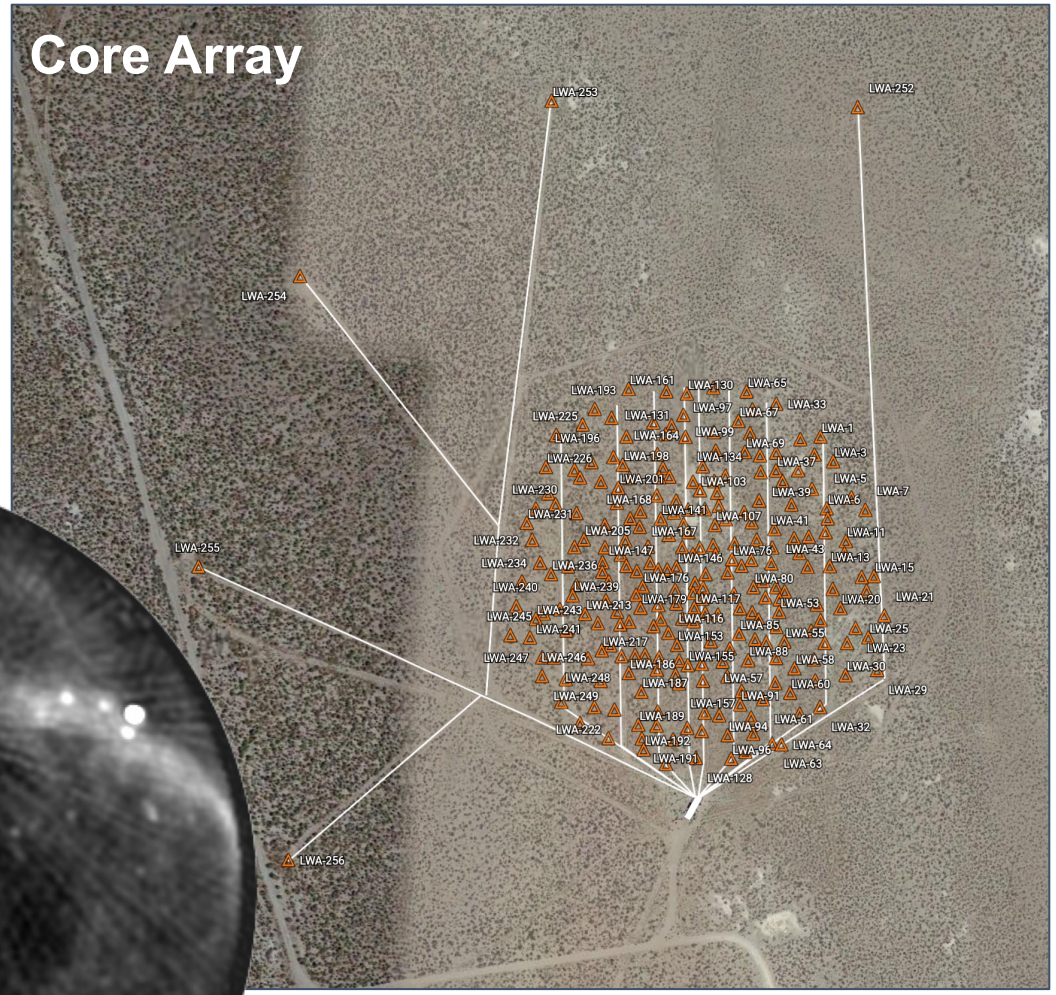
Stage I (2013–2014)

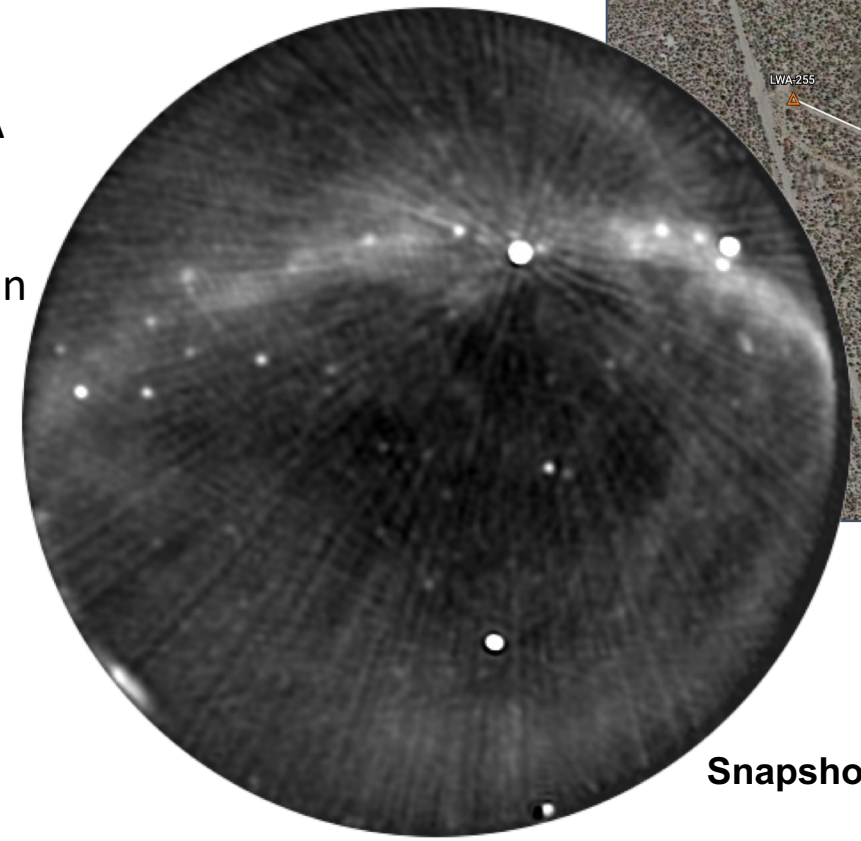
Stage II (2015–2020)

Stage III OVRO-LWA-352 (2021–)

OVRO-LWA Stage I (2013–2014)

- 251 LWA crossed-dipole antennas, in 200 m diameter core
- 5 LEDA outriggers — total power measurements (**Price+2018**)
- full cross-correlation with 512-input LEDA correlator (**Kocz+2015**)
- 28-84 MHz band, 24 kHz / 1 deg resolution

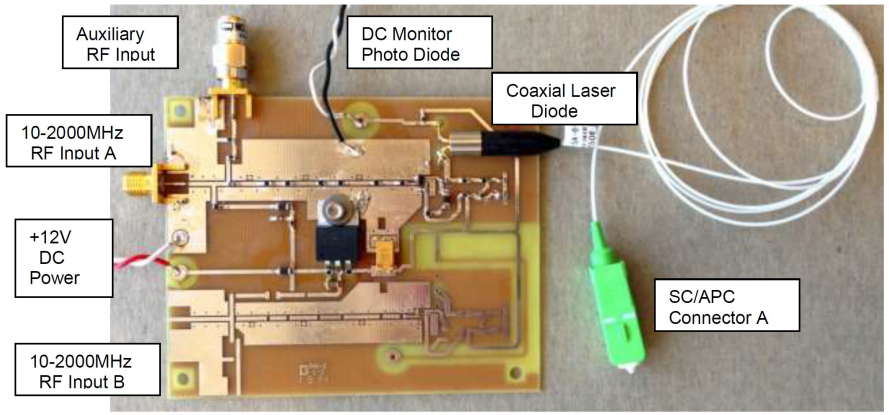


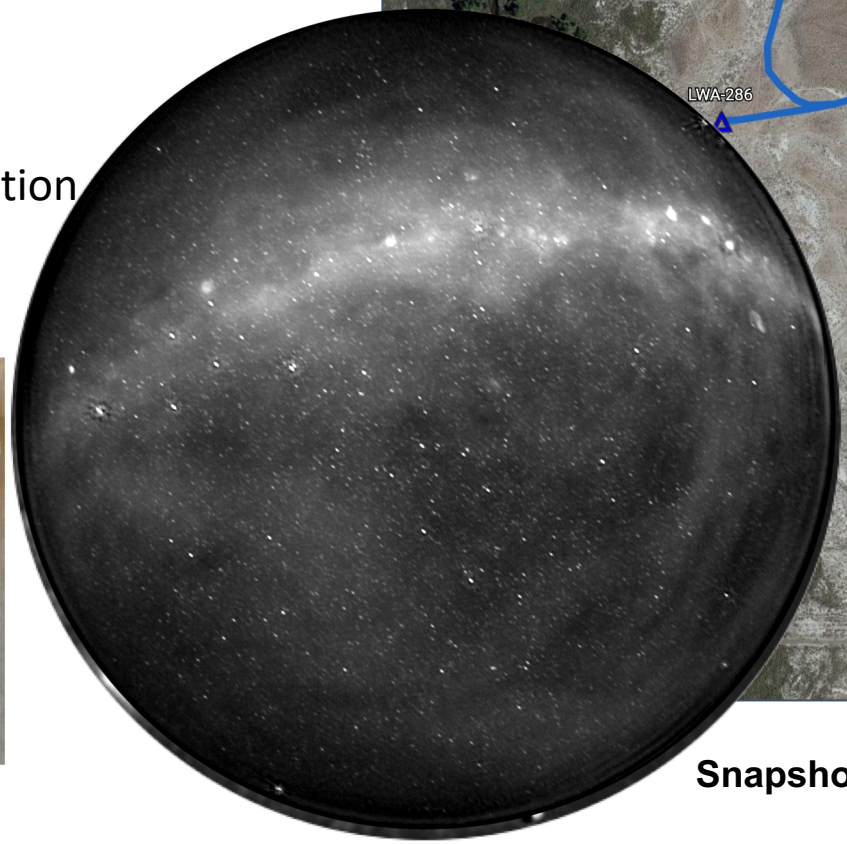


Snapshot with core array

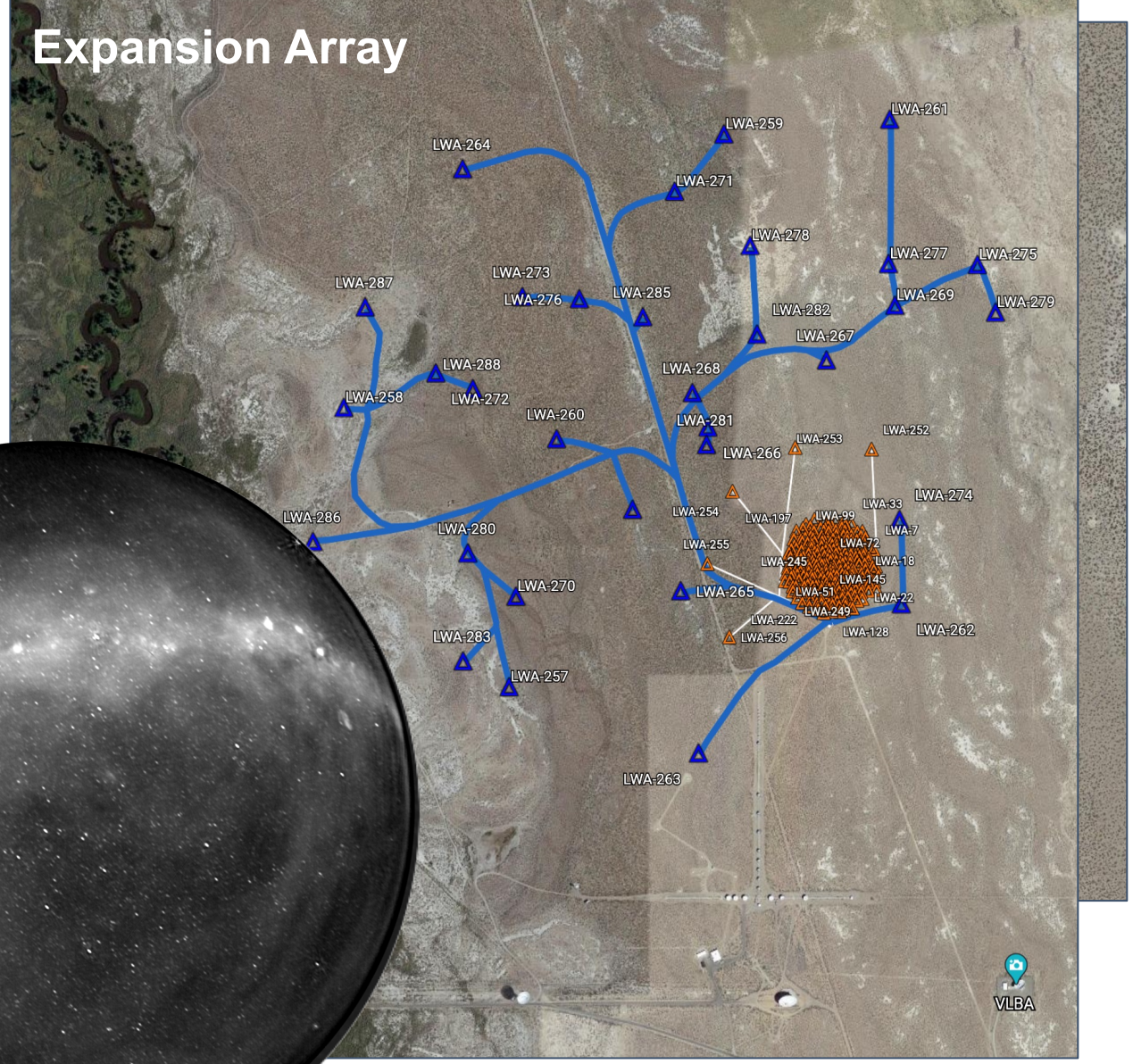
OVRO-LWA Stage II (2015–2020)

- Addition of 32 fiber-fed antennas, out to 1.5 km baselines
- Custom fiber-link board (**Sandy Weinreb**)
- ~800 mJy snapshot sensitivity
- 28-84 MHz band, 24 kHz / 7 arcmin resolution

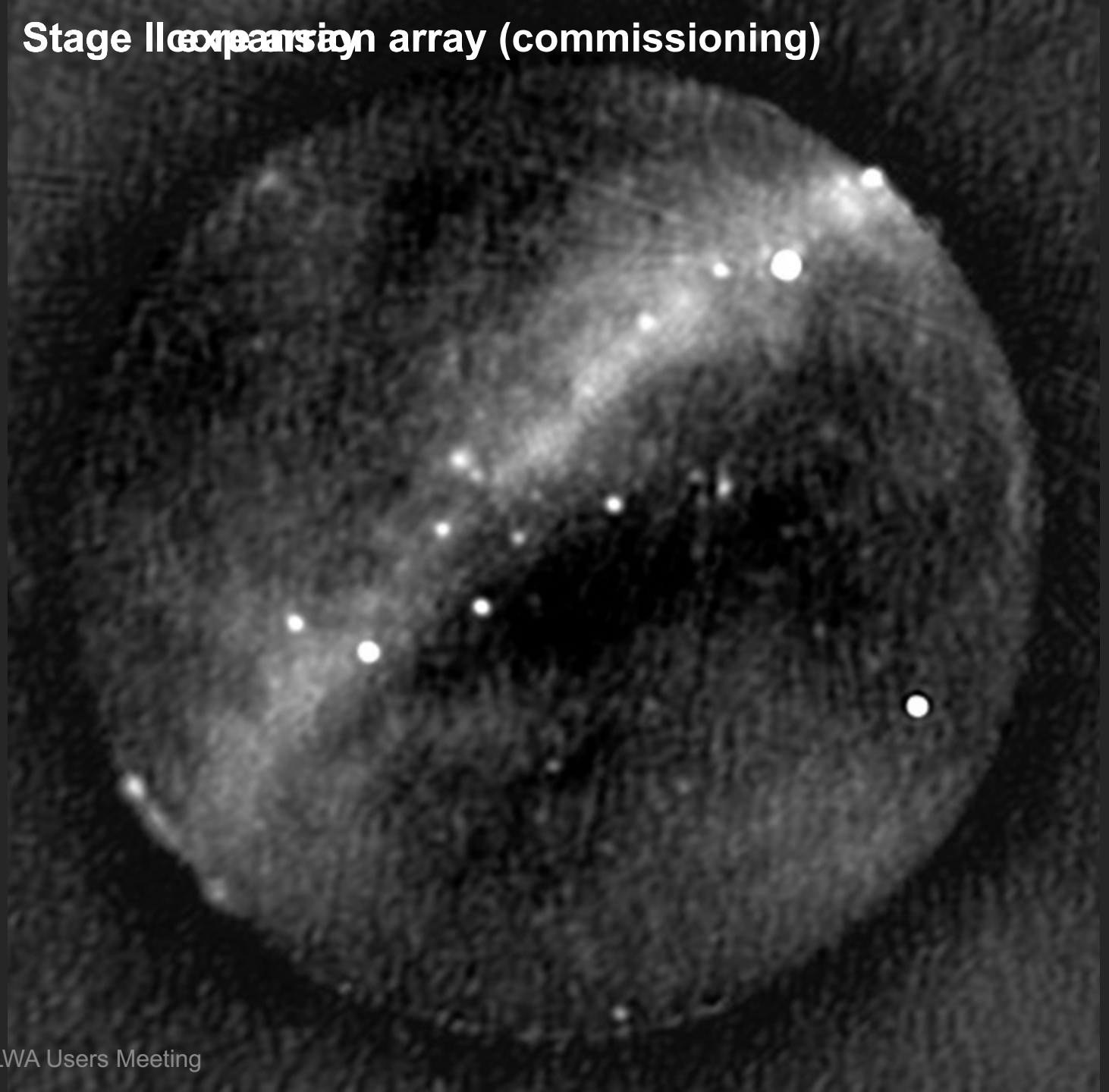




Snapshot with expansion array



Stage II expansion array (commissioning)



OVRO-LWA-352 Stage III (2021–)

- Additional 64 fiber-fed antennas, out to 2.4 km baselines
- 243 core antennas, 109 long-baseline antennas
- Configuration design (**Dave Woody**) optimized to suppress confusion (sidelobe and classical)
- **12-85** MHz band**,** 24 kHz / **5 arcmin** resolution

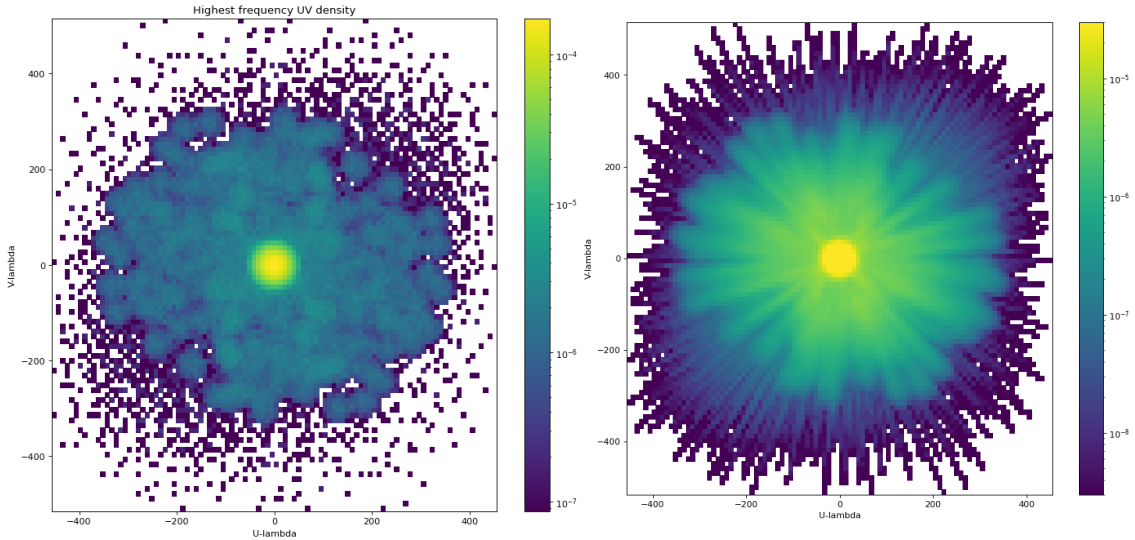


Image credit: Yuping Huang

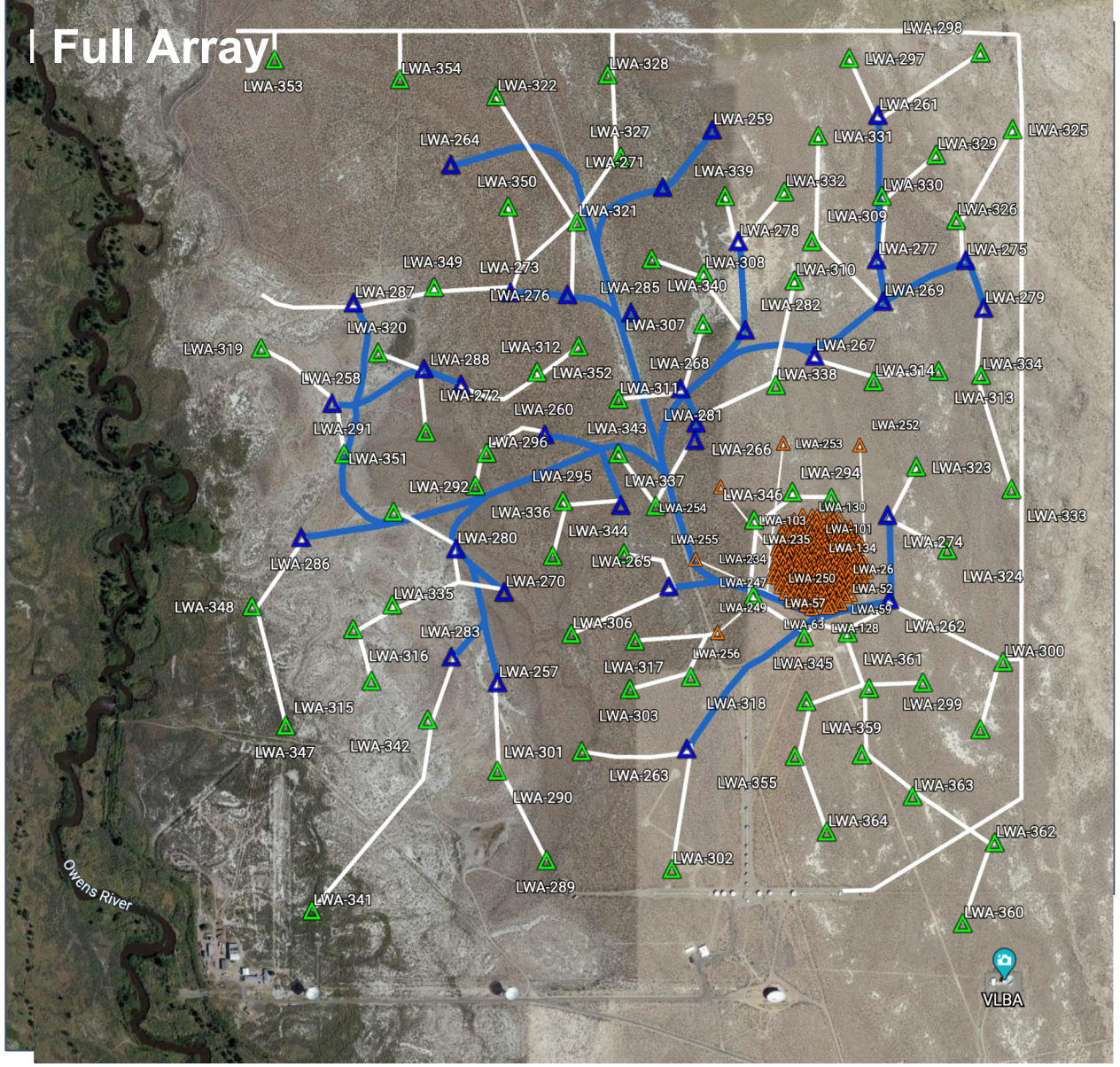


Image credit: Morgan Catha

OVRO-LWA-352 Science Goals

Cosmic Dawn **Eastwood+2018, 2019**

- m-mode analysis – high fidelity, high resolution all-sky maps (Stokes IQUV)
- Co-PI: Judd Bowman (ASU)

Transients **Anderson+2019, Huang+*in prep***

- All-sky imaging – 1000 hours, 10 s int time and >70 MHz BW

Extrasolar Space Weather **Anderson+*in prep*, McKeon+*in prep***

- All-sky imaging and deep Stokes V searches
- Co-PI: Andrea Isella (Rice)

Cosmic-ray Air Showers **Monroe+2020**

- Real-time event detection on FPGAs
- Co-PI: Andrew Romero-Wolf (JPL)

Solar Dynamic Imaging Spectroscopy **Chhabra+2021**

- Dedicated Solar beam to trigger fast (0.1 s) visibilities
- Co-PI: Dale Gary (NJIT)

LIGO/Virgo Prompt Radio Counterparts **Anderson+2018, Callister+2019**

- Raw voltage stream (5 ns) to ~10 min buffer

Planetary Aurorae and Lightning

- Dedicated Jovian beam
- Co-PI: Andrew Romero-Wolf (JPL)

OVRO-LWA-352 Science Goals

Cosmic Dawn Eastwood+2018, 2019

- m-mode analysis – high fidelity, high resolution all-sky maps (Stokes IQUV)
- Co-PI: Judd Bowman (ASU)

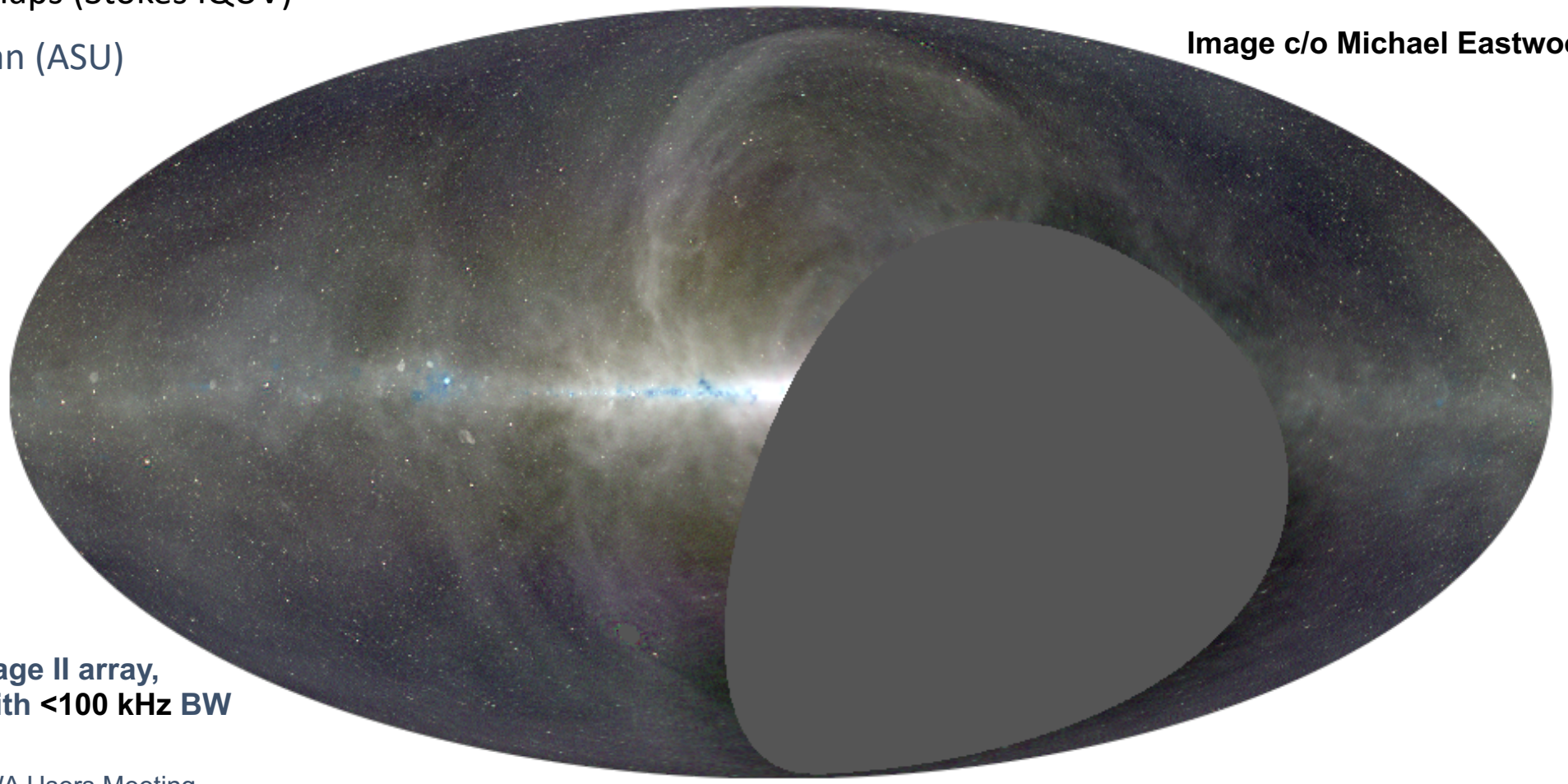


Image c/o Michael Eastwood

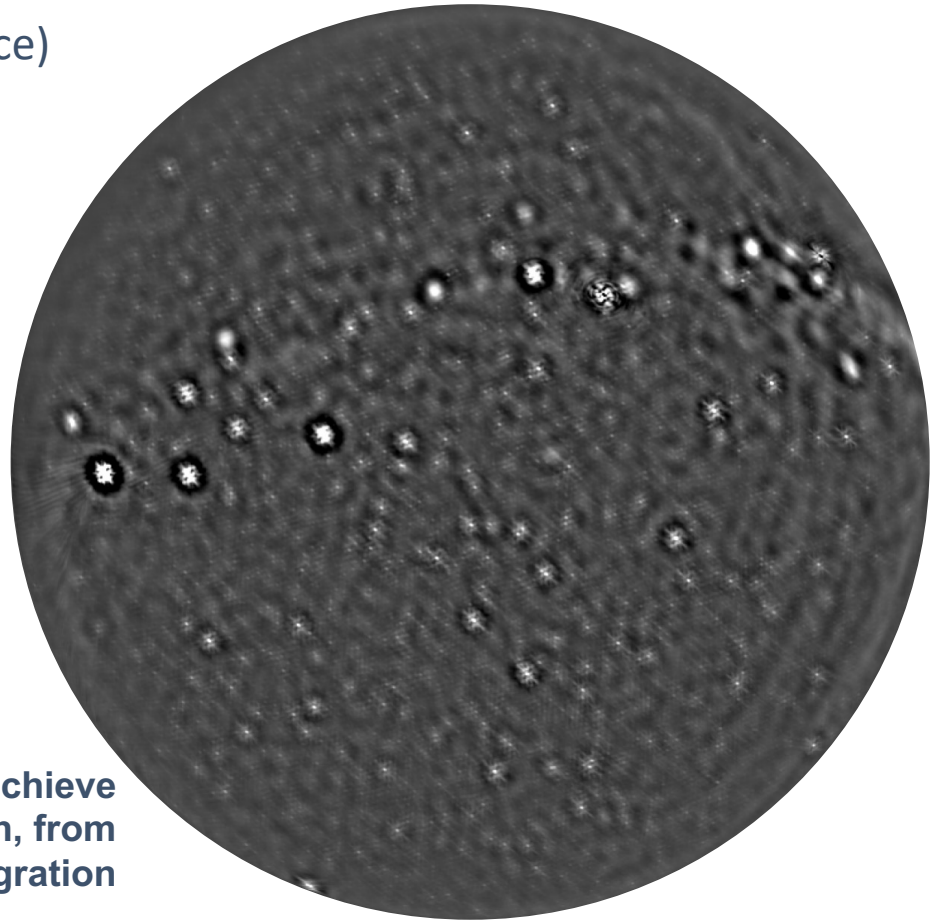
m-mode map from Stage II array, 28 hour integration with <100 kHz BW

OVRO-LWA-352 Science Goals

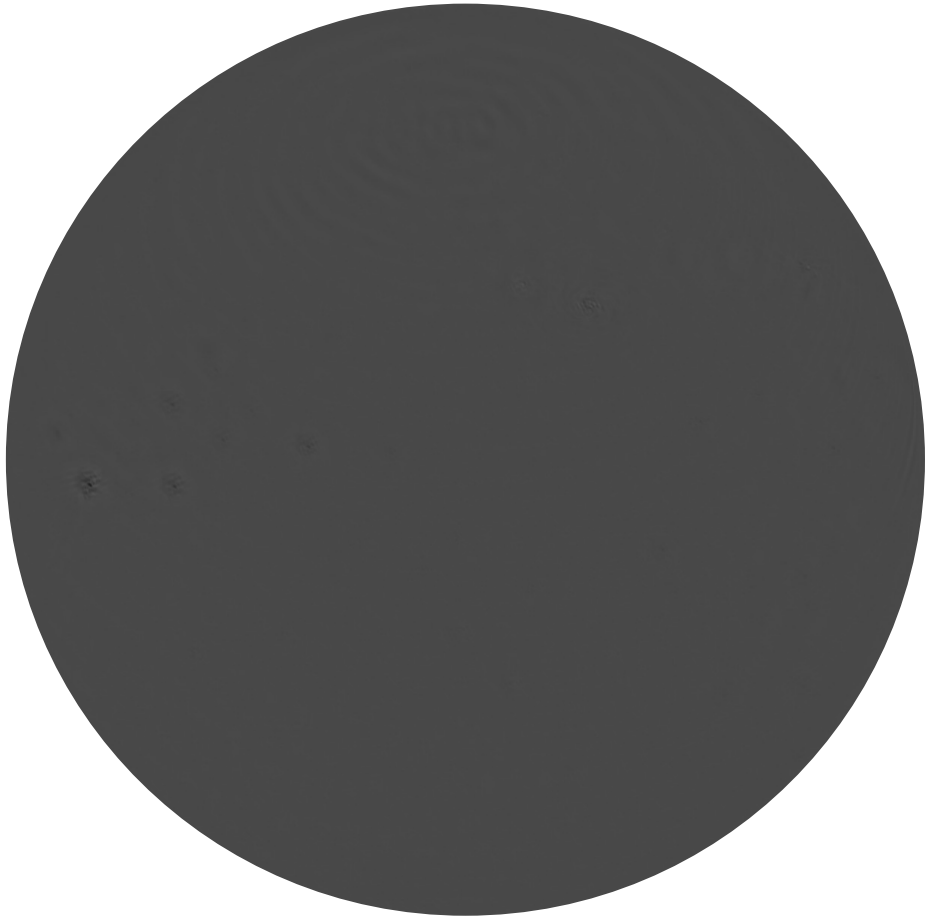
Extrasolar Space Weather

Anderson+*in prep*, McKeon+*in prep*

- All-sky imaging and deep Stokes V searches
- Co-PI: Andrea Isella (Rice)



Stokes I



Stokes V

Stokes V Stage II images achieve ~30 mJy noise at zenith, from 33–48 MHz with few hour integration

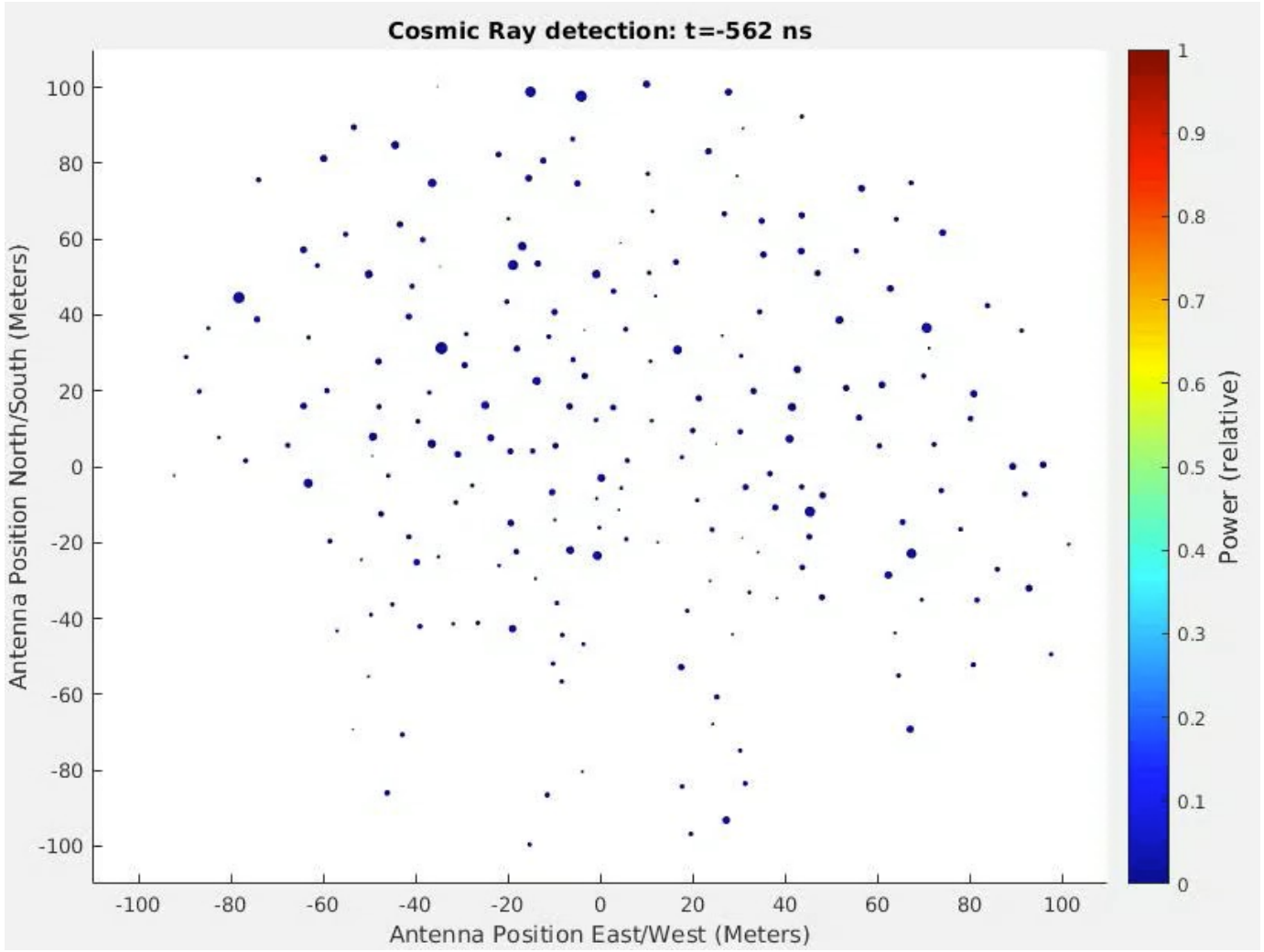
OVRO-LWA-352 Science Goals

Cosmic-ray Air Showers Monroe+2020

- Real-time event detection on FPGAs
- Co-PI: Andrew Romero-Wolf (JPL)

- Will run commensally with other observing modes.
- Larger OVRO-LWA-352 array footprint means sensitive to higher E cosmic-rays.
- CR sub-system and analysis being developed by Kathryn Plant.

Movie c/o Ryan Monroe

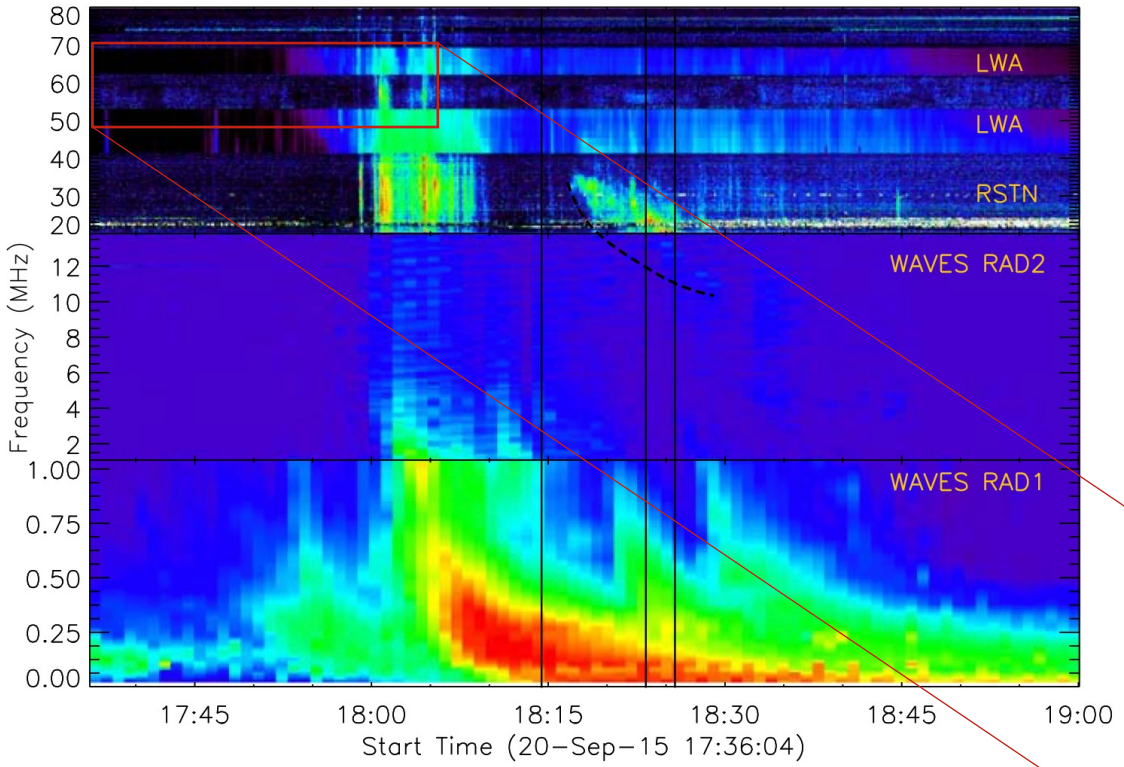


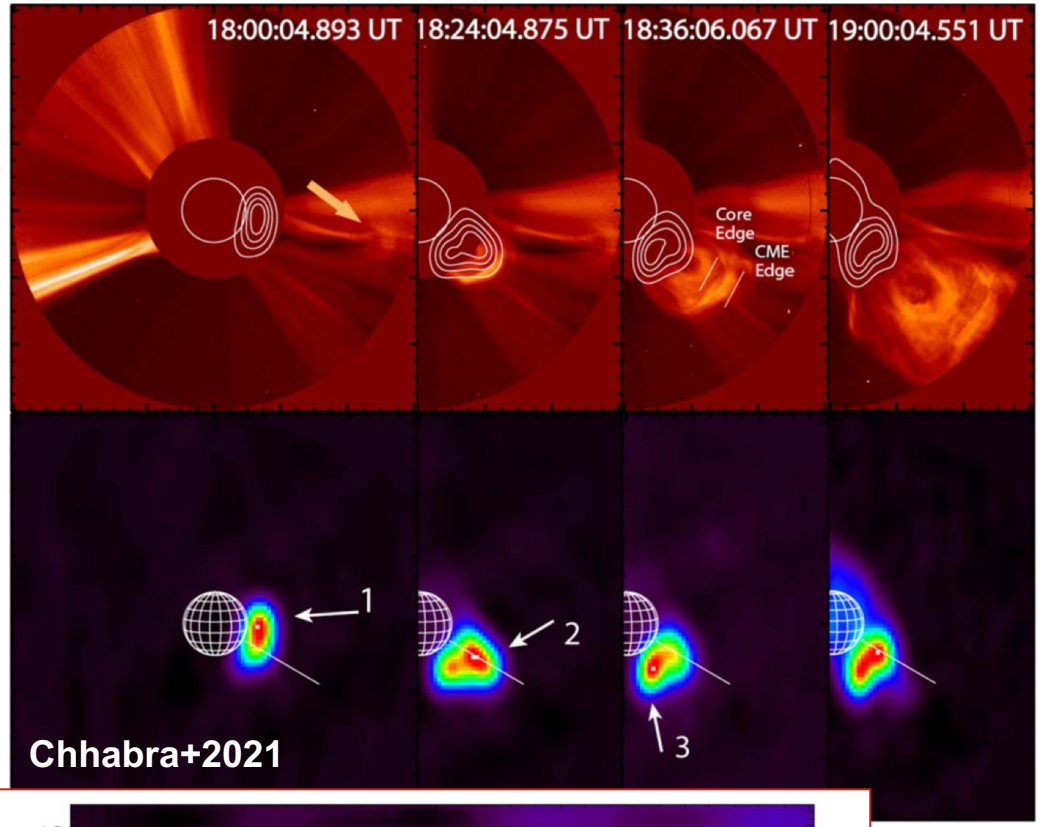
Cosmic-ray detection with Stage II array, showing air shower moving across array core.

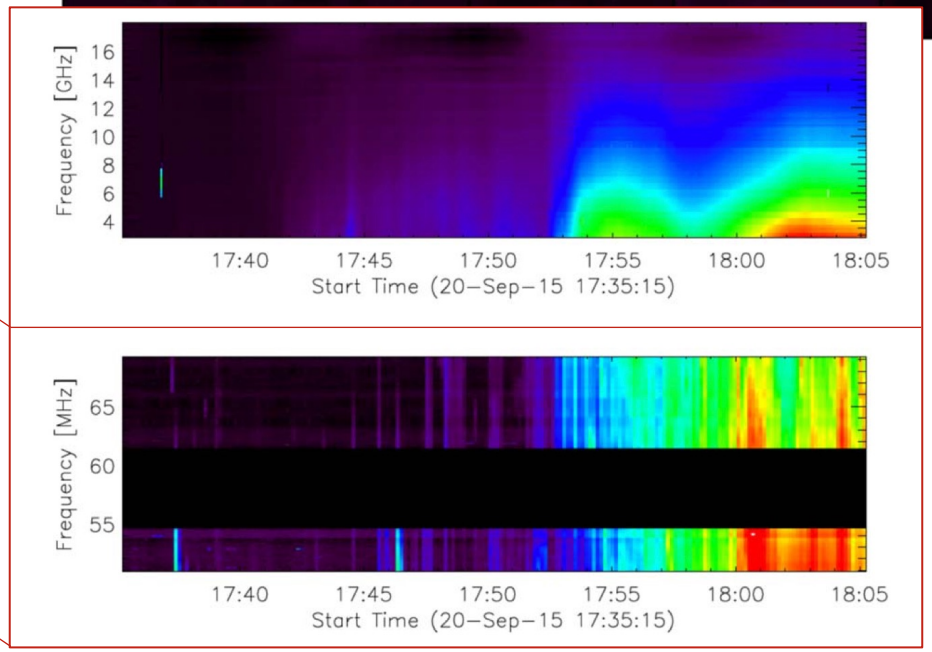
OVRO-LWA-352 Science Goals

Solar Dynamic Imaging Spectroscopy Chhabra+2021

- Dedicated Solar beam to trigger fast (0.1 s) visibilities
- Co-PI: Dale Gary (NJIT)







All-singing, All-dancing Digital Back-end™

Correlator

"slow" visibilities – 704-input full cross-correlation (10 s)

Cosmic Dawn Transients Extrasolar Space Weather

"fast" visibilities – 96-input full cross-correlation (0.1 s)

Solar Dynamic Imaging Spectroscopy

Beamformer

power beam – 12 independently steerable beams (1 ms)

Solar beam Planetary Aurorae and Lightning Pulsar monitoring

voltage beam – 2 voltage beams

VLBI

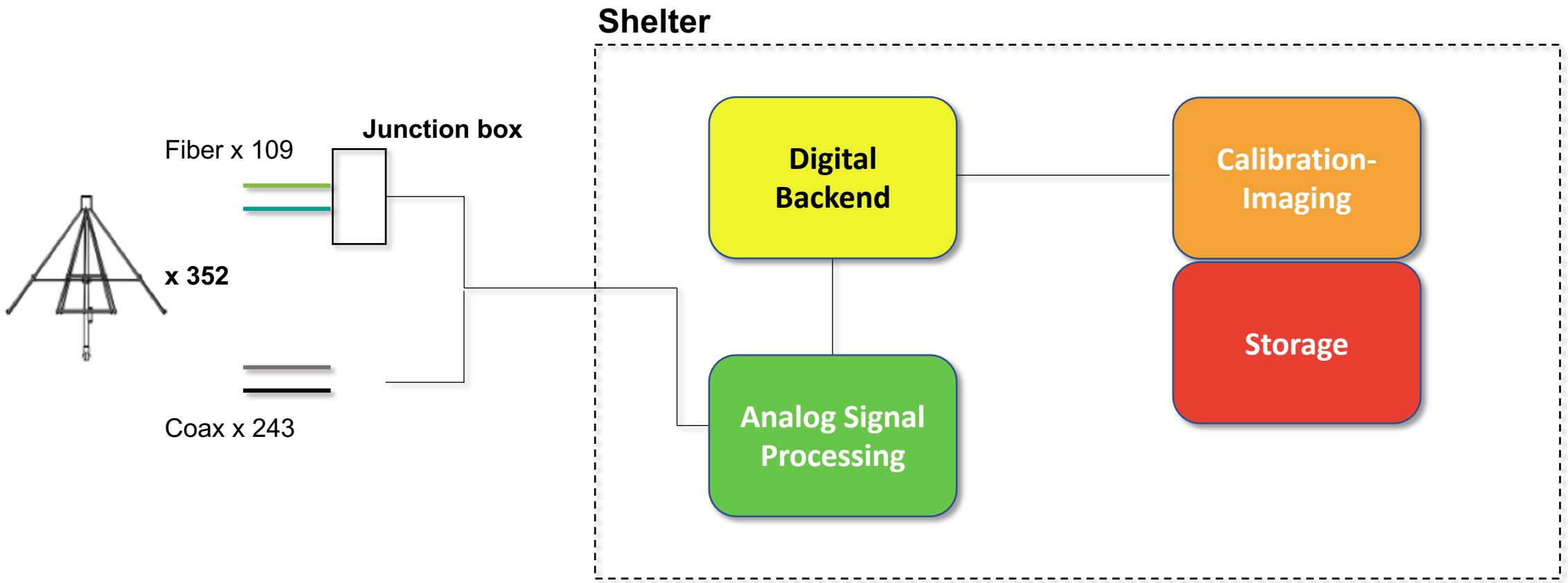
Voltage buffer

LIGO/Virgo Prompt Radio Counterparts

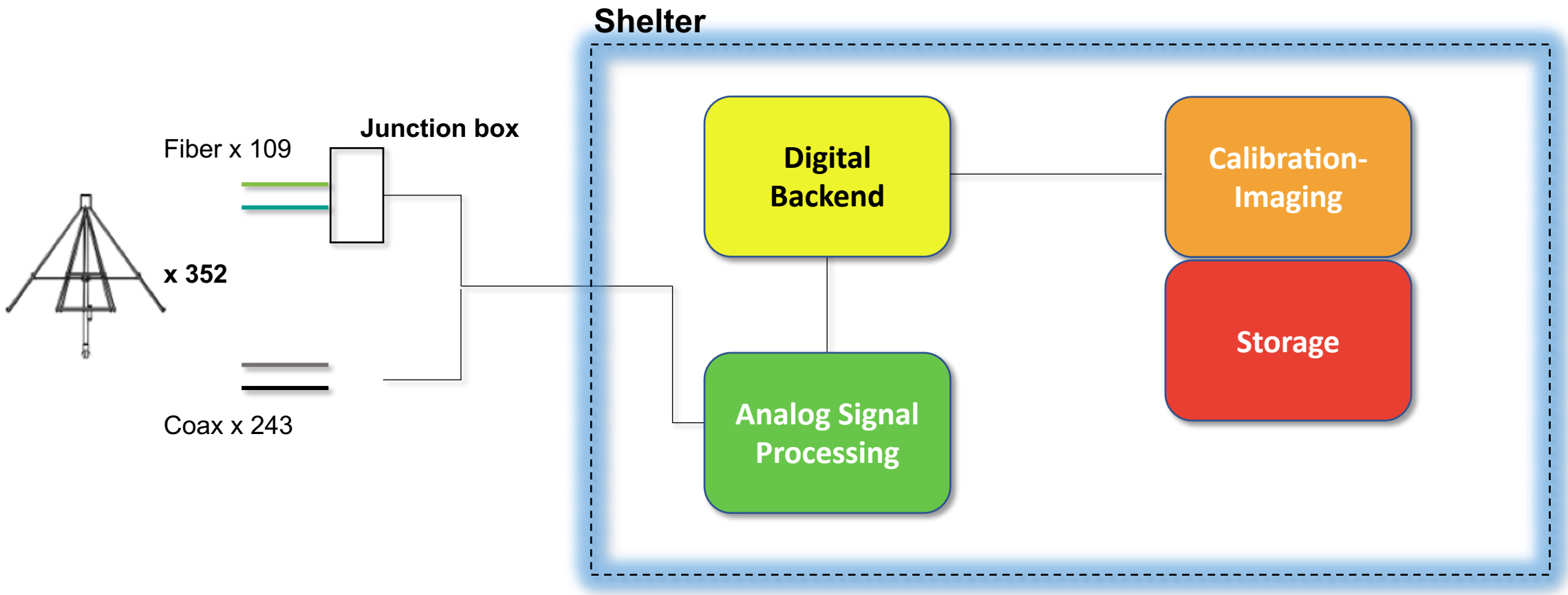
Cosmic-ray detection

Simultaneous!

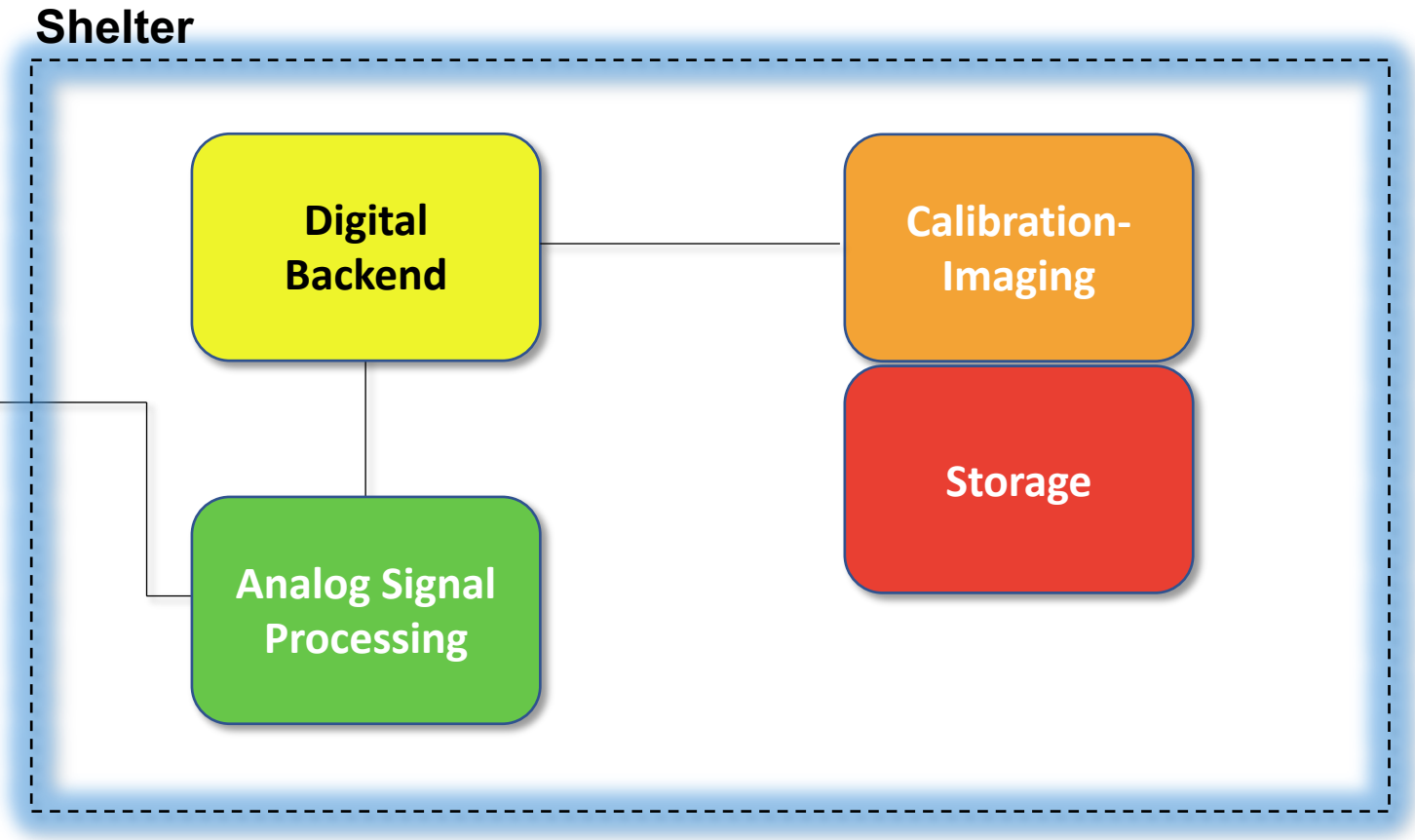
Signal path and sub-system overview



Signal path and sub-system overview

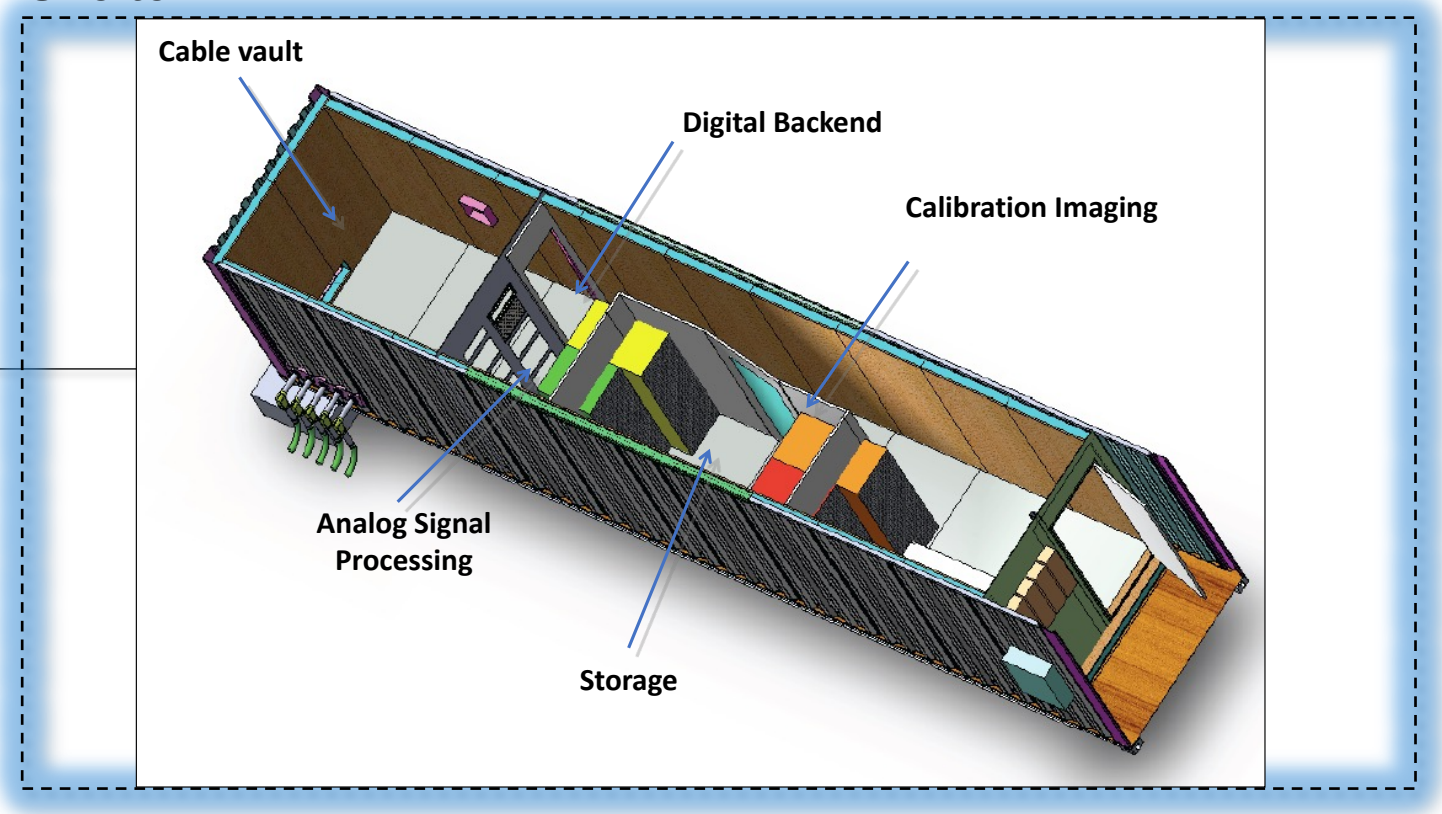


Signal path and sub-system overview



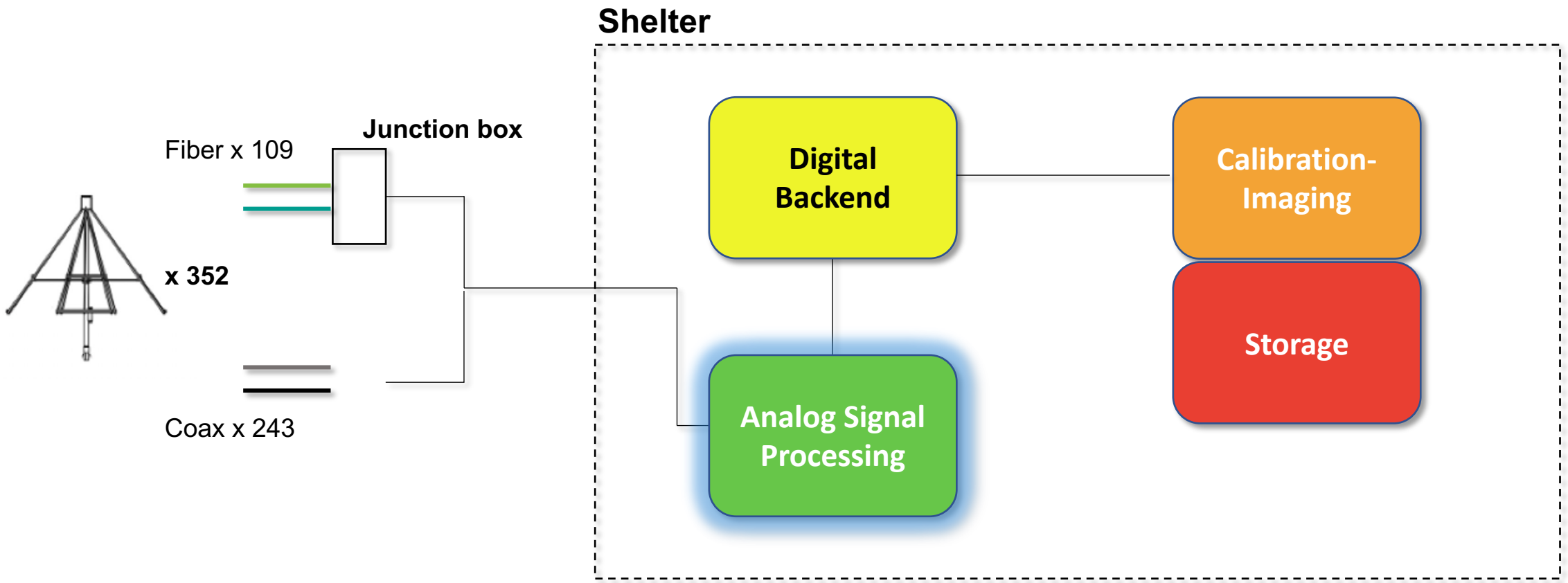
Signal path and sub-system overview

Shelter

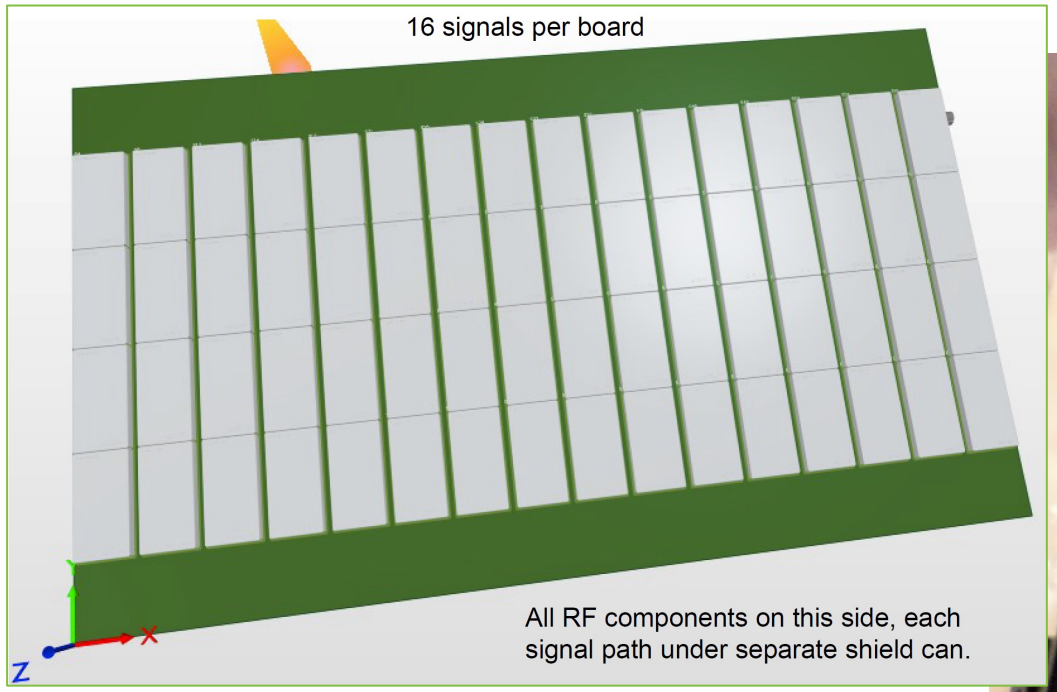


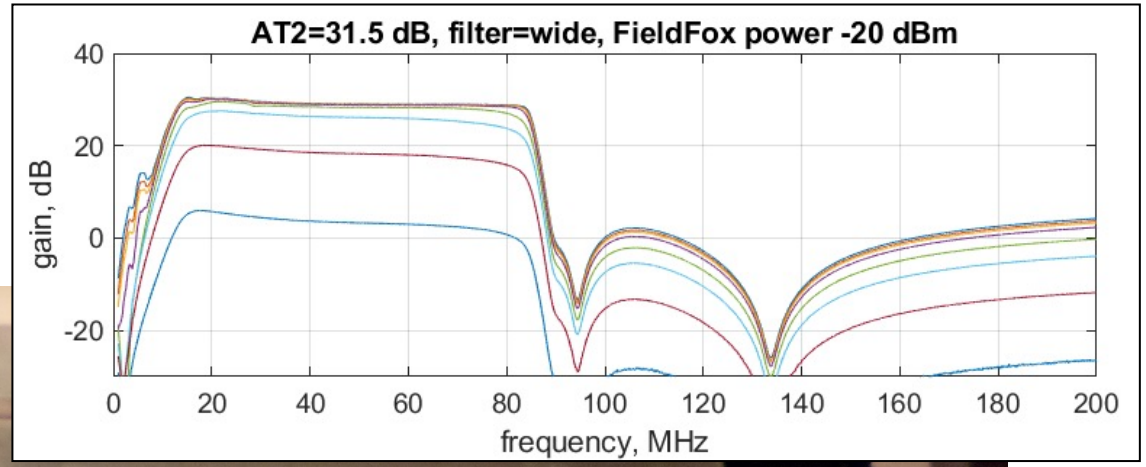
Images c/o Gregg Hallinan

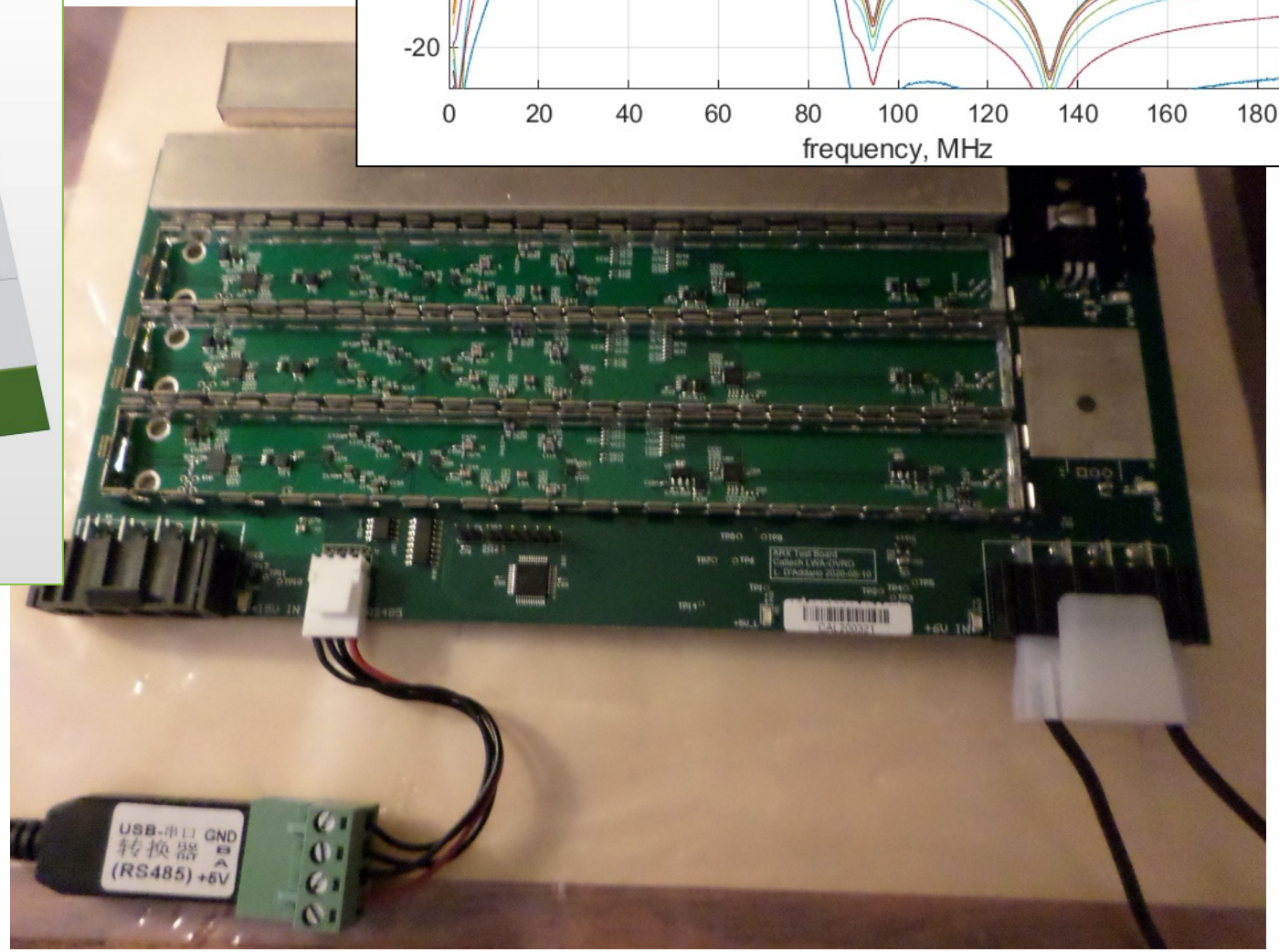
Signal path and sub-system overview



Signal path and sub-system overview

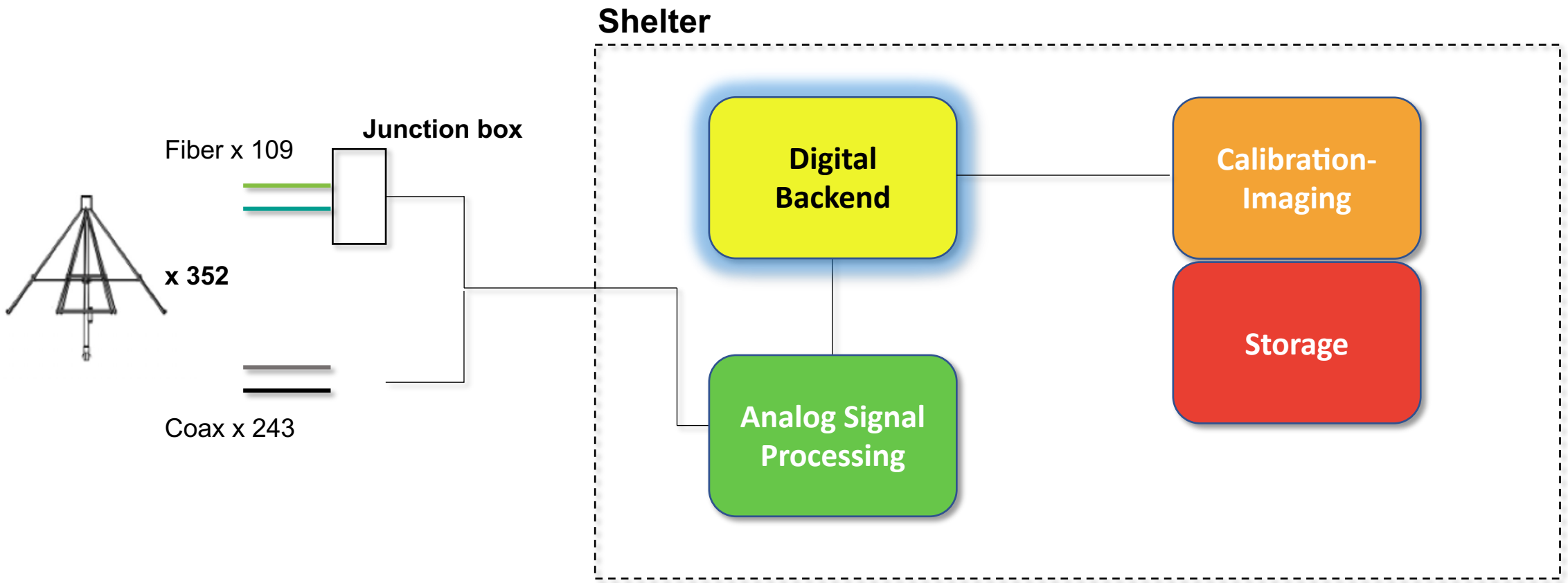






Images c/o Larry D'Addario

Signal path and sub-system overview



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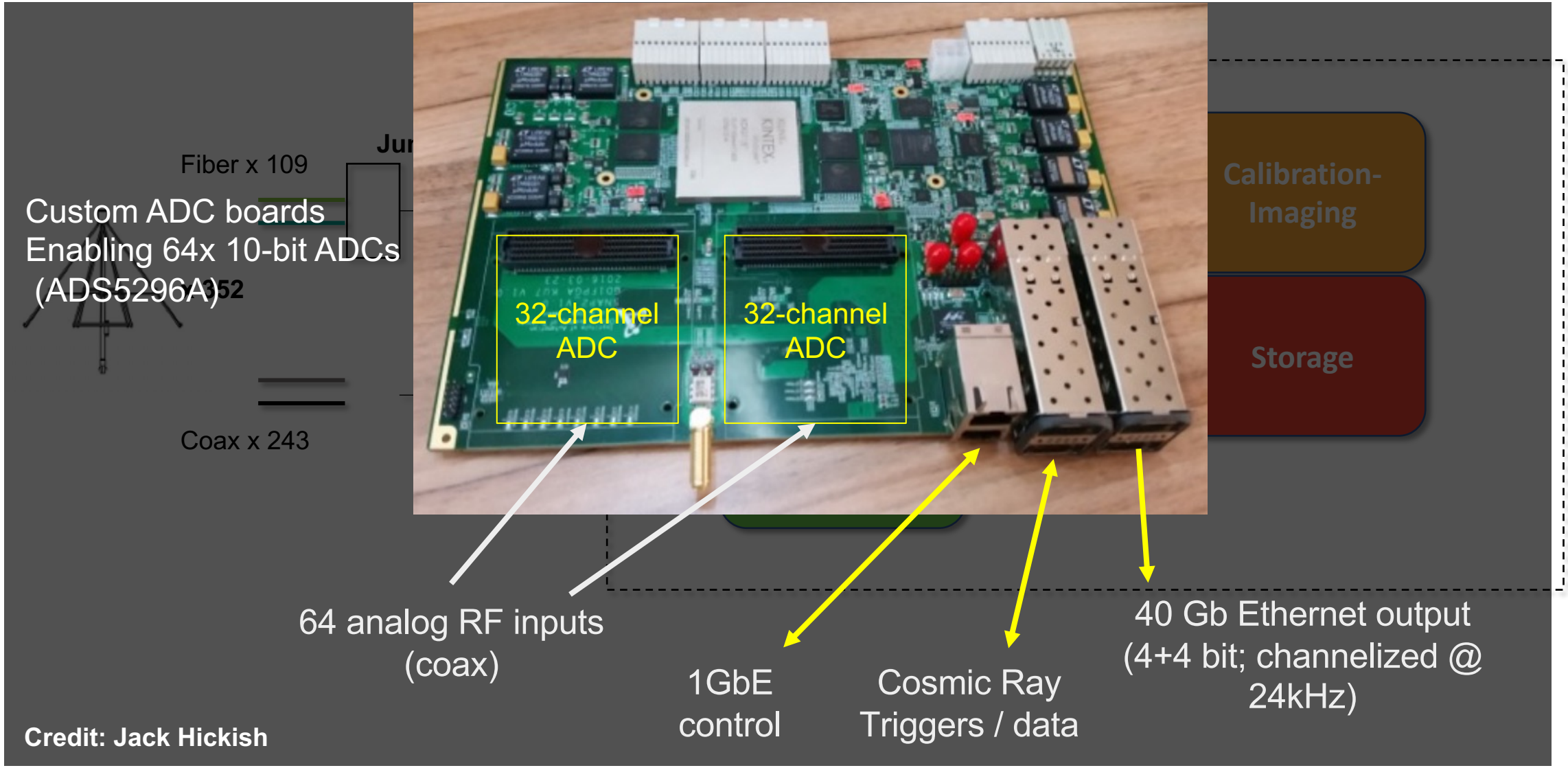
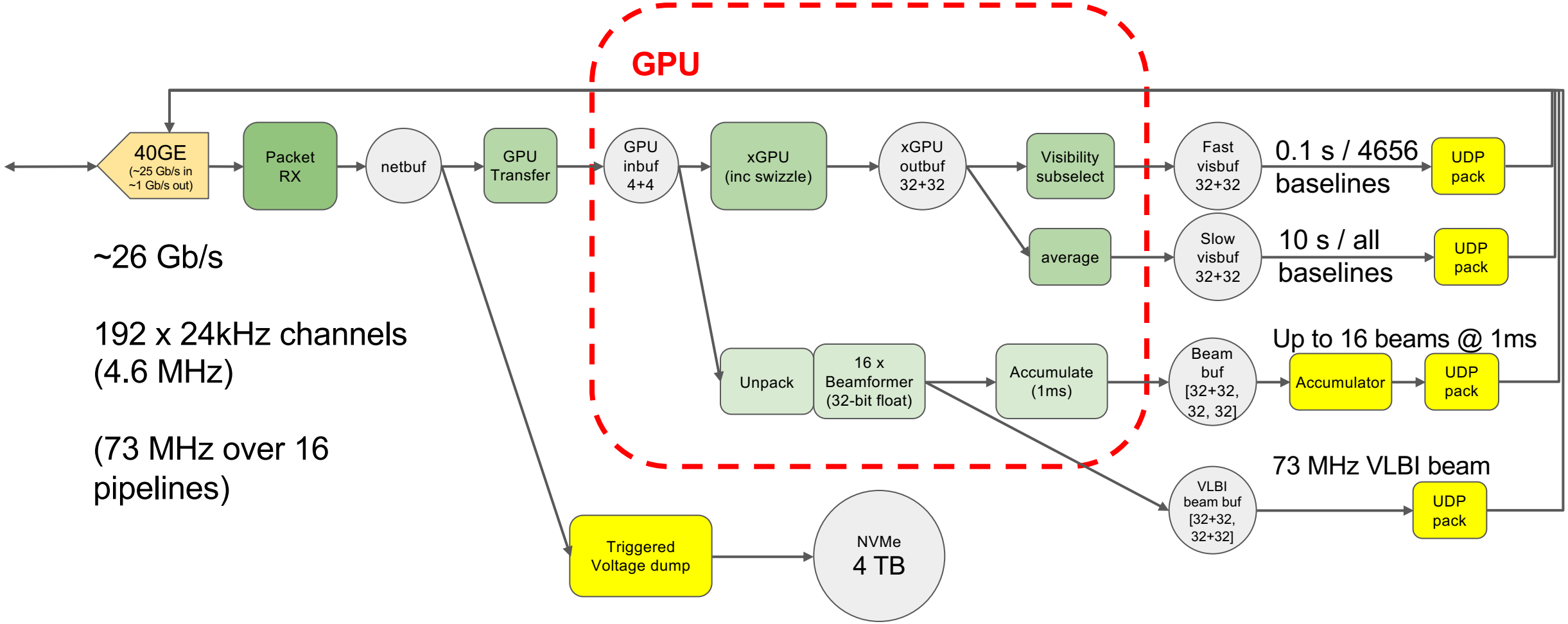


Silicon Mechanics Rackform R353.v7
GPU: 2 x PNY NVIDIA GeForce RTX 2080 Ti Blower Edition



~26 Gb/s

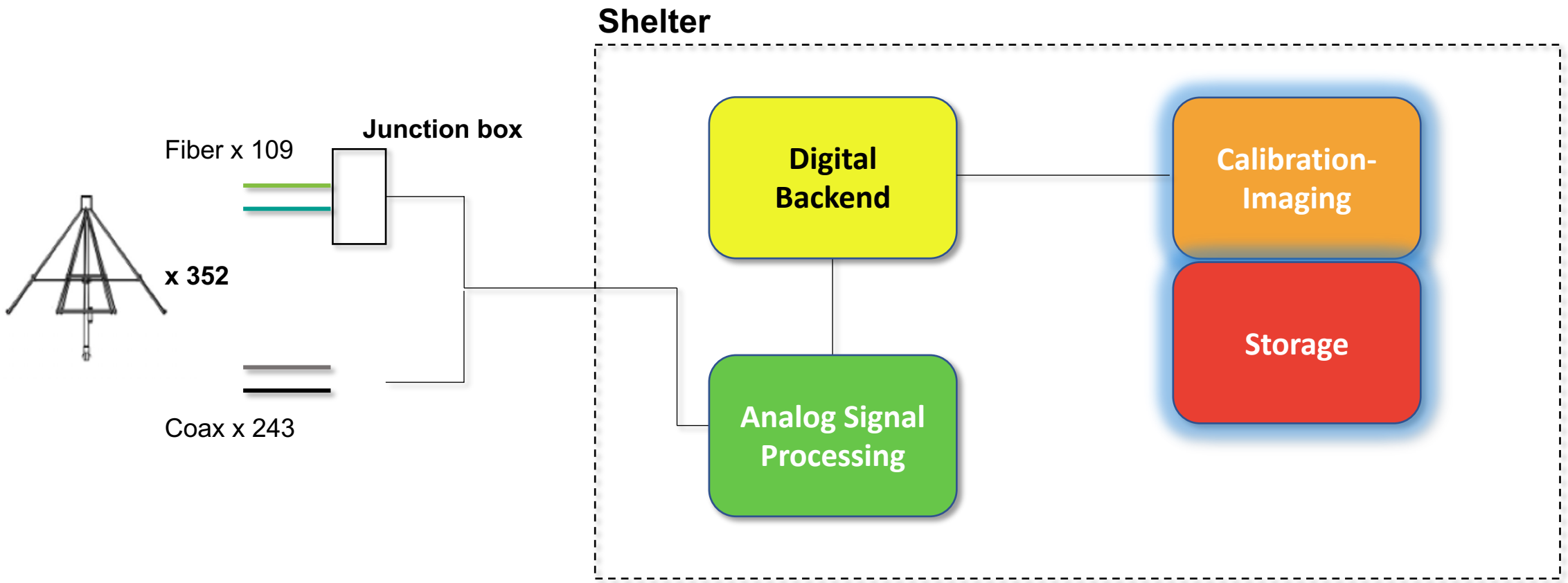
192 x 24kHz channels
(4.6 MHz)

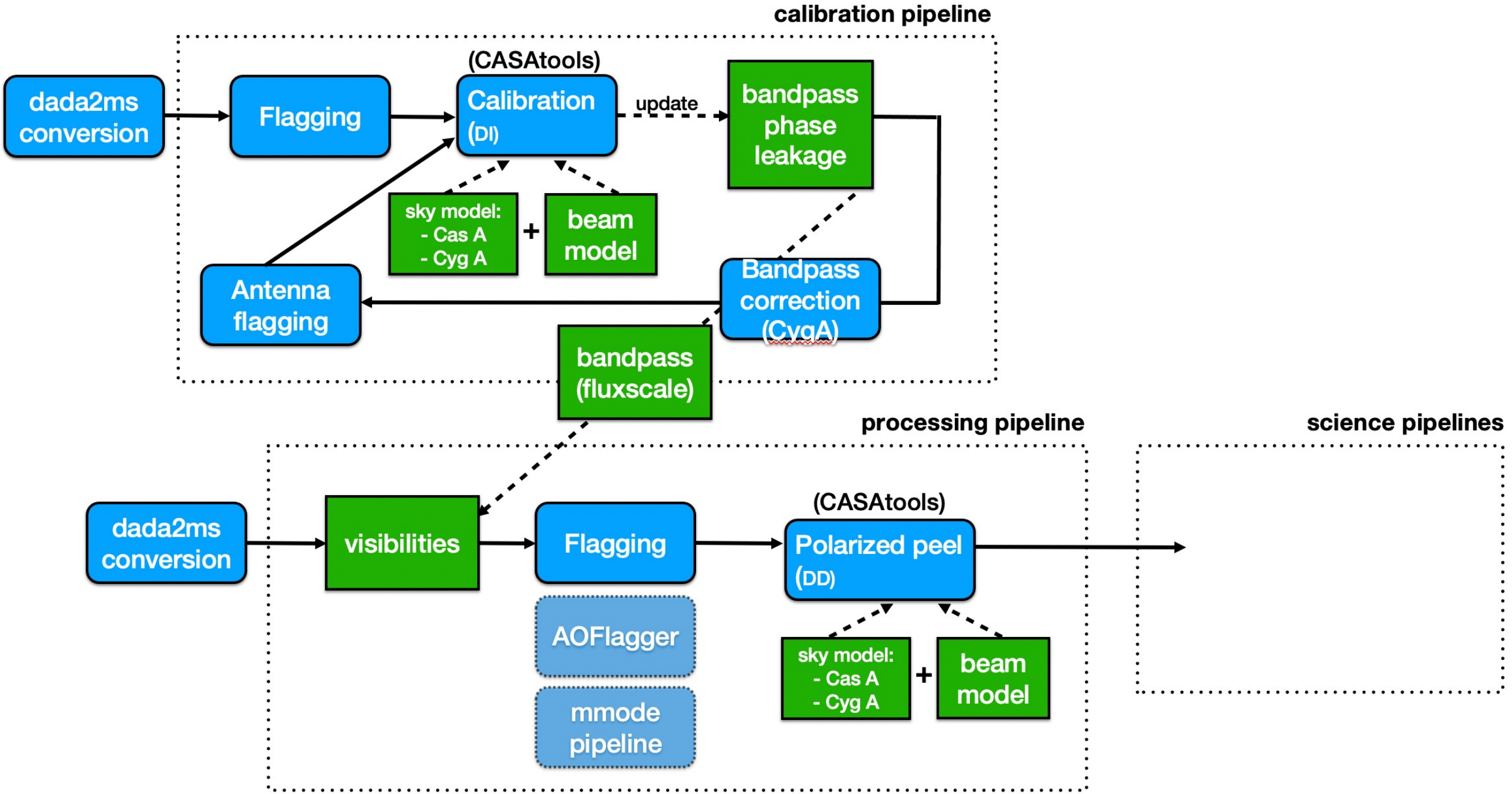
(73 MHz over 16
pipelines)

>2 minute pre-trig buffer (6 TB RAM)
~20 minute post-trig buffer (60 TB NVMe SSD)

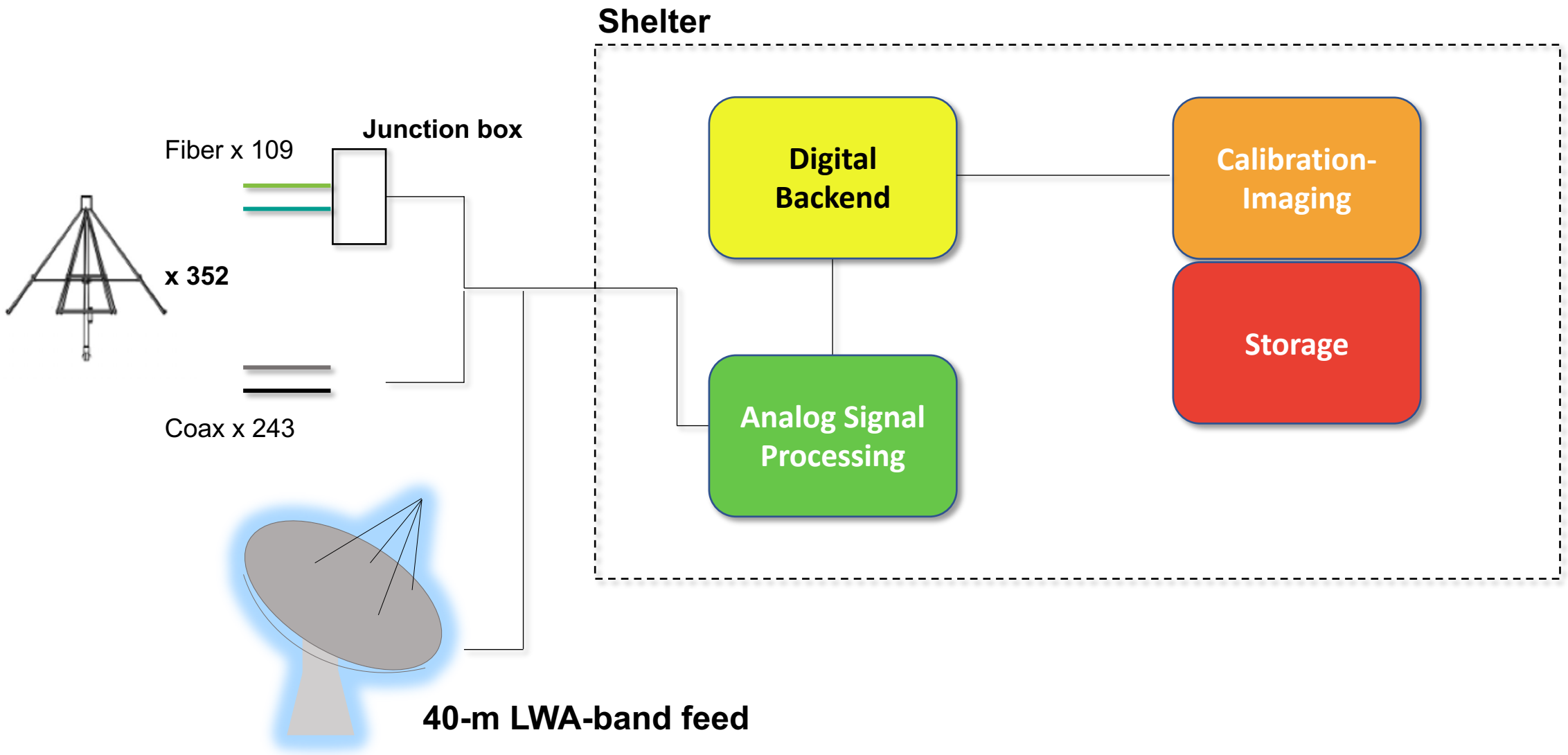
Credit: Jack Hickish

Signal path and sub-system overview



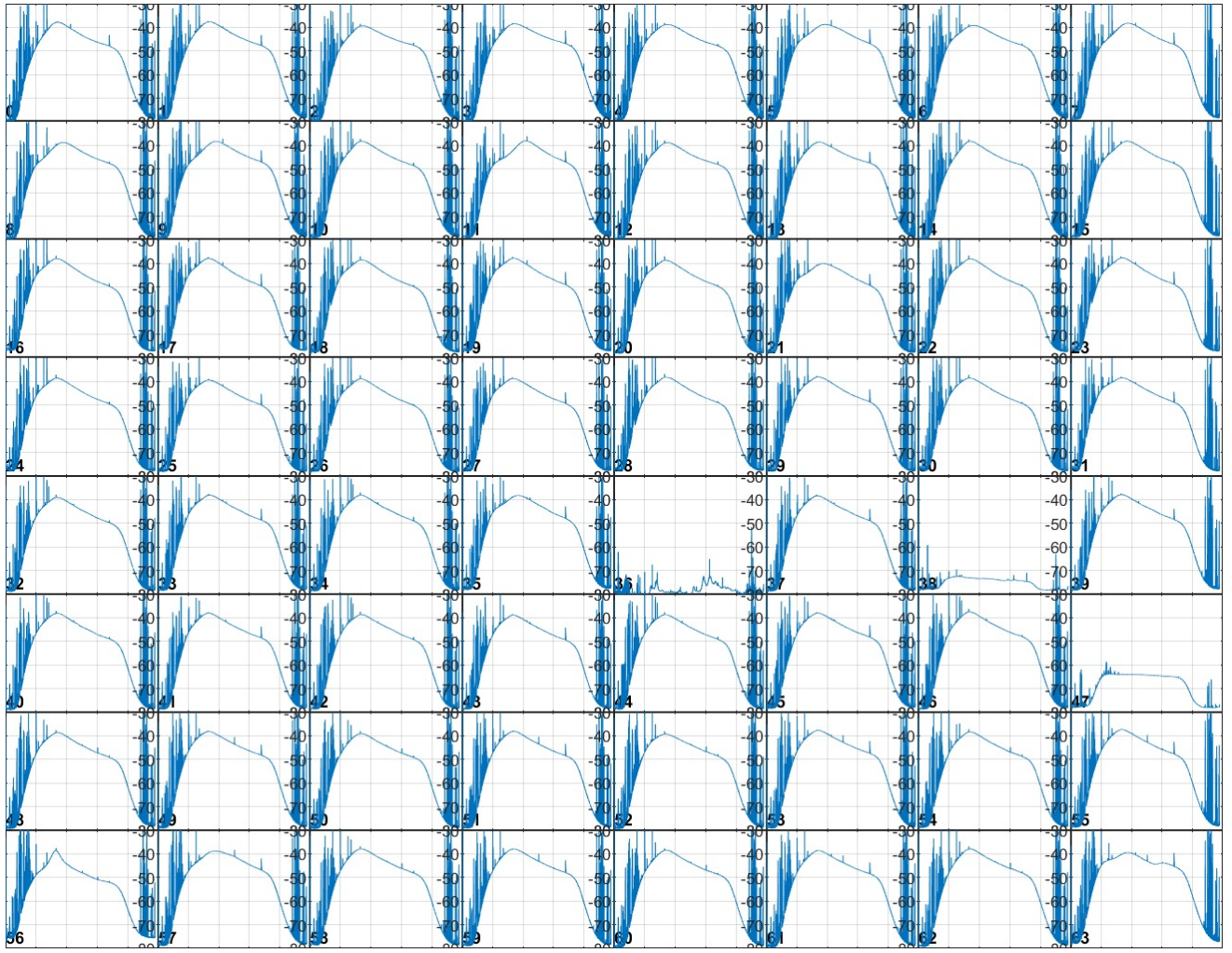

calibration pipeline
(CASAtools)
dada2ms conversion
Flagging
Calibration (DI)
update
bandpass phase leakage
sky model: - Cas A - Cyg A
+
beam model
Antenna flagging
Bandpass correction (CygA)
bandpass (fluxscale)
processing pipeline
science pipelines
dada2ms conversion
visibilities
Flagging
(CASAtools)
Polarized peel (DD)
AOFlagger
mmode pipeline
sky model: - Cas A - Cyg A
+
beam model

Signal path and sub-system overview



Commissioning Status

- Currently in end-to-end testing phase
- 64 signal paths →
  4 fully populated ARX boards,
  1 fully populated SNAP2 board,
  32 existing core (coax) antennas
- Transition to full system roll-out to begin in ~1 month
- Science commissioning to commence in early 2022



Credit: Larry D'Addario

Summary

- 2.5 year upgrade to the final stage of the OVRO-LWA-352 currently underway
- Addition of 64 antennas, out to maximum of 2.4 km baselines
- New analog receiver boards
- New 704-input digital backend (fast and slow visibilities), 12x beam-former, real-time cosmic-ray detection, voltage buffer
- Large compute cluster, 5PB storage, and near real-time pipeline development
- 40m dish w/ LWA-band feed for dipole holography