Results from the LOFAR2.0 Dwingeloo Test Station

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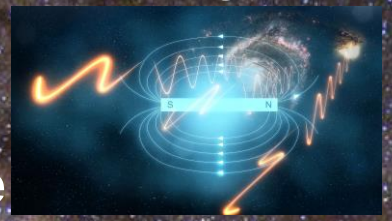
NWO

LOFAR

Cosmic magnetism



Supermassive black holes

Early Universe

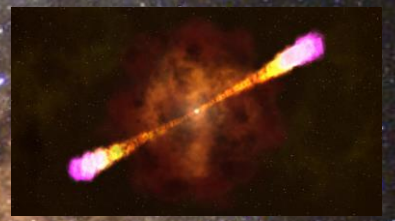
Supernovae

Pulsars

Galaxy clusters

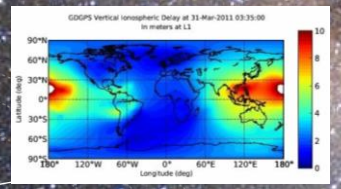
Space weather

Gravitational wave events



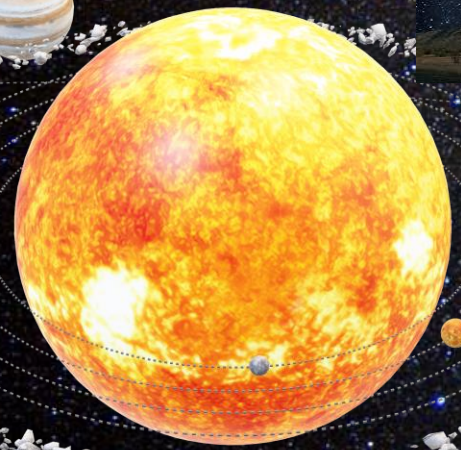
Meteors

Ionosphere



Nearby galaxies

Sun



Lightning

Cosmic rays

Interstellar medium

Fast radio bursts

Solar System Planets

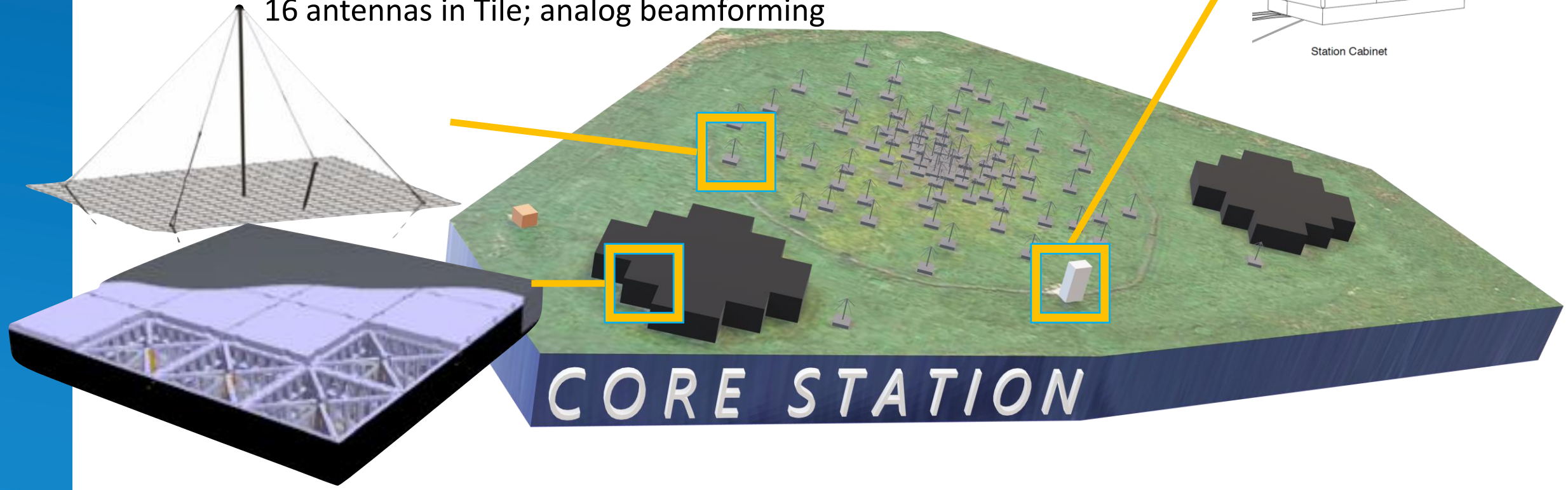
Credit: Jason Hessels

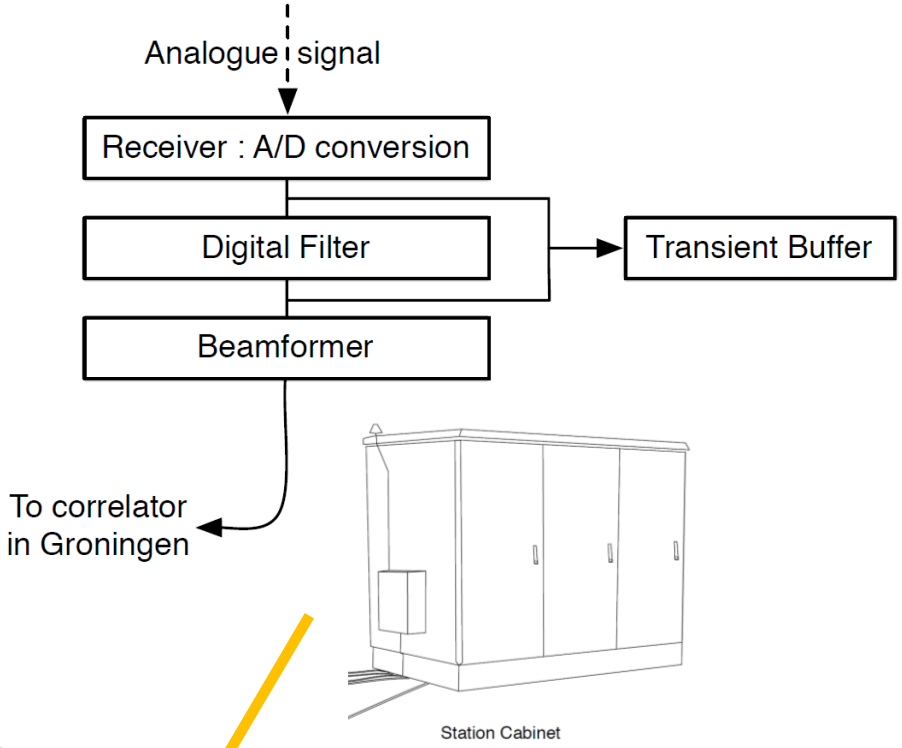
The LOFAR Telescope in numbers

- 52 Stations
  - 4.992 Low Band Antennas
  - 50.688 High Band Antennas
    - 3.168 HBA Tiles
- Input data rate
  - LOFAR1: 14 Tbps
  - LOFAR2: 45 Tbps
- Central Processor
  - Correlator, beamformer, ..
  - Datawriter
- Long Term Archive

Antenna types in the Station

- Frequency coverage
  - 10 – 90 MHz: Low Band Antenna
  - 110 – 240 MHz: High Band Tile
    - 16 antennas in Tile; analog beamforming

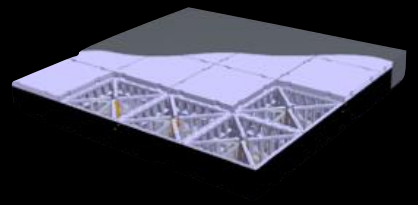




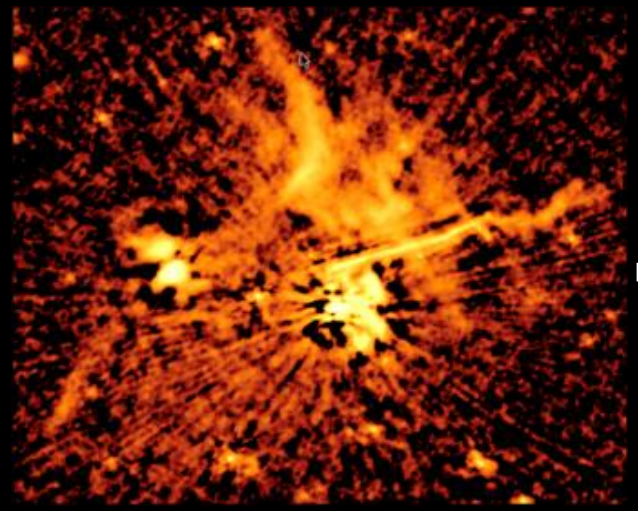
The LOFAR2.0 upgrade, the challenge

credit: Jason Hessels

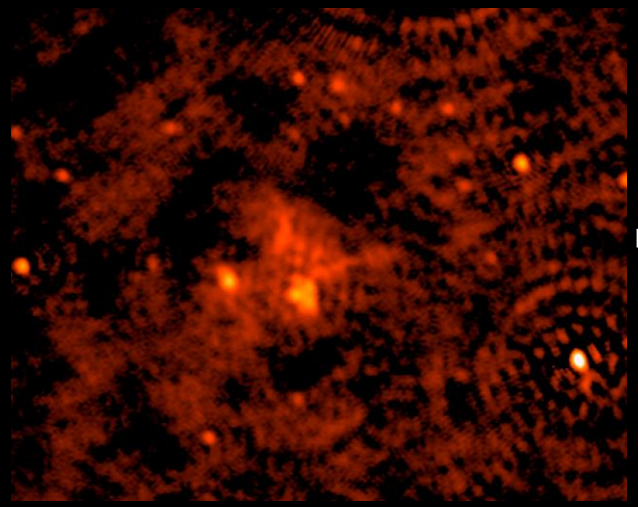
High-Band



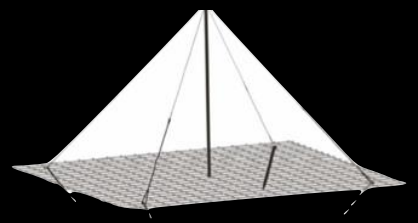
Scientifically limited



No ionospheric correction



Low-Band



2x

Breakthrough techniques

Transfer Information

LOFAR2.0

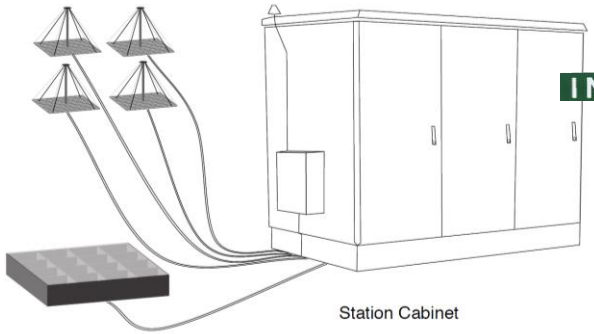
Precision clock

Rich in science

Ionosphere well modeled

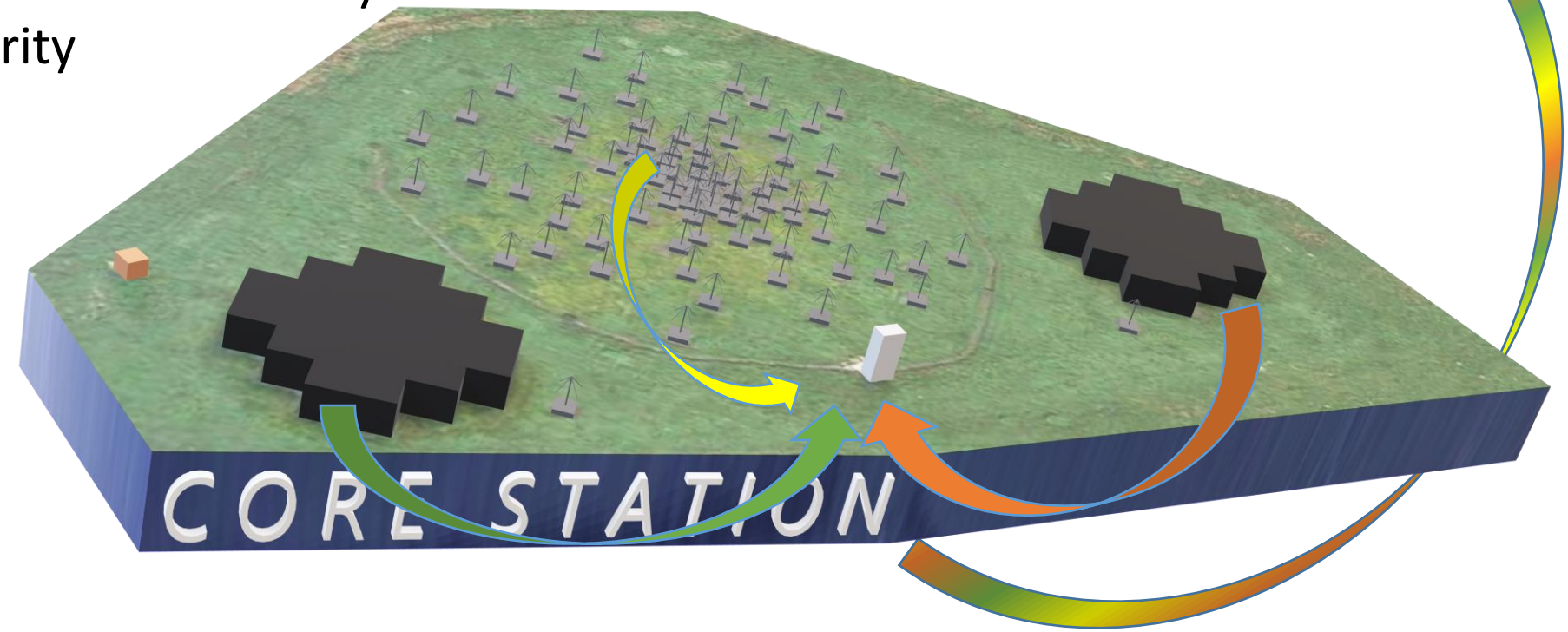
The Goal

LOFAR2.0 Station Upgrade

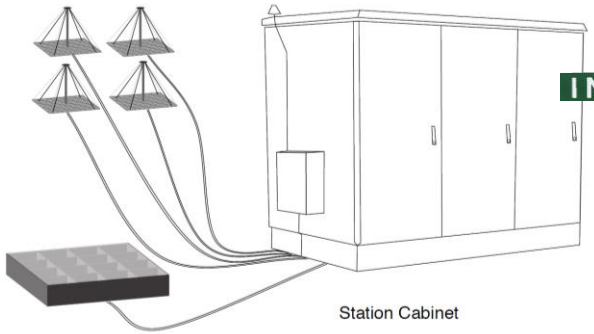


- Limitation: One out of three antennas active
- LOFAR2.0 will improve this
  - simultaneous Low + High Band observing
  - increased Low Band sensitivity
  - Improve linearity
- Challenge:
  - More power consumption
  - Keep station available on hot days

Central Processor



LOFAR2.0 Station Upgrade



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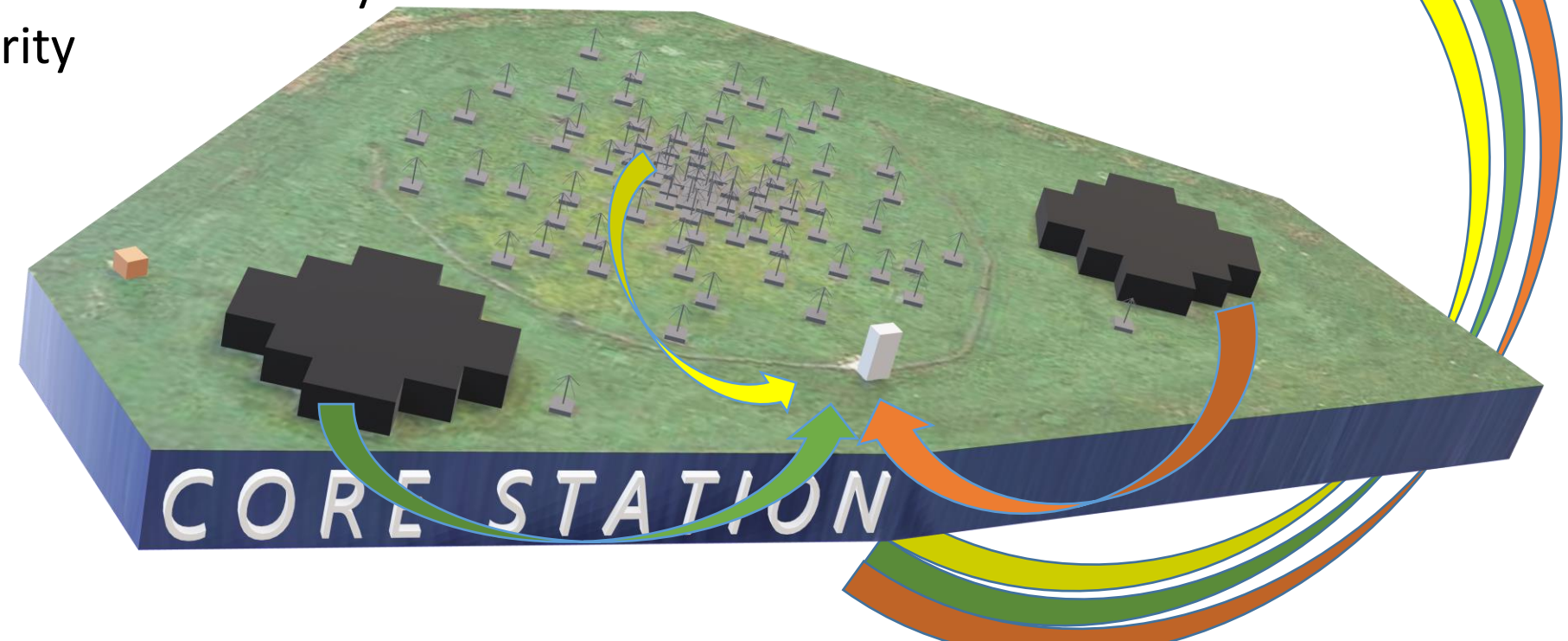
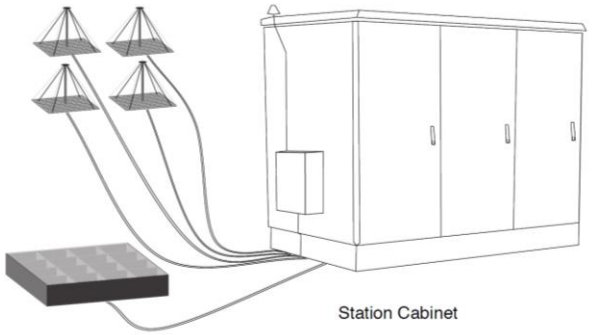
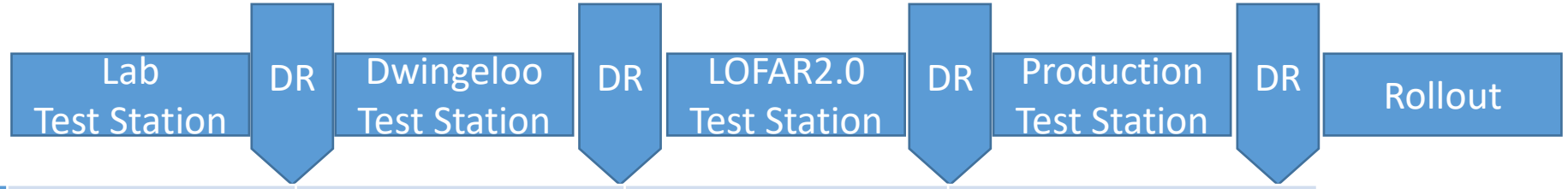


LOFAR2.0 Verification and Validation



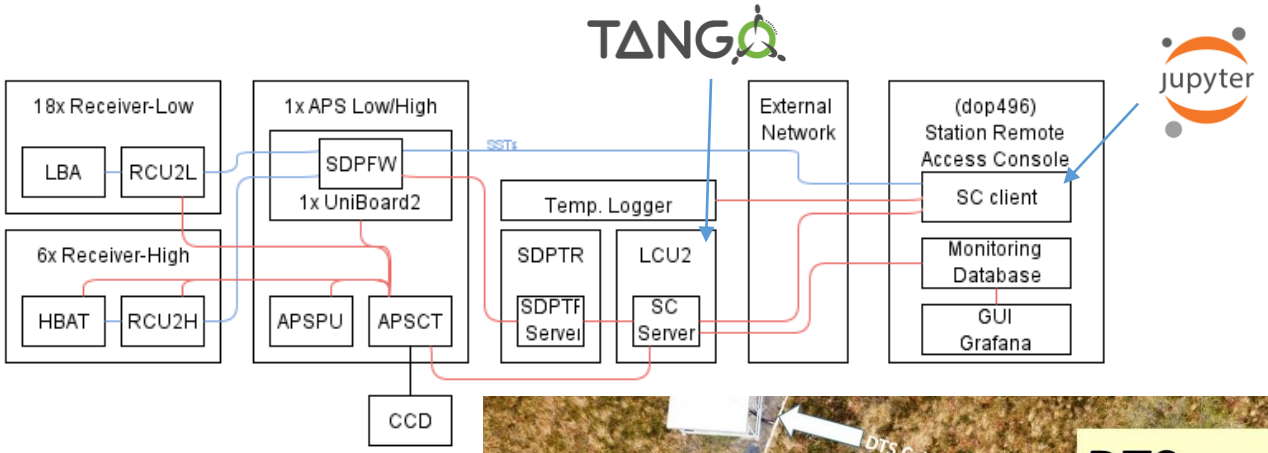
- Test phases

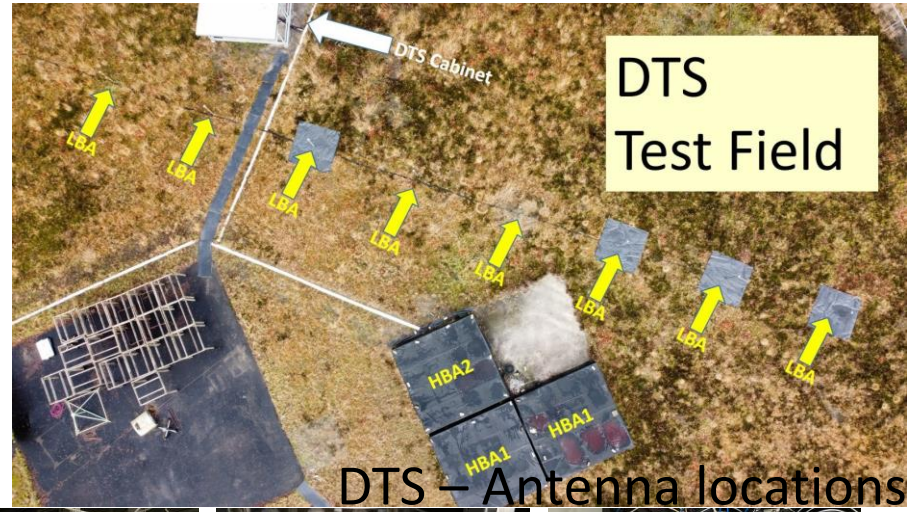


Location	Lab	Test field	Operational site	Operational site
Level of verification & validation	Receiver chain	Few receiver chains and full station infrastructure	Full integrated station; Station in array	Production test; >1 stations in array
N. active antennas	1 LBA 1 HBA Tile	9 LBAs 3 HBA Tiles	1 core station: 96 LBAs 2 x 24 HBA Tiles	2 stations

Dwingeloo Test Station (DTS)

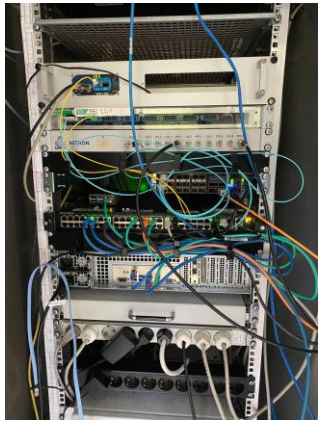
- Close to the office
  - Quick debugging
- Integration of 9 receivers



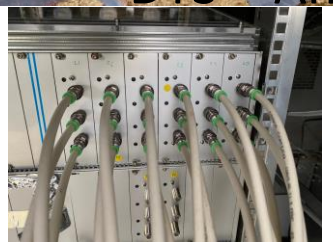
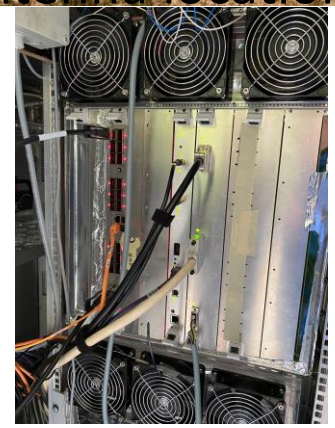


DTS – Antenna locations


DTS - Cabinet


Rack 3

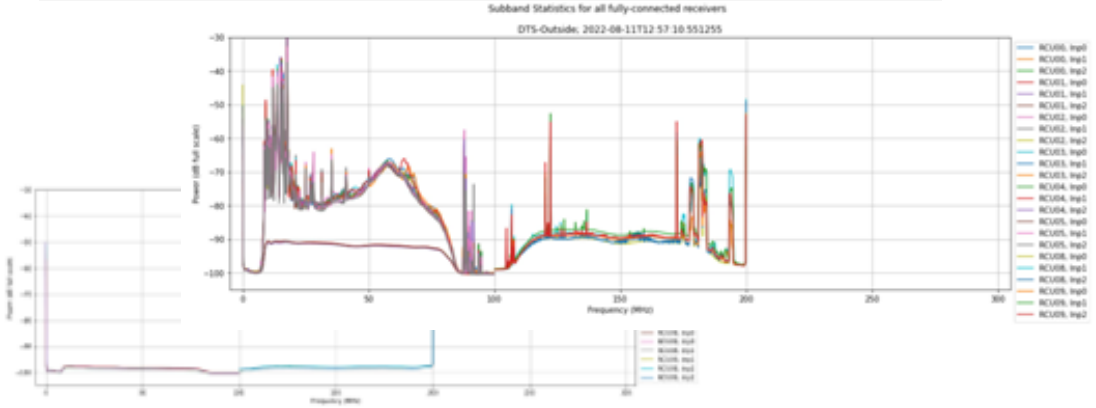

Rack 1




Rack 0

Startup sequence

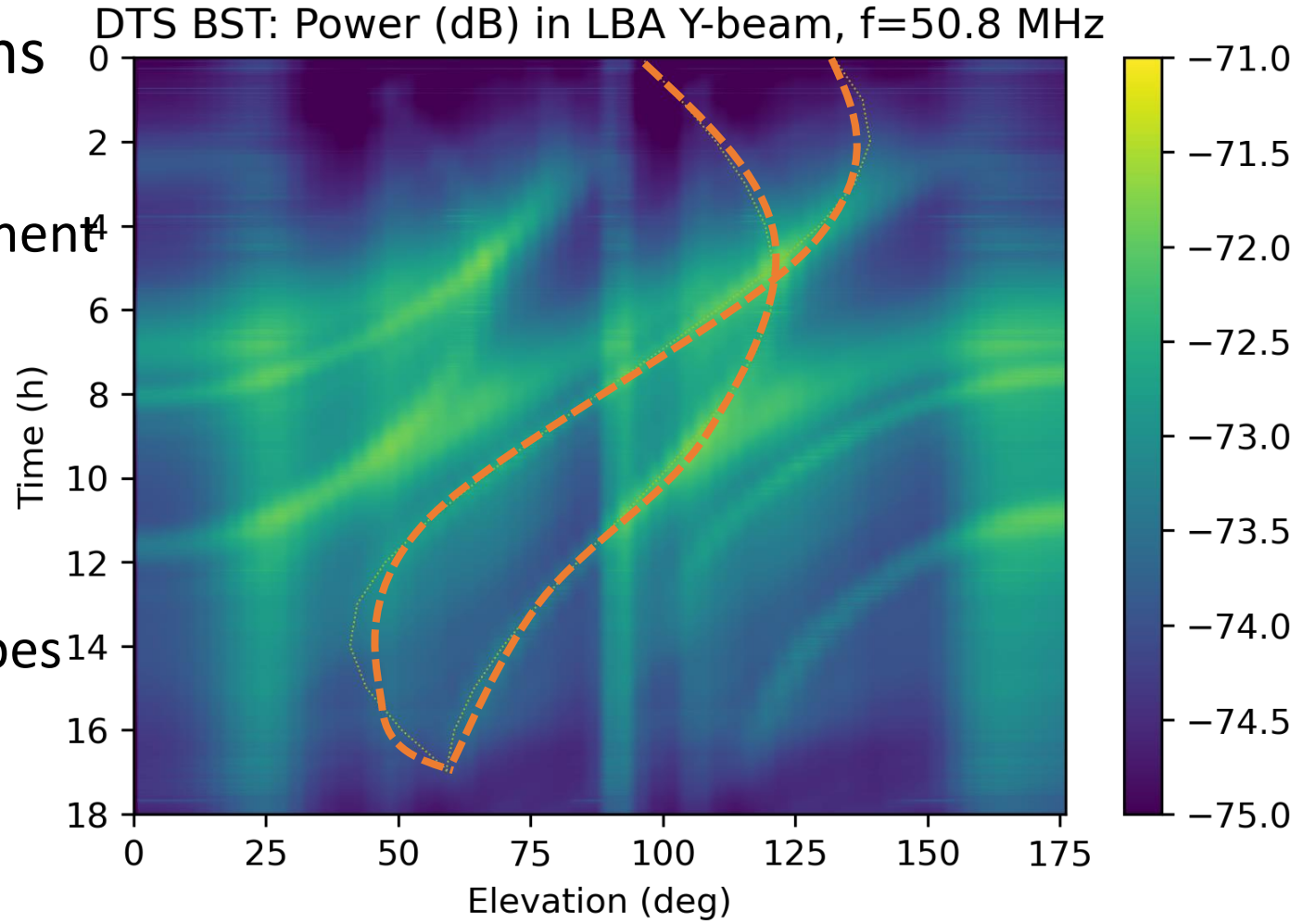
- One software call to startup DTS
  - Hibernate -> On State (only)
  - Set to default configuration
- End-to-end verification thereafter
  - Readout of subband statistics
  - Full LOFAR2.0 Bandwidth
  - End-to-end: antenna – control software

```
dut.init_and_set_to_default_config(devices, skip_boot=False)
```

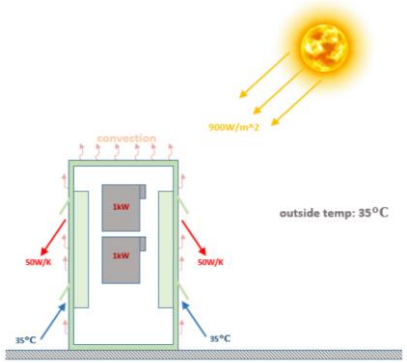


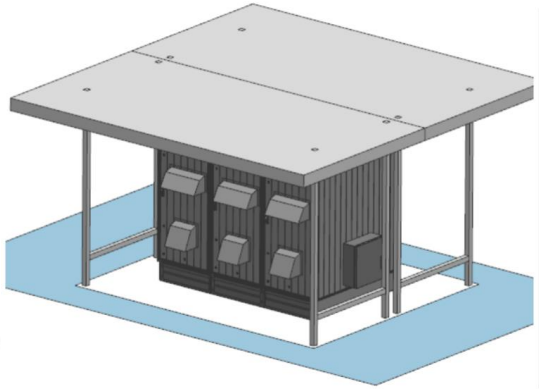
Beamforming LBA

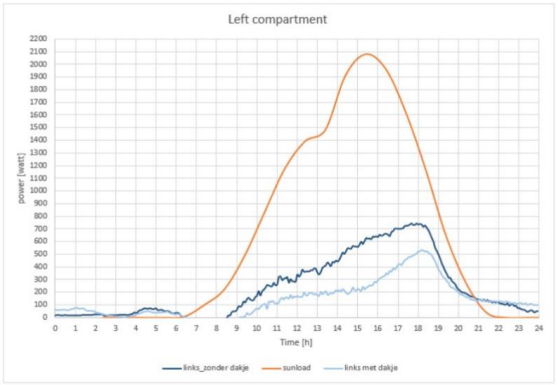
- Beams at different elevations
- Observe sky
  - Cyg A and Cas A most prominent
- Result:
  - Measurement matches with CygA/CasA trajectories
- Note
  - Other response is grating lobes
  - Ionosphere blocking before T = 2 h.



Cooling challenge

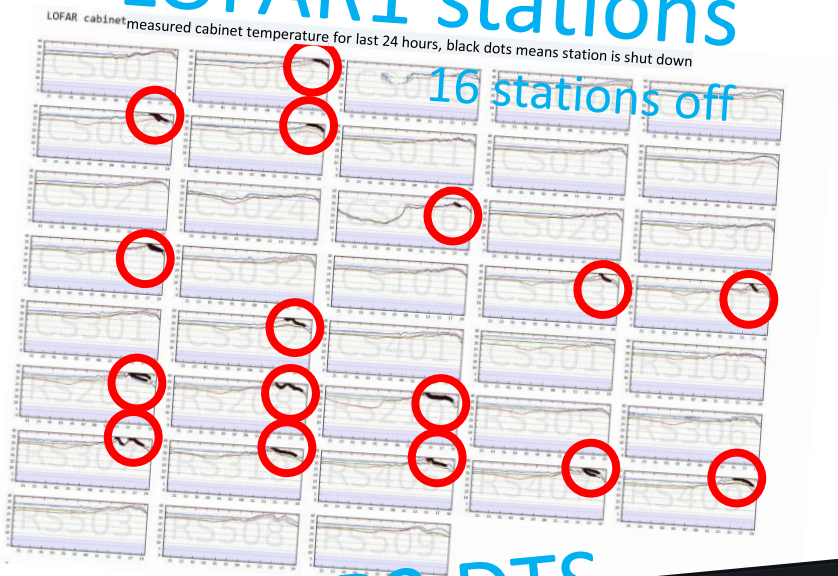




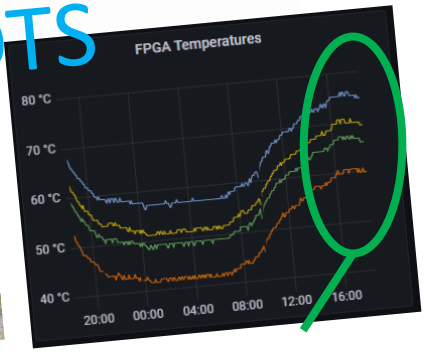


- LOFAR1: shutdown of station at 28 degree
- LOFAR2.0
  - More processing → heat production
  - Prevent shut-down at lower temperatures
- Improvements: add roof, prevent recirculation
- DTS Experiment on hot day:
  - 18 July 2022: max temp: 36.5 deg C (KNMI Hoogeveen)
  - Perform standard observation and
  - Simulate LOFAR2.0 power dissipation
- Result: LOFAR2.0 can cope higher temperatures!
  - 50 °C → 0.05 hour downtime per year.

LOFAR1 stations



LOFAR2 DTS

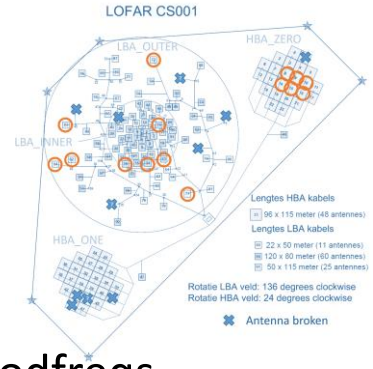


Not tripped!

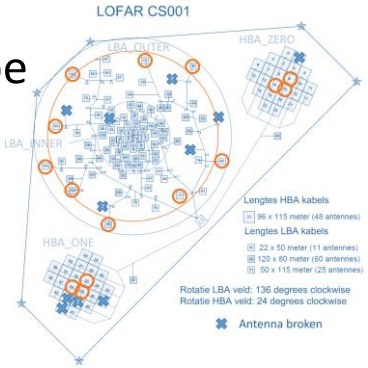
Plan forward: LOFAR2.0 Test Station

- Verification of transition ✓
  - Connections ✓
    - Antennas to RCU2 inputs
    - Power
    - Network
    - Clock
  - Calibration of antennas ✓
    - Phase and amplitude
    - Redundant baselines
  - Beamforming ✓
    - Antenna positions
  - Rollout ✓
    - Labels, tools, instructions

- Validation - 1
  - Analog beamforming ✓
  - End-to-end linearity
    - XST, product FM-DAB → intermodfreqs 24hour intergreren, compare with LOFAR1
  - Crosstalk Low/High → this cycle

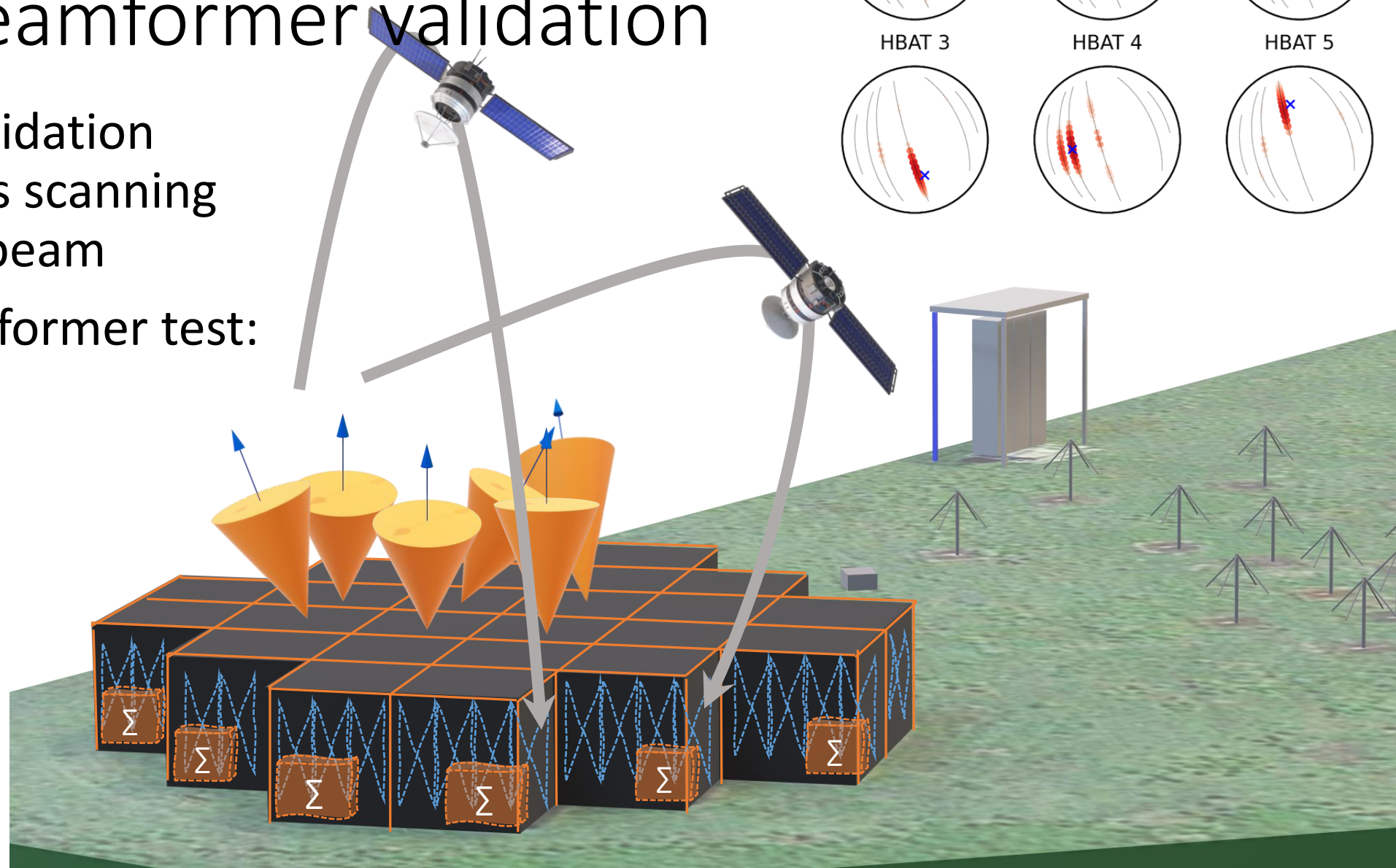


- Validation – 2 → Start next cycle
  - Crosstalk HBA sub-stations (upper lim)
  - Beamforming and Imaging
    - RECV-Low: circle for beamshape
  - Cabinet shielding
  - Antenna connection scheme



LOFAR2.0 Test Station
Analog beamformer validation

- Tile-beam validation with satellites scanning through the beam
- Analog beamformer test:



Summary

- LOFAR2.0 Upgrade
  - All antennas
  - Full bandwidth
- Verification and Validation
  - Successfull validation in Lab Test Station and Dwingeloo Test Station
  - Next step: LOFAR2.0 Test Station

- Acknowledgements
  - Wim van Cappellen, Arno Schoenmakers, Paulus Kruger, Mark Ruiter, Gijs Schoonderbeek, Jan David Mol, Marchel Gerbers, Carla Baldovin, Roel Witvers
  - And many more in the development and operations teams