LOFAR Development Program: status & plans

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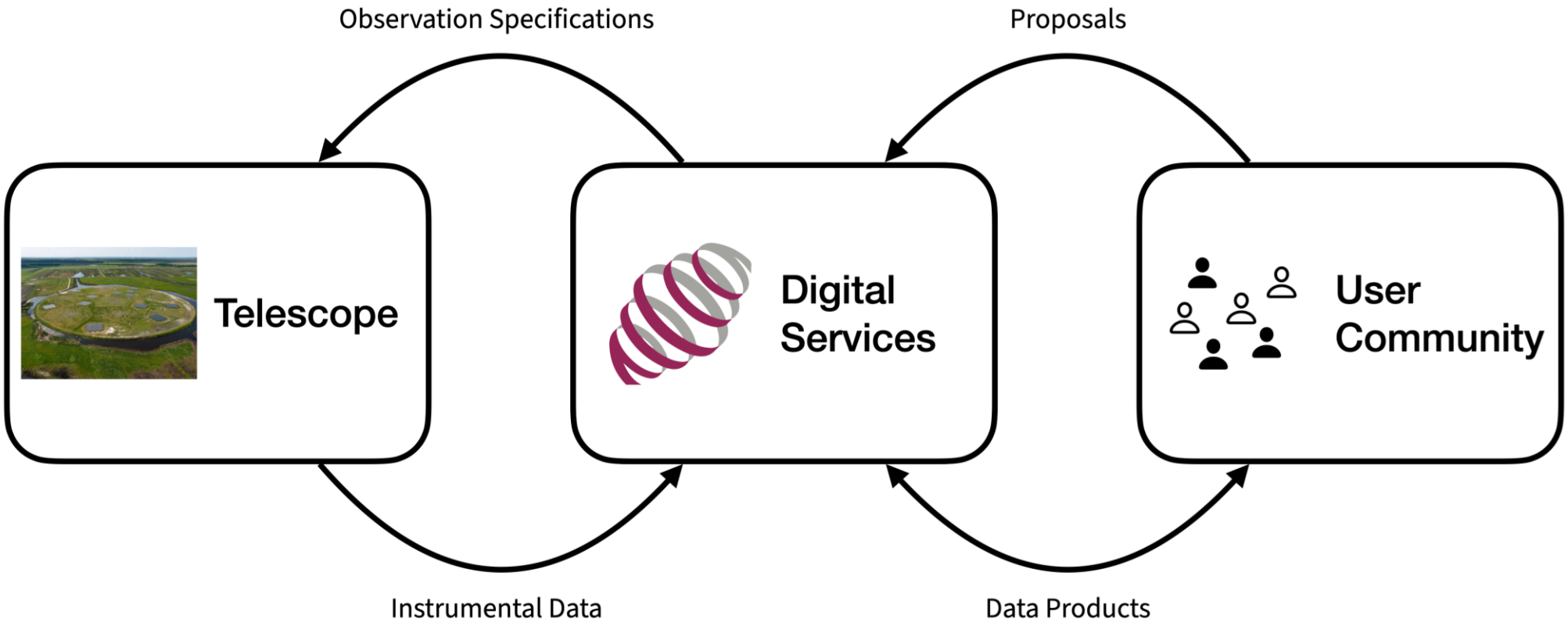
NWO

Scope



Credit: John Swinbank

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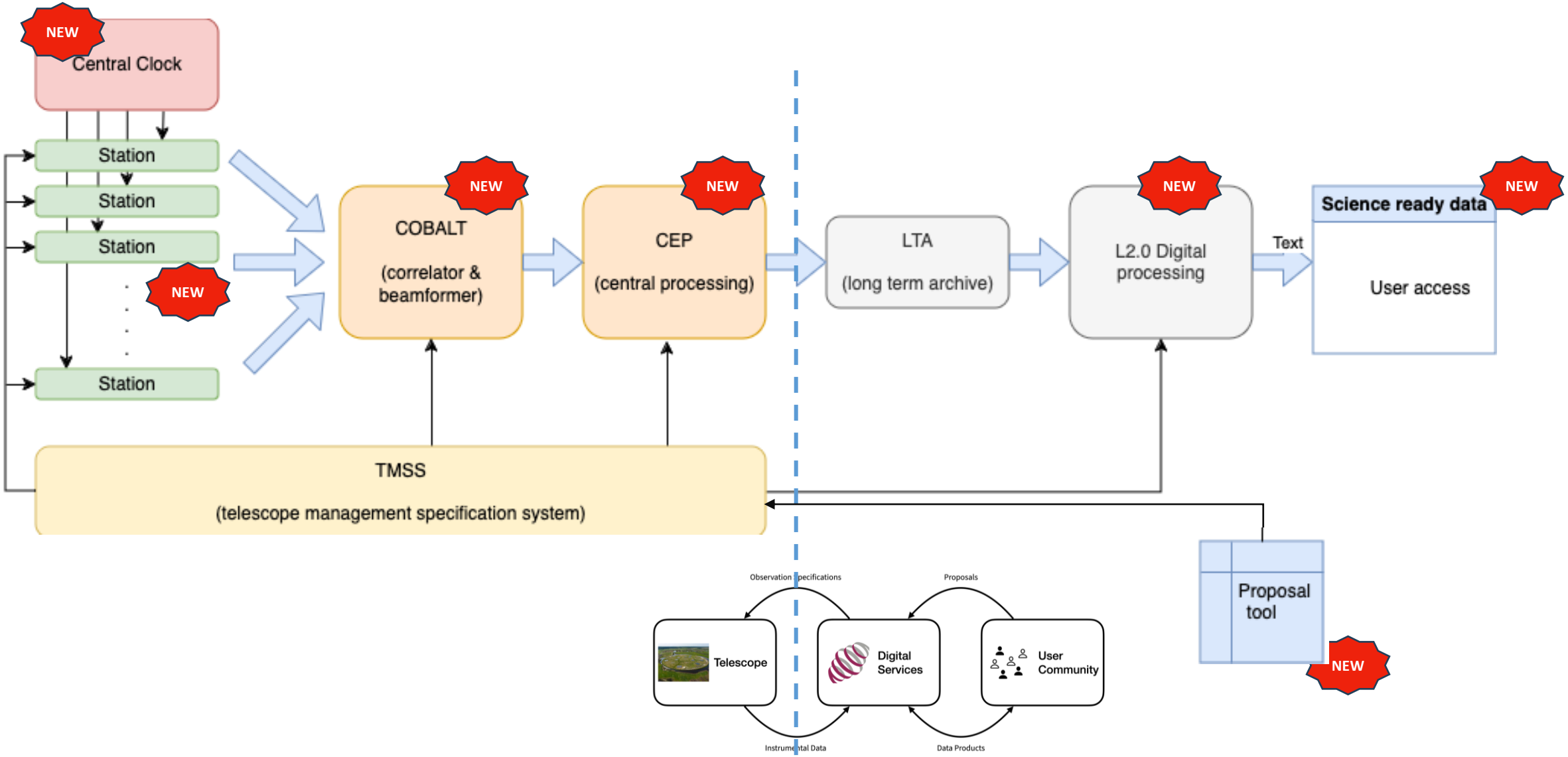
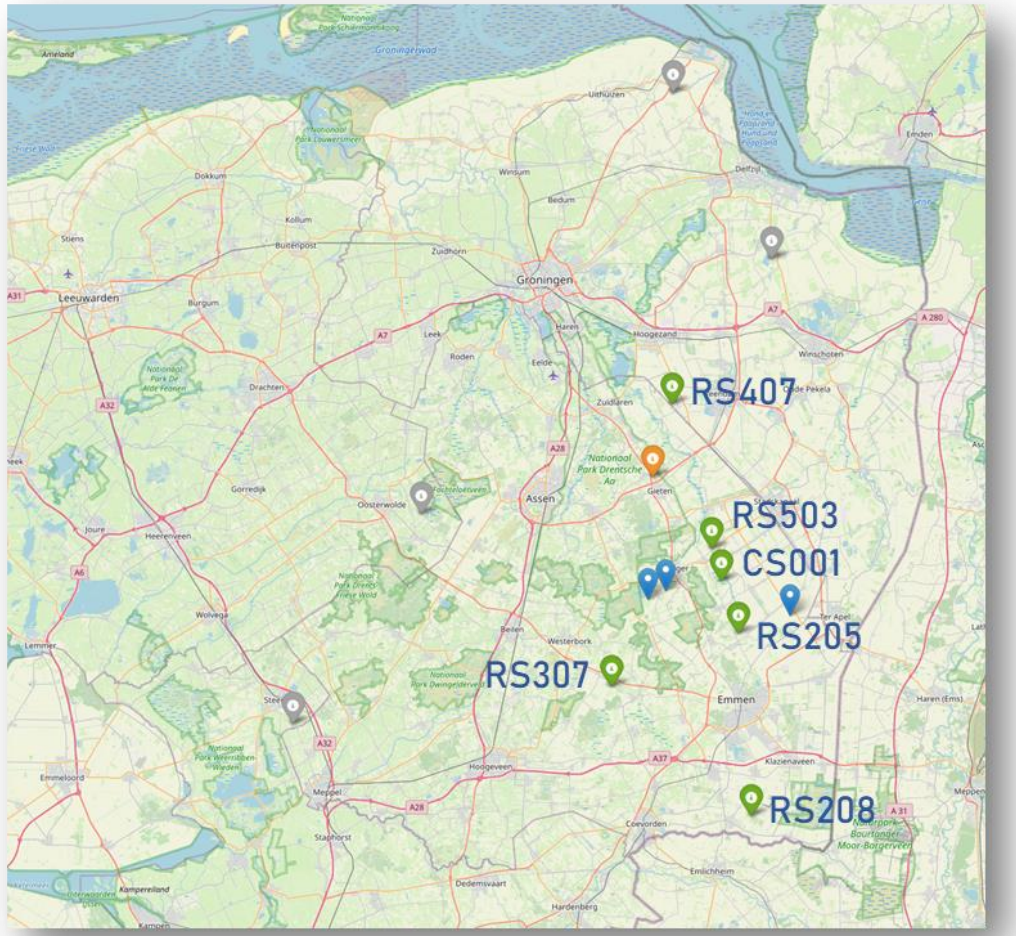
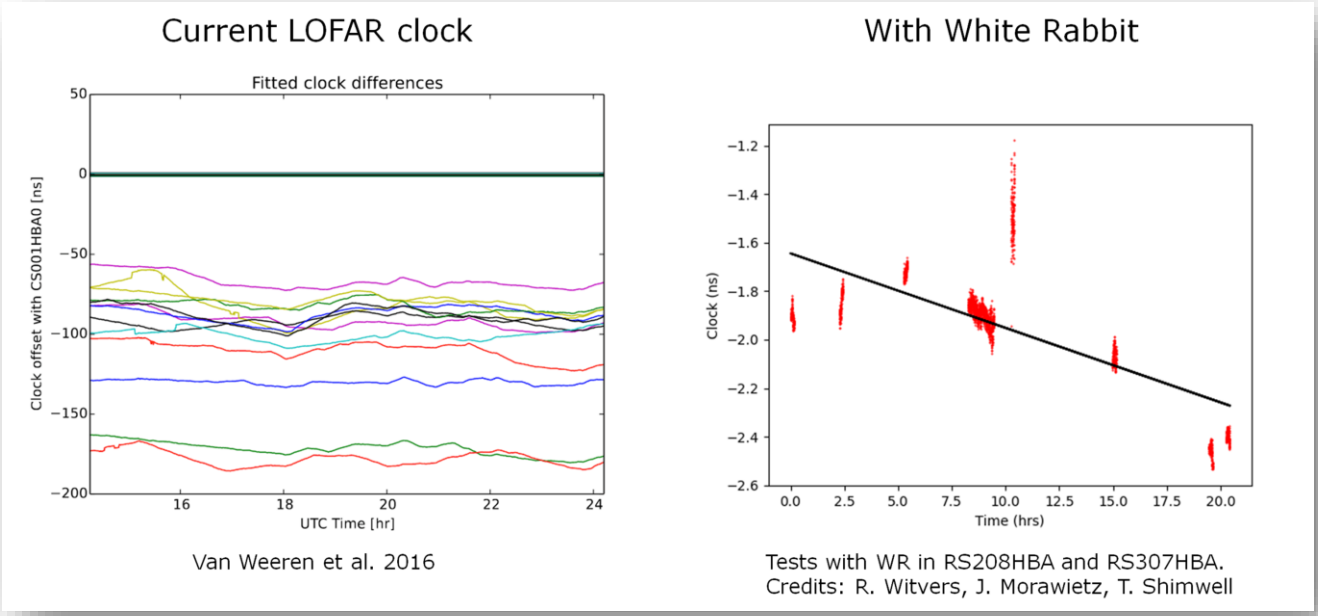
LOFAR2.0 is a new Observatory



Timing Distributor: Central clock

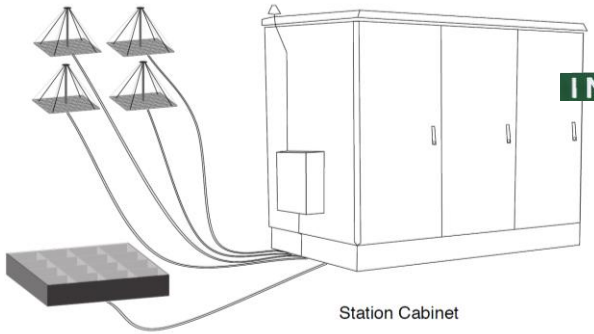




Van Weeren et al. 2016

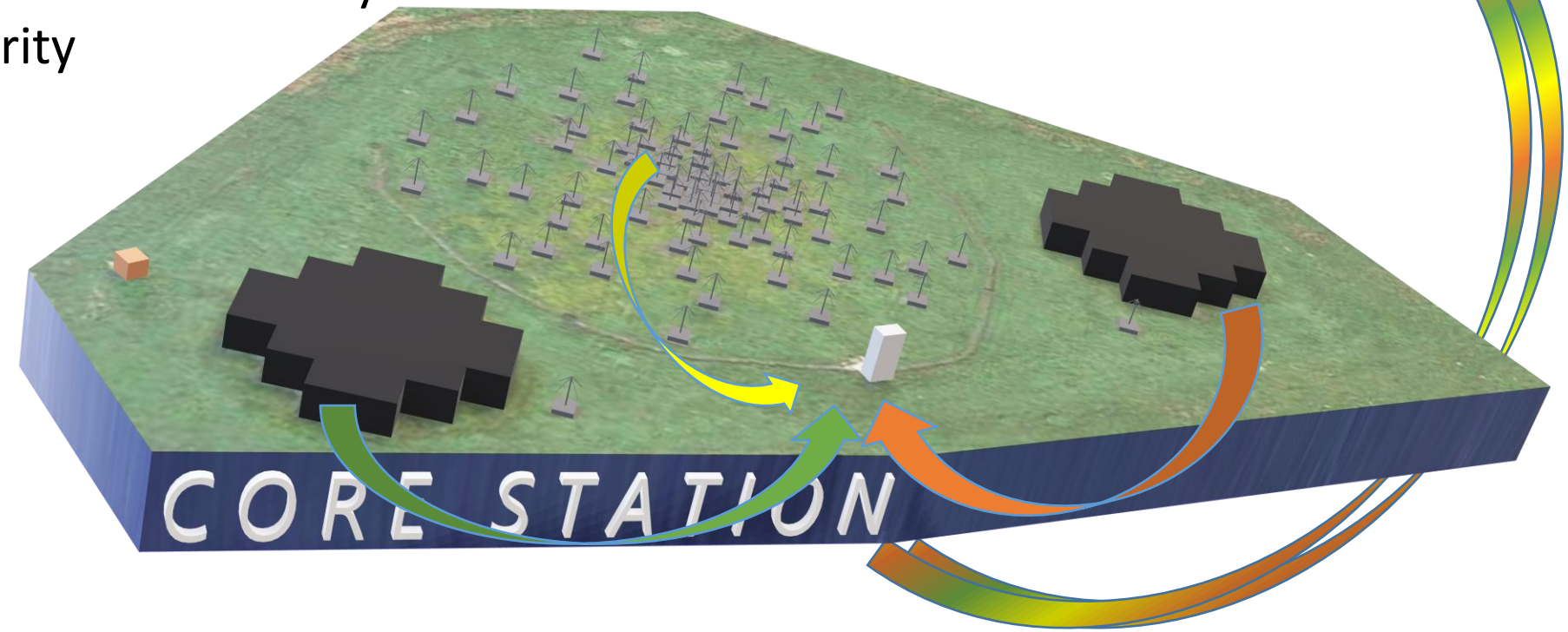
Tests with WR in RS208HBA and RS307HBA.
Credits: R. Witvers, J. Morawietz, T. Shimwell

LOFAR2.0 Station Upgrade

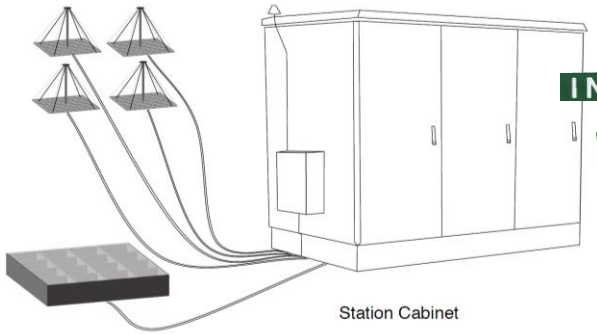


- Limitation: One out of three antennas active
- LOFAR2.0 will improve this
  - simultaneous Low + High Band observing
  - increased Low Band sensitivity
  - Improve linearity
- Challenge:
  - More power consumption
  - Keep station available on hot days

Central Processor



LOFAR2.0 Station Upgrade



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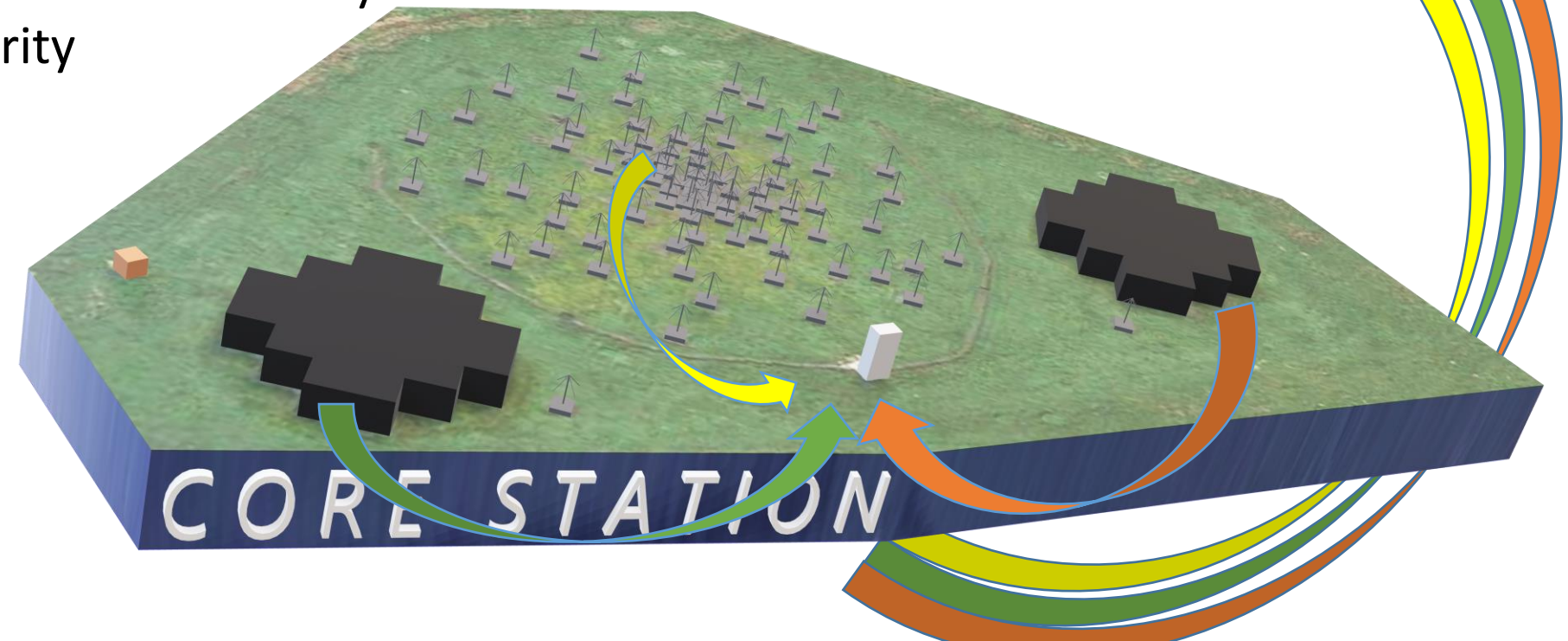
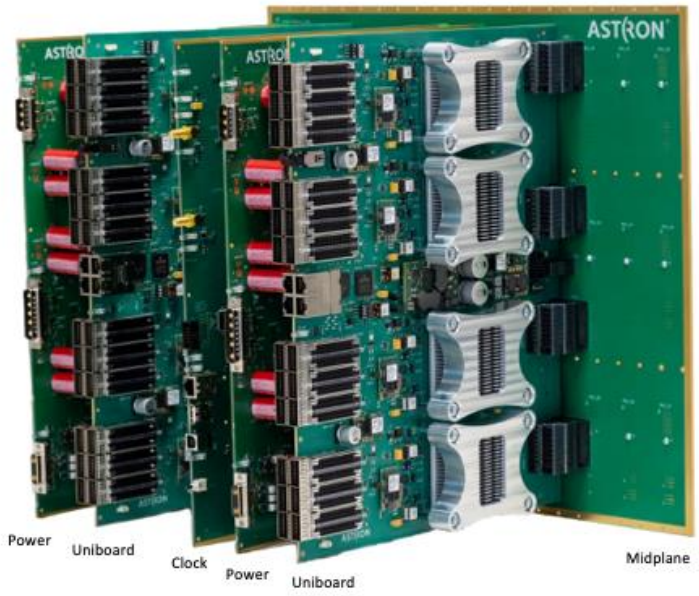
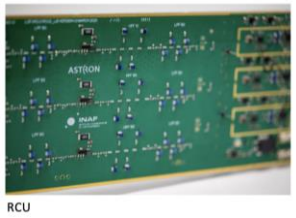


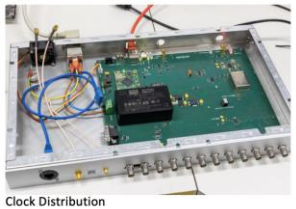
LOFAR2.0 Test Station Results

- Simultaneous Low-Band and High-Band observing

LOFAR2.0 Test Station hardware

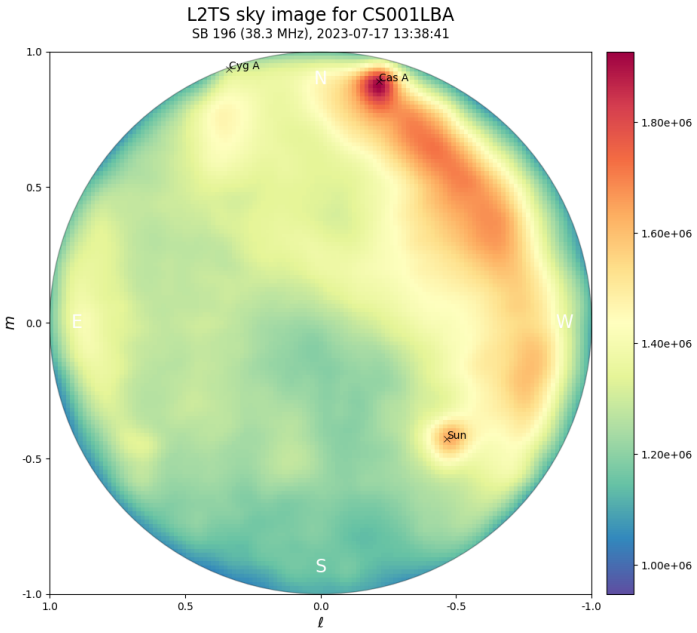


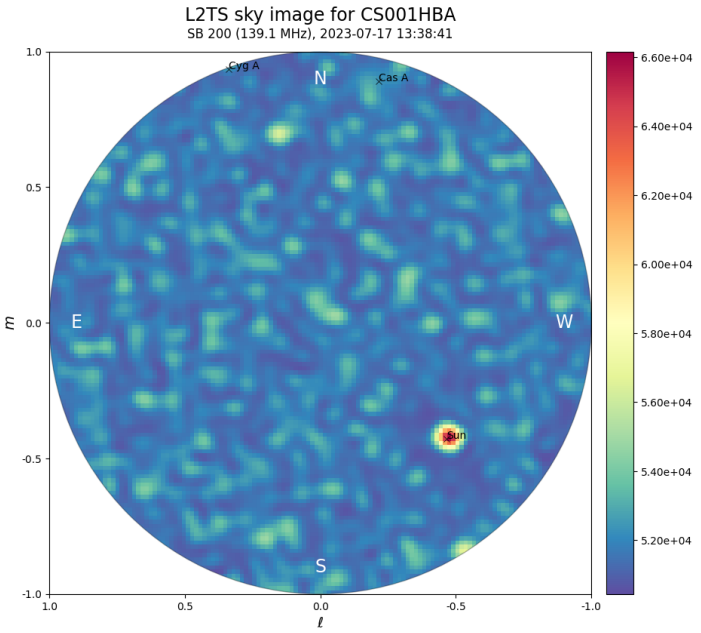

RCU


Clock Distribution

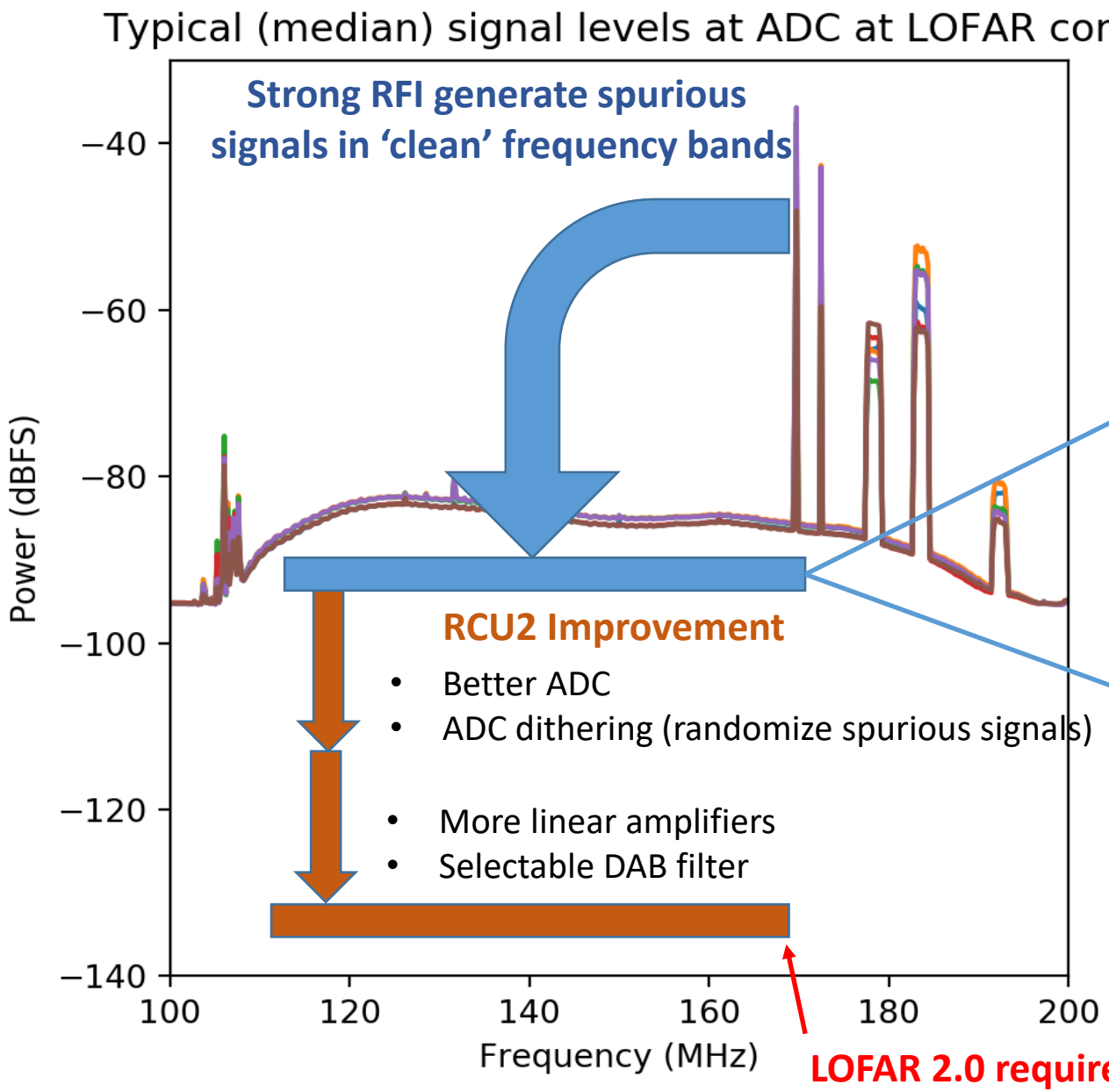

Subrack

First simultaneous LBA+HBA all-sky images with LOFAR2.0!

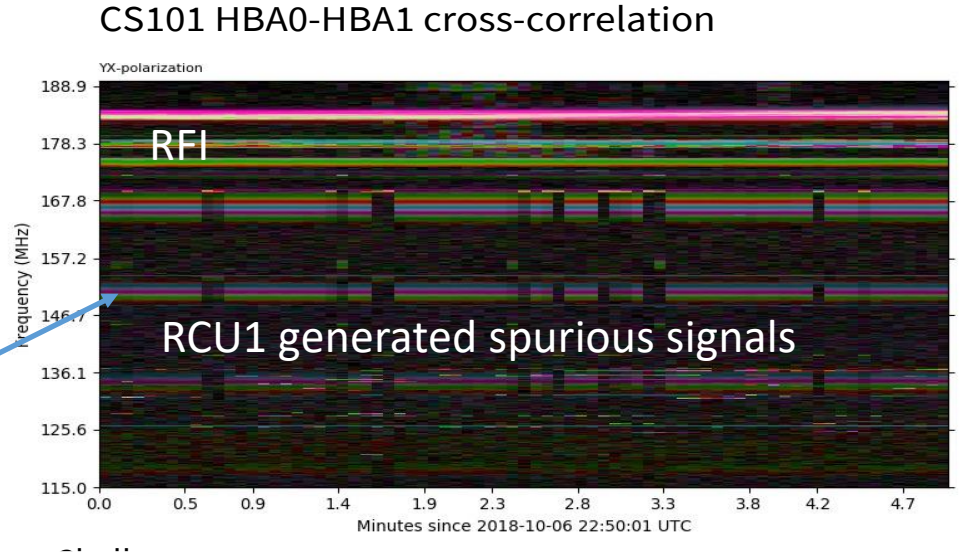




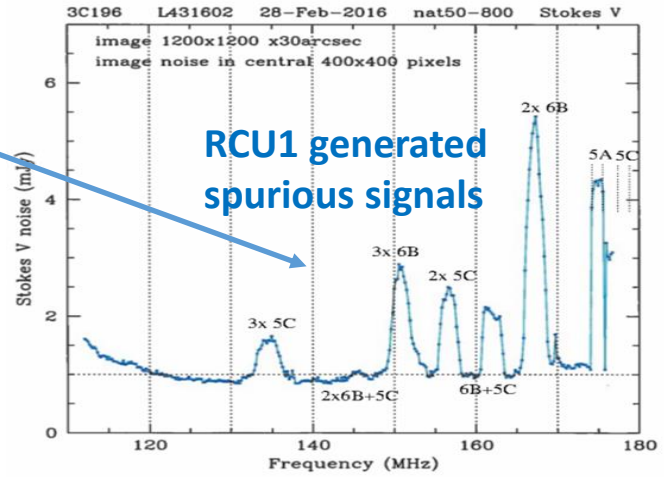
LOFAR 2.0 RCU2 improved linearity



- Spurious signals are correlated i.e. seen in visibilities



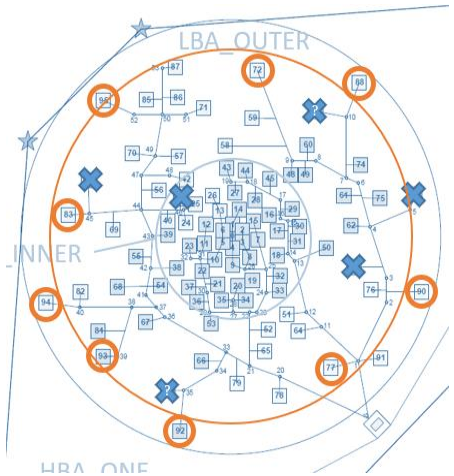
- Spurious signals dominate noise after long integration

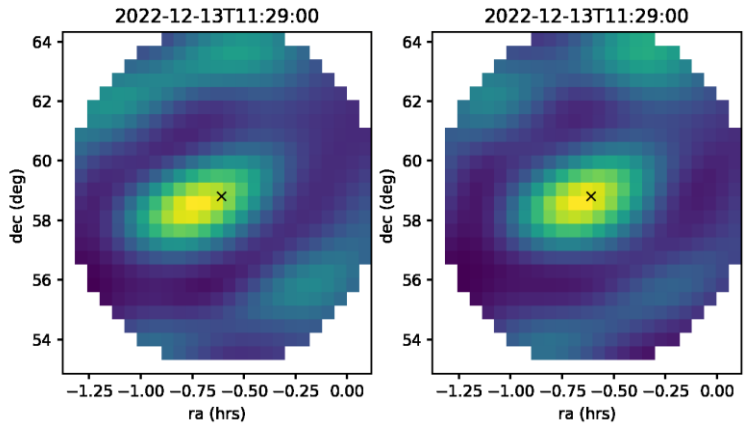


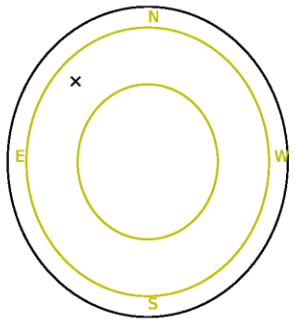
LOFAR 2.0 requirement: Spurious signal < thermal noise after 1000h

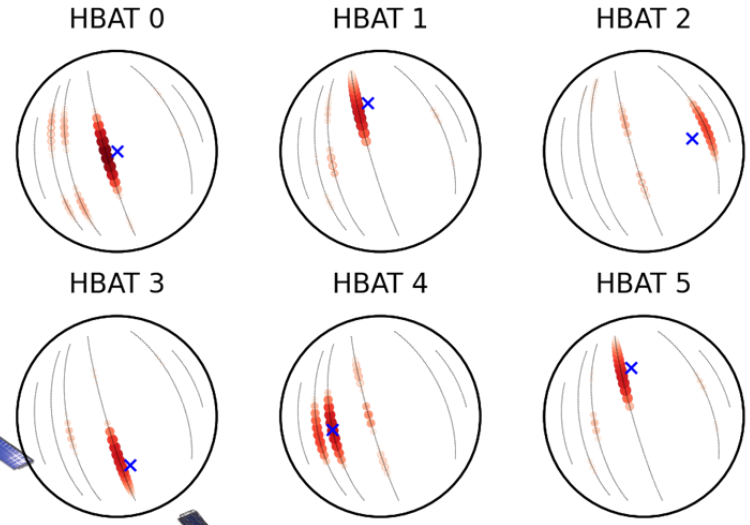
LOFAR2.0 Test Station: Beamformer validation

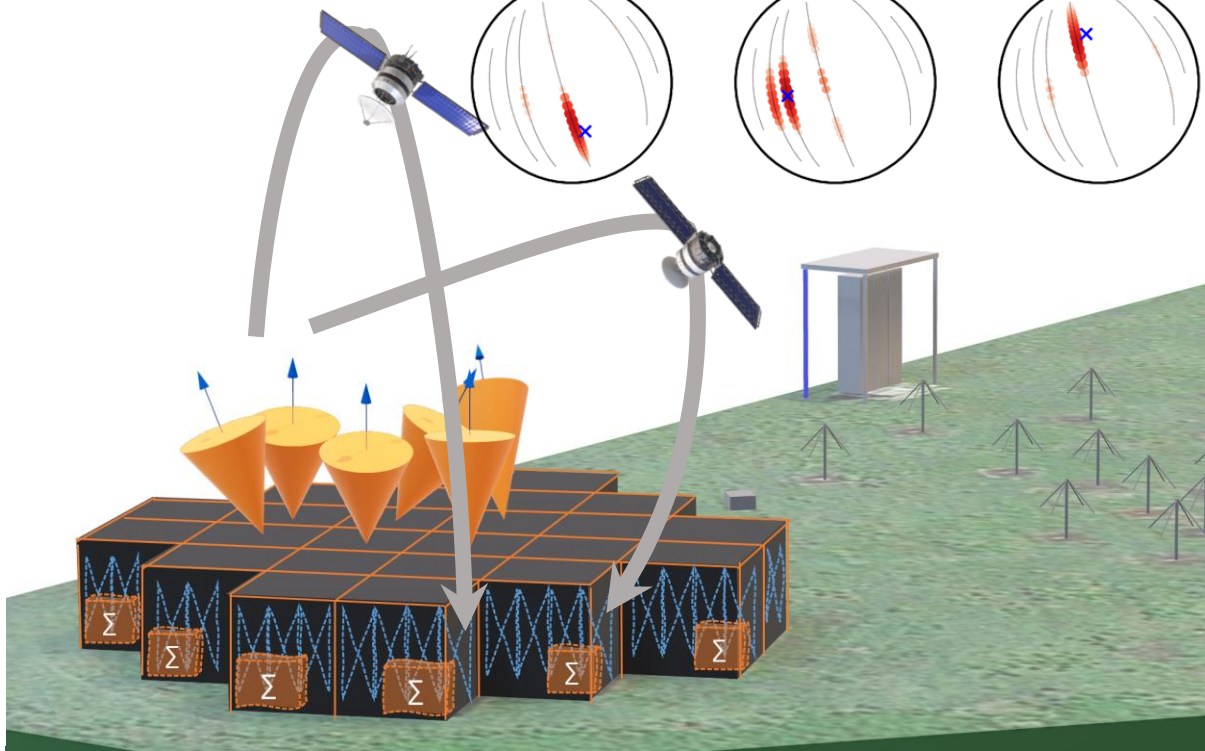
- Tile (analog) beamformer, validation with satellites
  - Static pointing of tile
- Station (digital) beamformer
  - Dynamically tracking a source



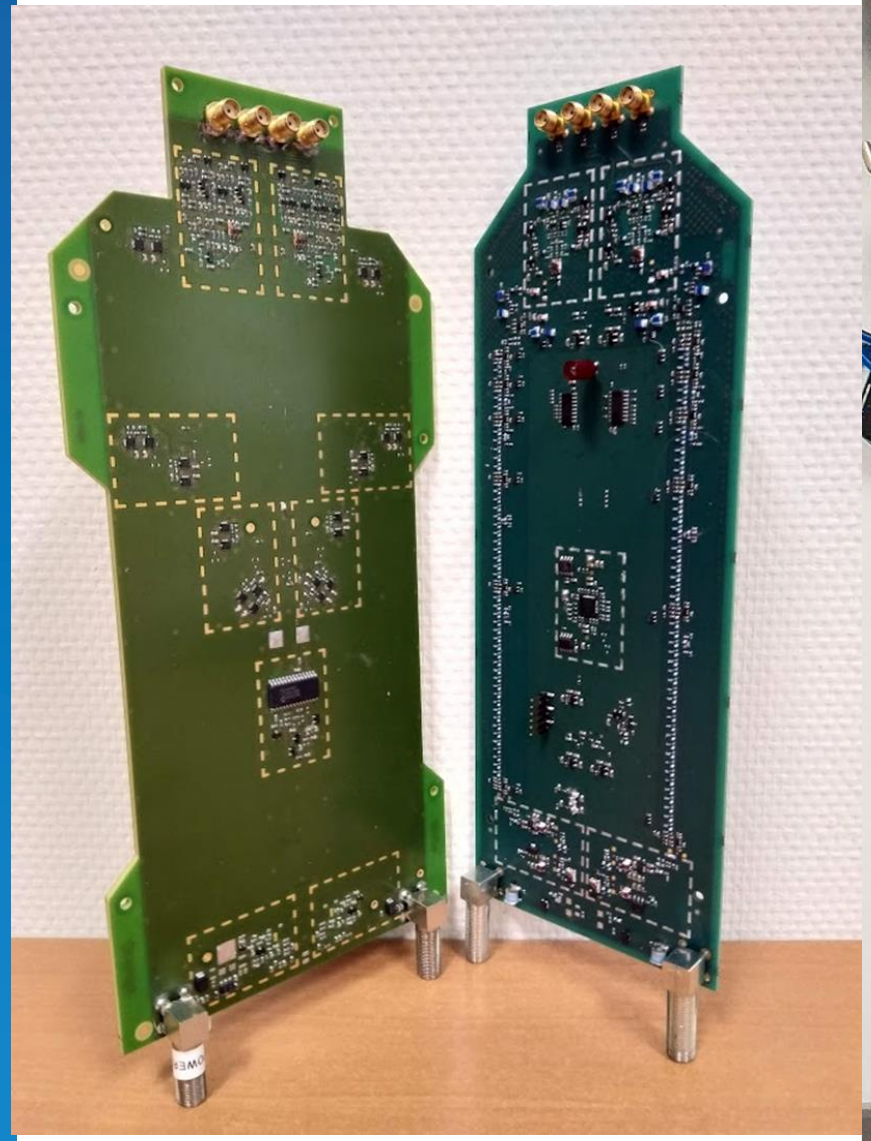


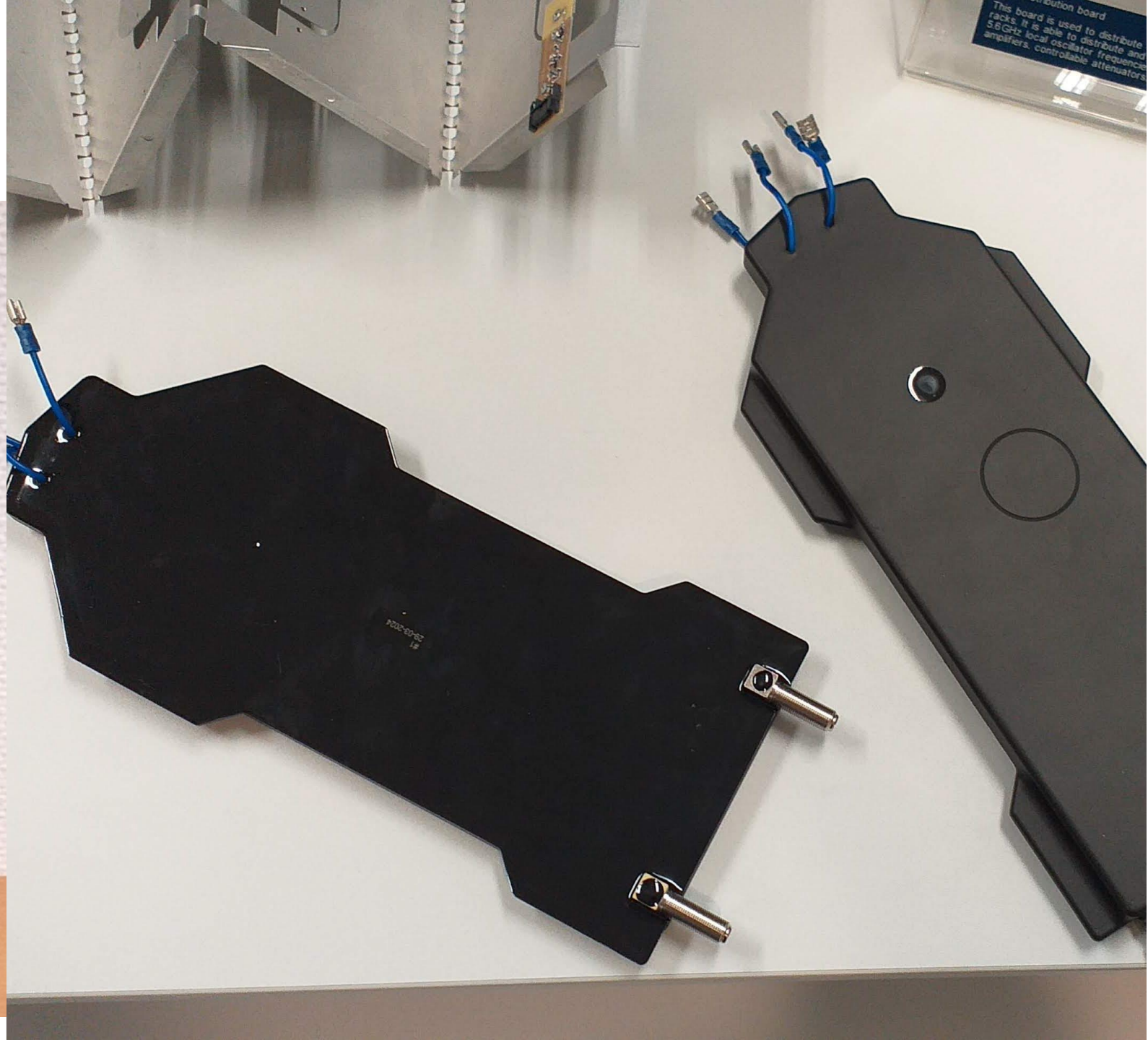






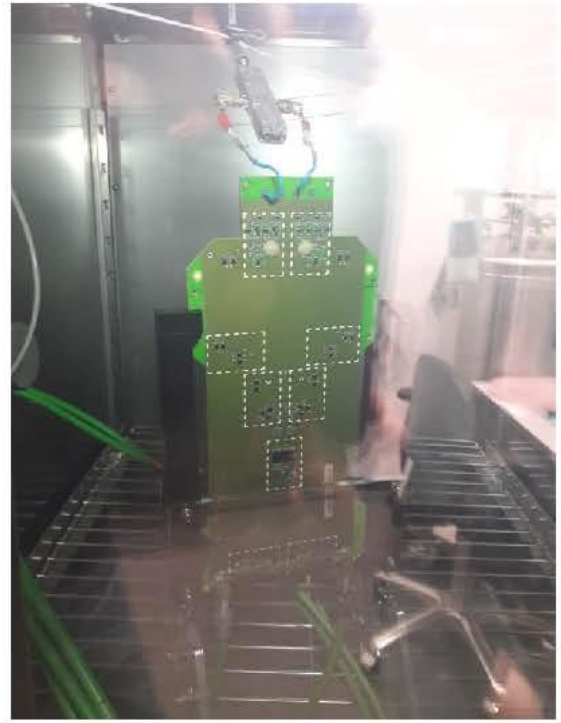
Dual-beam HBA electronics

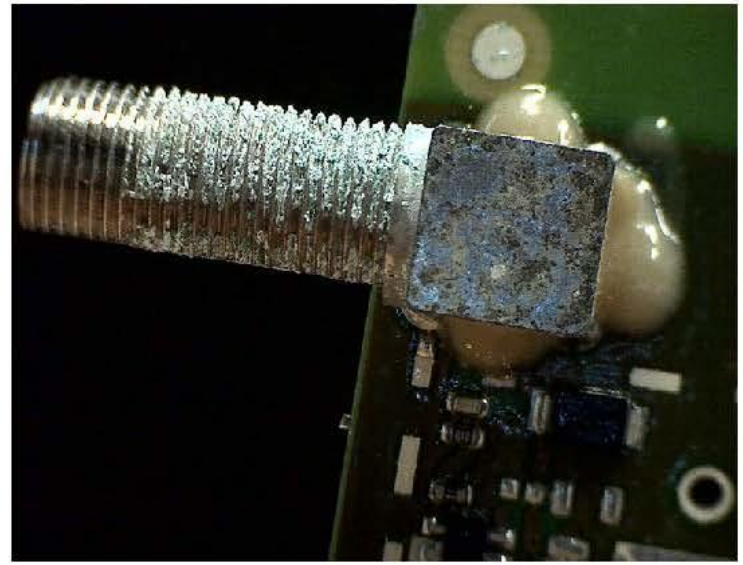


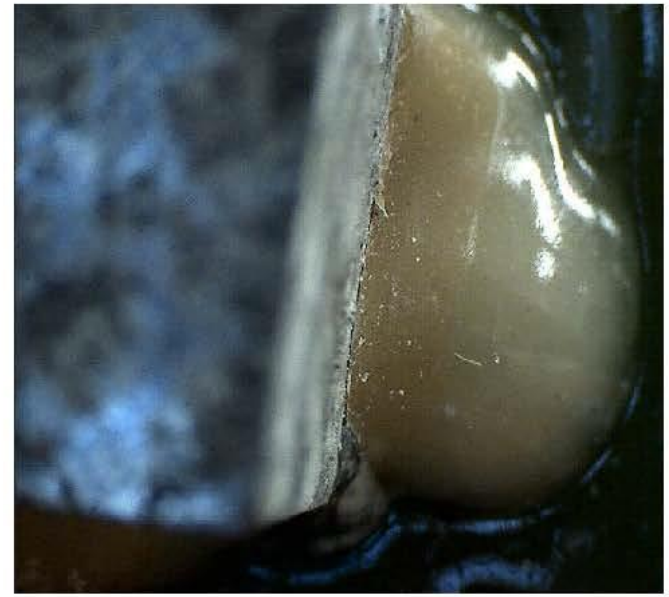


Lifetime test

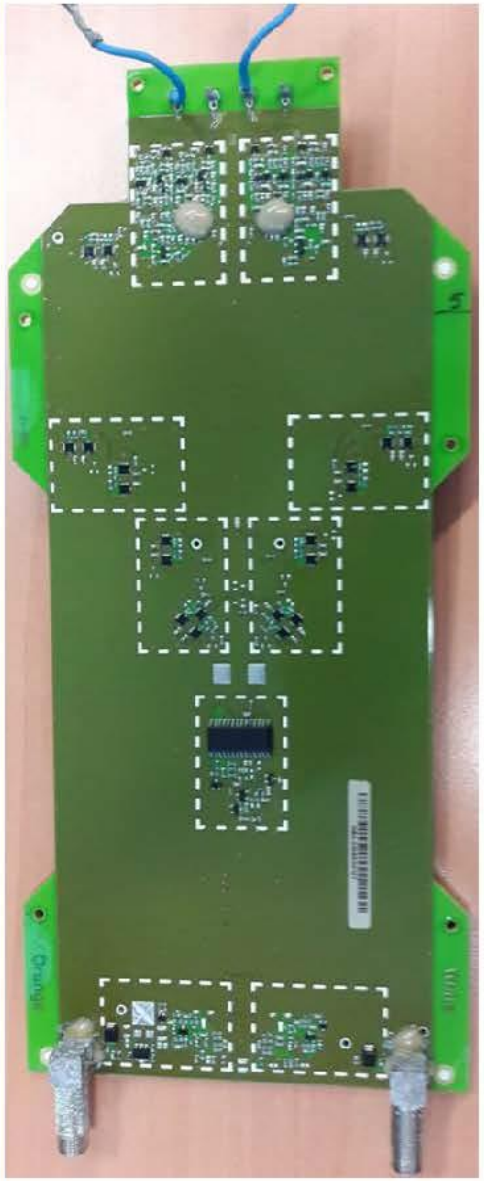
Old LNA after 5 weeks in environmental chamber

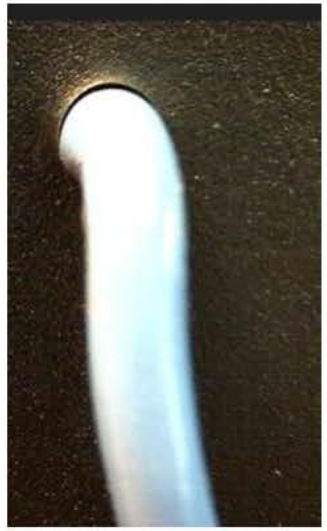






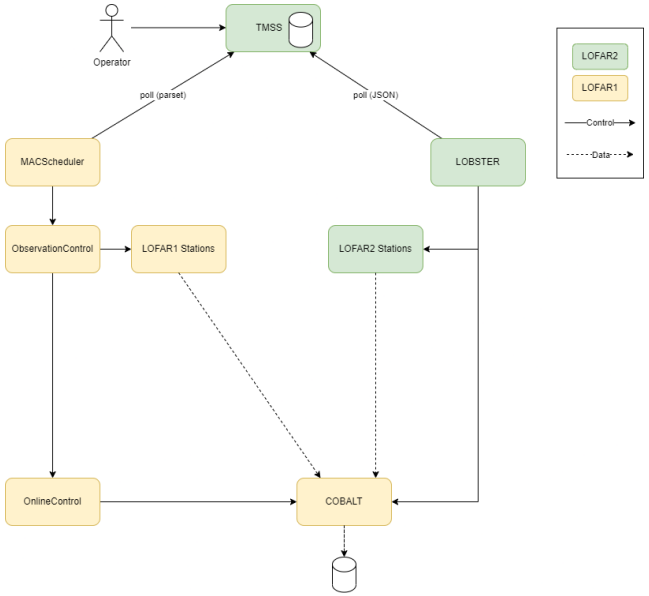
Lifetime : LOFAR 1 vs DANTE

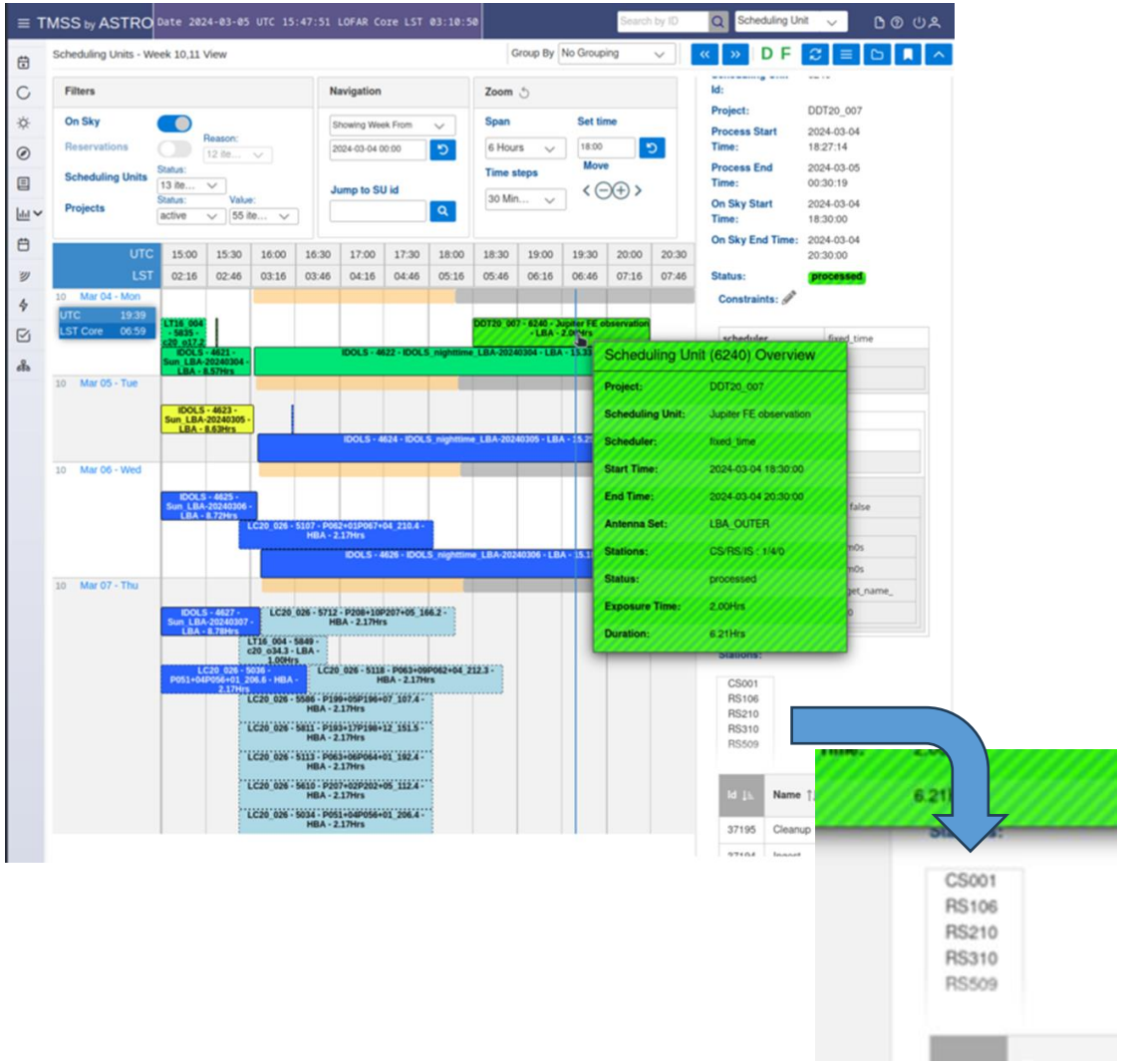




Control software

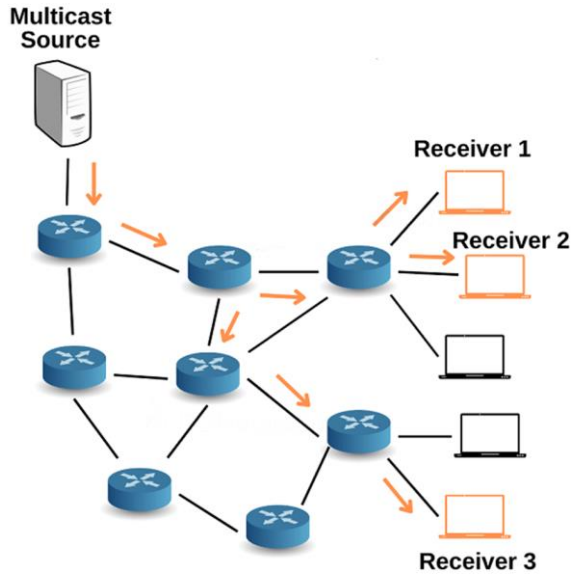
- Improved interface for monitoring & control
- We can run LOFAR1, LOFAR2 and LOFAR1 + LOFAR2 observations with Cobalt through TMSS

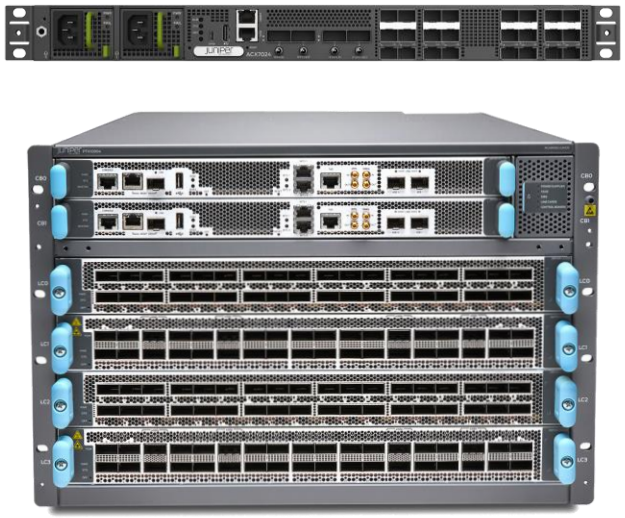


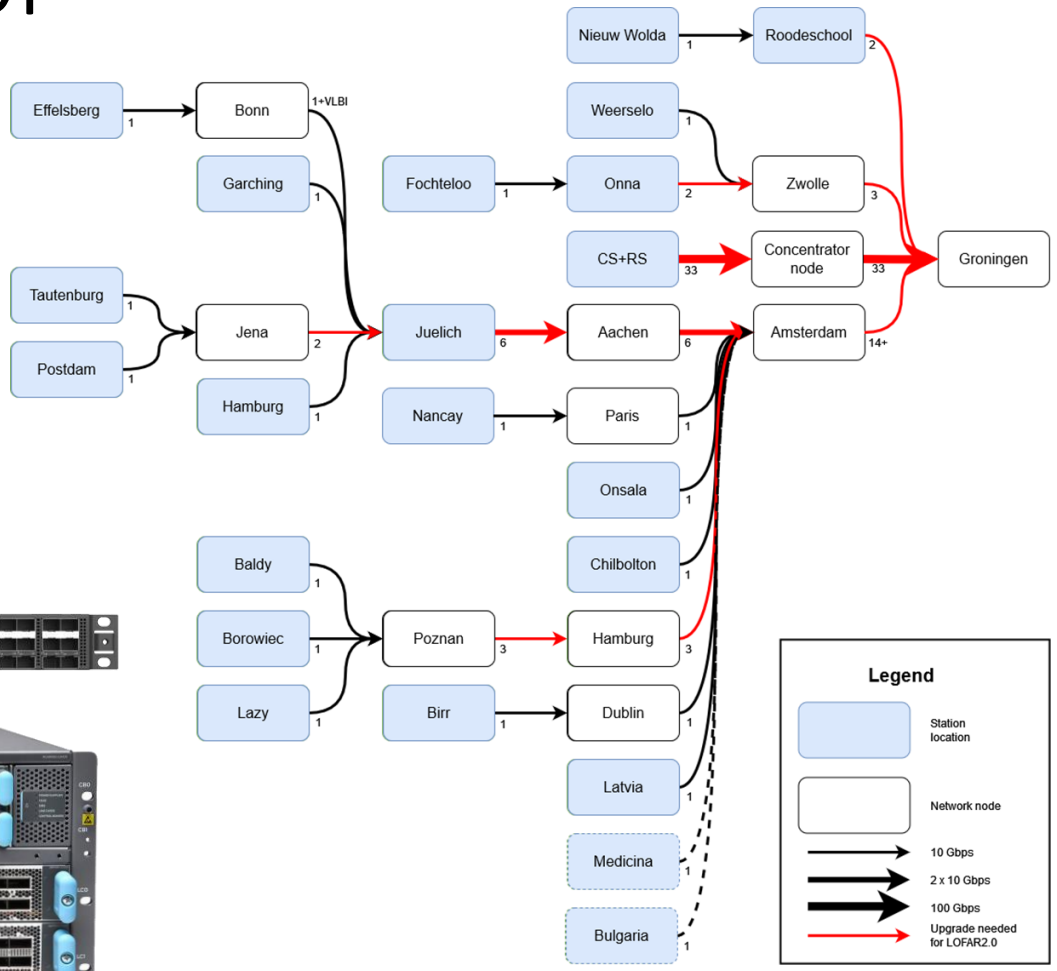


Network & Central Processor

- Development ongoing:
  - 25G per station at start for DUPLLO
  - LENSS upgrade: 100G per station
  - Multicast should fit our use case







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LOFAR2.0 timeline

LOFAR observations will be interrupted from 1 September 2024

Design ✓
2018 -- 2023

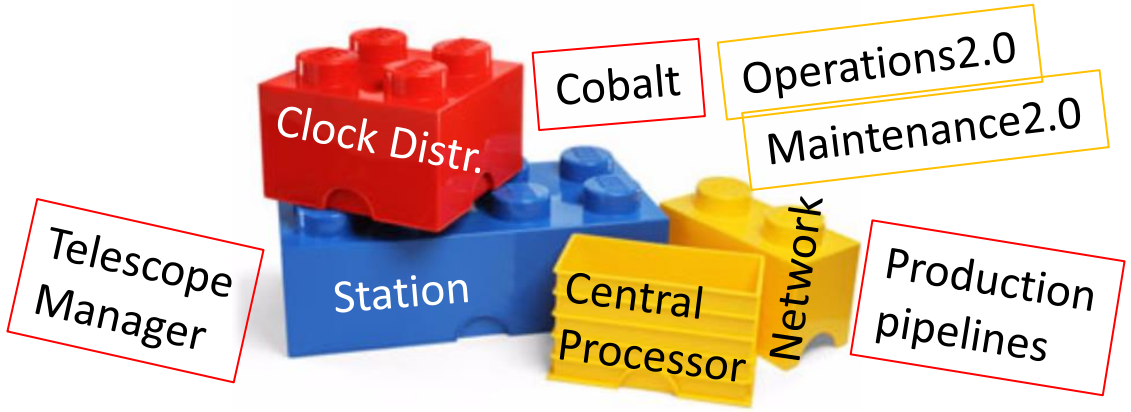
Verification ✓
2021 – 2023

Dwingeloo Test Station
- L2TS phase 1 (1 subrack, 9 LBA + 9 HBA)
- L2TS phase 2 (first full LOFAR2.0 station)

Rollout
2024 – 2026

- Production Test Stations (2 stations)
- All other stations
- Timing Distributor (White Rabbit)

LOFAR2.0: Many changes



- LOFAR2.0 upgrade: A lot of changes planned
- How to integrate into a working telescope? How to validate?
- Array Releases
  - Series of end-to-end systems with increasing complexity
  - Use (and learn) as early as possible
  - Step-wise approach

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Array Releases

AR-A

AR-B

No. LOFAR2.0 stations	1	3	
Single clock to	LOFAR2.0 station +remote stations	LOFAR2.0 stations +remote tations	LOFA +rem
Central processor	LOFAR1	Limited	L
Network		NL - Ready	

- Goal Array Release A: “A Station”
  - Deliver first LOFAR2.0 data to users
  - Monitoring & control by operators and maintainers
  - Use Telescope Manager to schedule observations
  - Validate internal interfaces (Telescope Manager, Central Processor)

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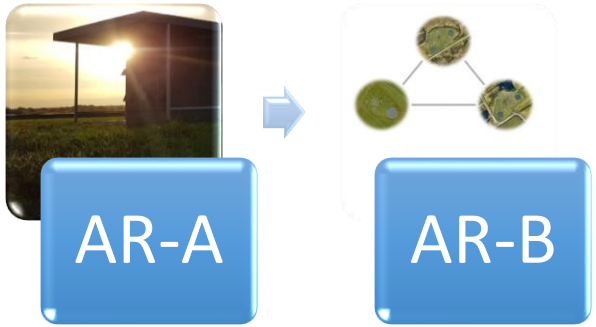
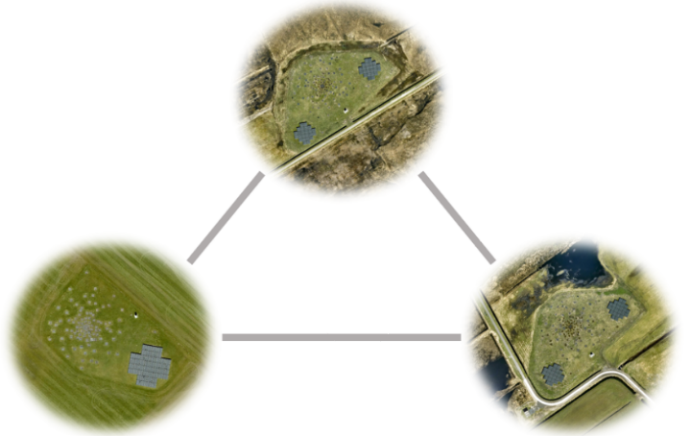
Array Releases



No. LOFAR2.0 stations	1	3
Single clock to	LOFAR2.0 station +remote stations	LOFAR2.0 stations +remote stations
Central processor	LOFAR1	Limited
Network		NL - Ready



- Goal Array Release B: “Both Stations”
  - Validate complete LOFAR2.0 clock distribution path to two stations
  - Validate closure phase (3 stations)
  - Handover of stations to operations
  - Deliver LOFAR2.0 datasets to SDC

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Array Releases

No. LOFAR2.0 stations	1	3	4	38 (Dutch)	54 (Europe)
Single clock to	LOFAR2.0 station +remote stations	LOFAR2.0 stations +remote stations	LOFAR2.0 stations +remote stations	Dutch stations	Dutch stations
Central processor	LOFAR1	Limited	Limited	LOFAR2.0	LOFAR2.0
Network		NL - Ready			EUR - Ready

- Goal Array Release C: “Central Area”
  - Validation of amplitude closure (4 stations)
  - Validation of pipelines (for e.g. array calibration)
  - Validation of operational modes (beamformed, imaging)
  - Build up experience in LOFAR2.0 Operations and LOFAR2.0 Maintenance

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Array Releases

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Single clock to	LOFAR2.0 station +remote stations	LOFAR2.0 stations +remote stations	LOFAR2.0 stations +remote stations	Dutch stations	Dutch stations
Central processor	LOFAR1	Limited	Limited	Full LOFAR2.0	Full LOFAR2.0
Network		NL - Ready			EUR - Ready

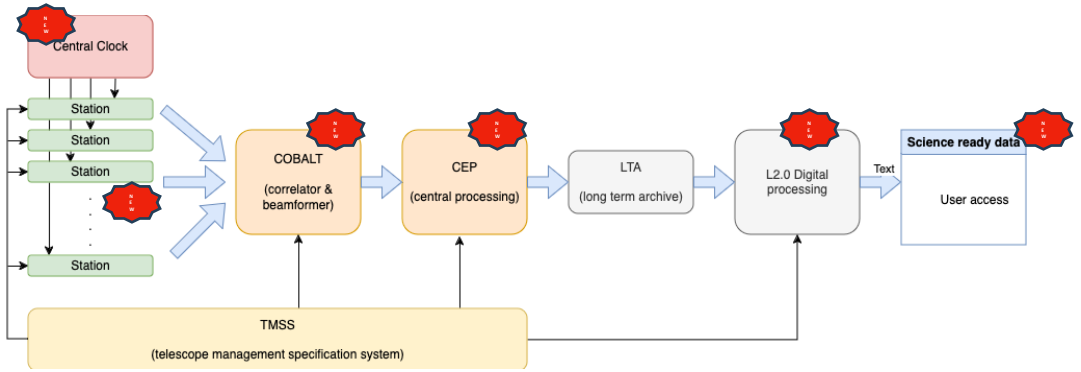
- Goal Array Release D: “Dutch Stations”
  - Validation of Dutch Array to meet performance reqts
  - Validation of specification and scheduling
  - Validation of quality assurance pipelines
  - Validation of transient buffer functionality

Array Releases

No. LOFAR2.0 stations	1	3	4	38 (Dutch)	54 (Europe)
Single clock to	LOFAR2.0 station +remote stations	LOFAR2.0 stations +remote tations	LOFAR2.0 stations +remote tations	Dutch stations	Dutch stations
Central processor	LOFAR1	Limited	Limited	Full LOFAR2.0	Full LOFAR2.0
Network		NL - Ready			EUR - Ready

- Goal Array Release E: “European Stations”
  - All stations upgraded and new stations rolled out
  - Validate of ILT observing mode to meet performance reqts
  - Ready for 24/7 observing (first LOFAR2.0 cycle)

Summary



- LOFAR is undergoing a technological upgrade unlocking new capabilities and cutting-edge research
  - Increased LBA (10 – 90 MHz) sensitivity
  - Simultaneous LBA + HBA observing
  - ~10x more accurate clock synchronization
  - Redesign of HBA electronics
  - Network upgrade replacing 10 GbE with 100 and 400 Gbe technology
  - New correlator / beam former
  - More efficient postprocessing pipelines and improved data accessibility
  - And much more
- Array Releases for planning the validation efforts

Stay updated - LOFAR2.0 Newsletter:
https://www.astron.nl/lofar2-0-newsletter/