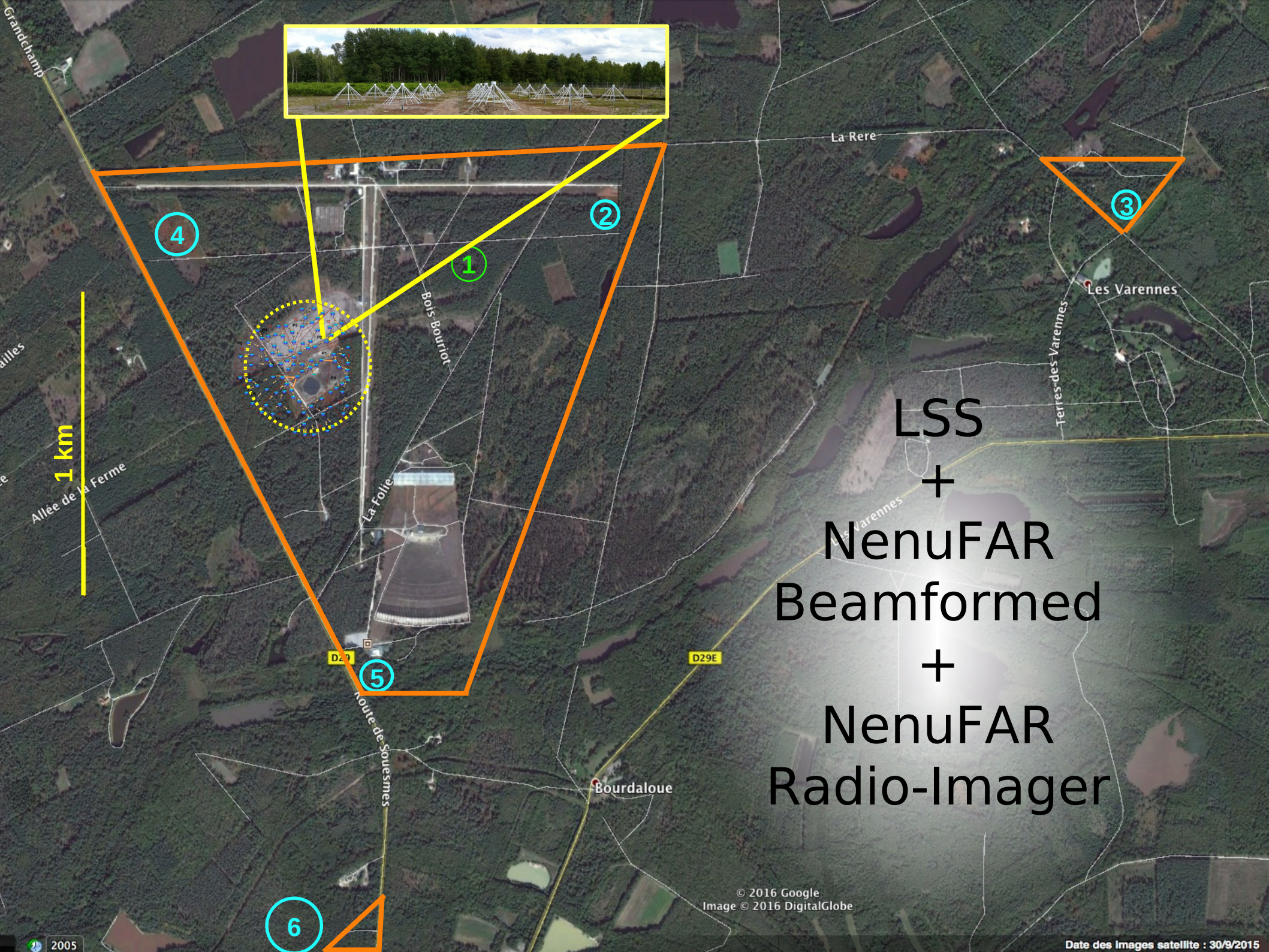
2nd NenuFAR User Workshop

NenuFAR*
Presentation & updates on the system

Cedric Viou
on behalf of the
NenuFAR-France team**

***: LESIA-OP, LPC2E-Orléans, USN-OP, CEA-Saclay, GEPI, LERMA, ONERA, ENS/IAP, OCA, ...*

*New Extension in Nançay Upgrading LOFAR


LSS
+
NenuFAR
Beamformed
+
NenuFAR
Radio-Imager
1 km
1
2
3
4
5
6
La Rere
Les Varennes
Terres-des-Varennes
Bois Bouriot
La Folie
Allée de la Ferme
Route de Souesmes
Bourdaloue
D29E
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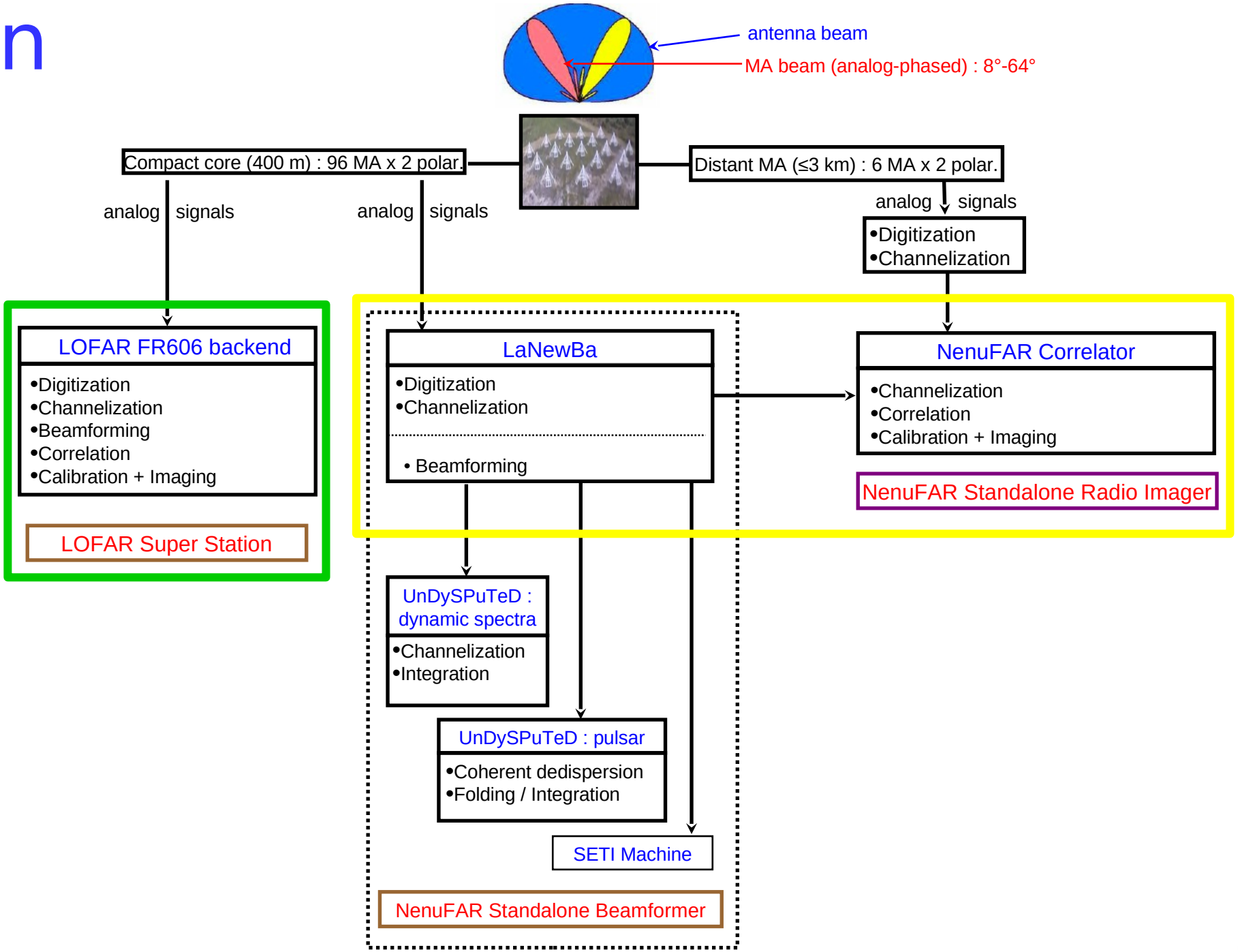
Plan


antenna beam
MA beam (analog-phased) : 8°-64°
Compact core (400 m) : 96 MA x 2 polar.
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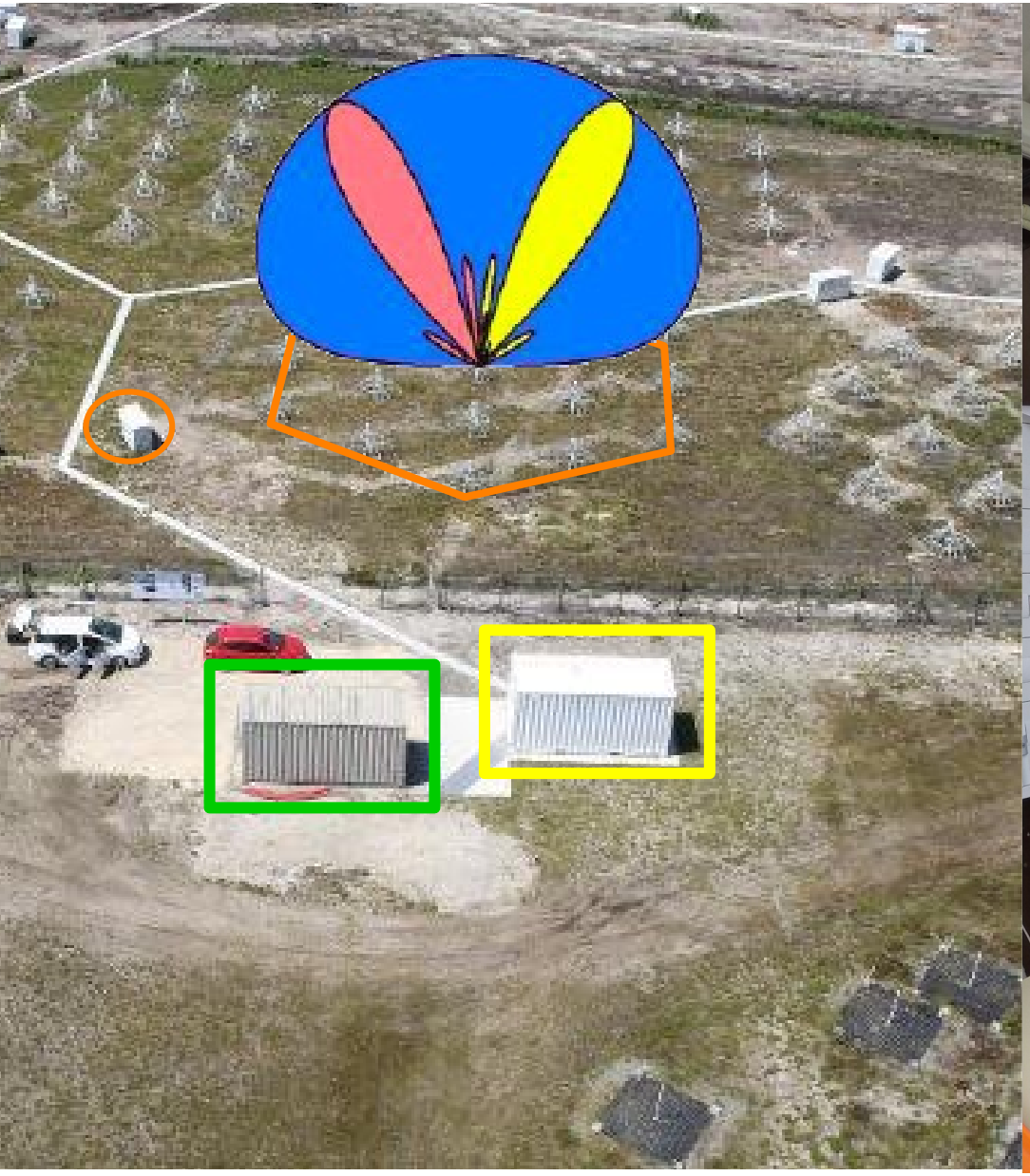
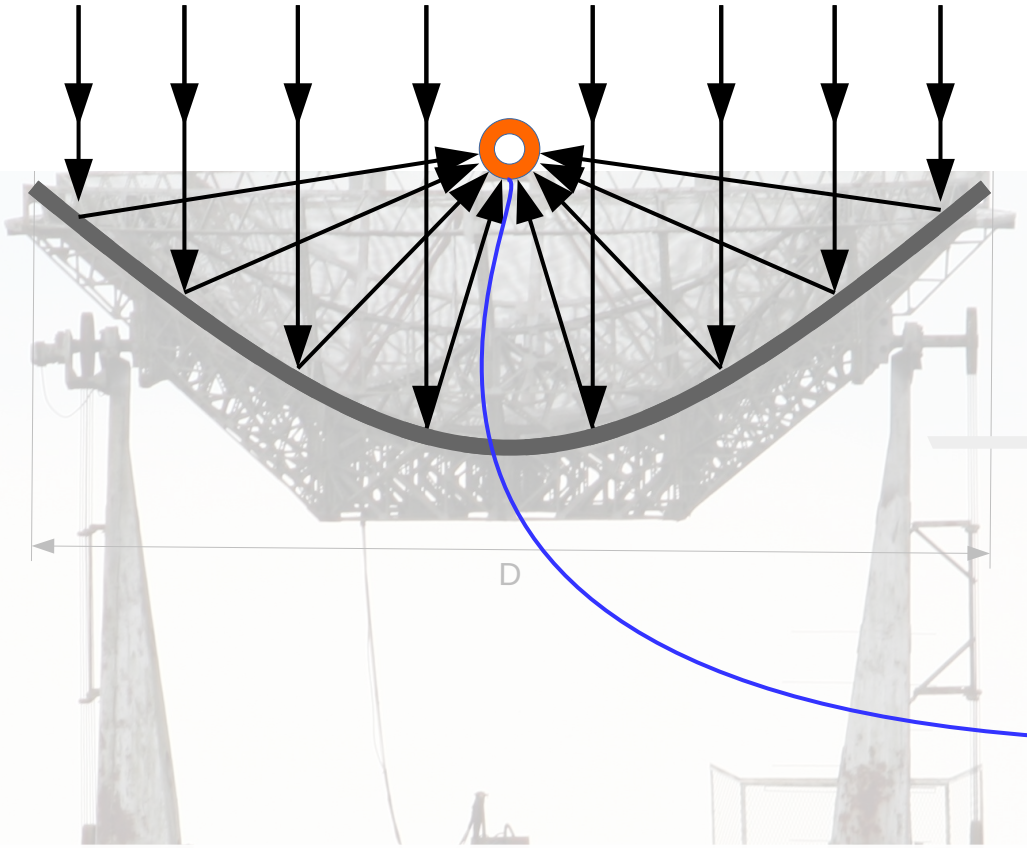
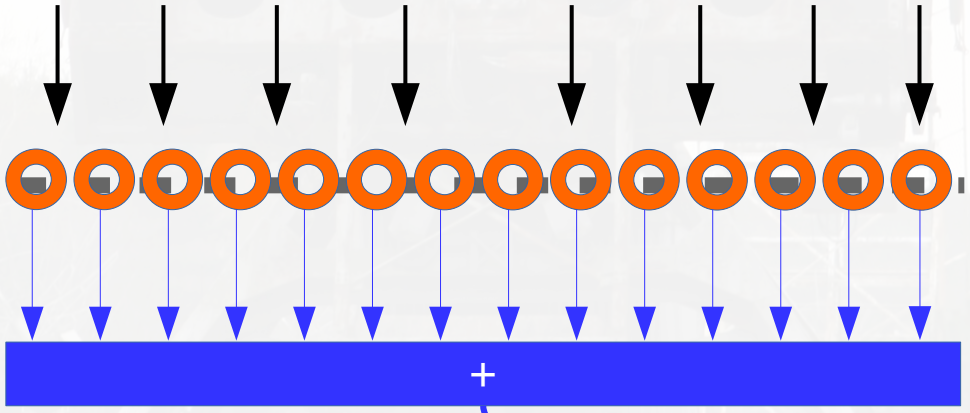
UnDySPuTeD : dynamic spectra
•Channelization
•Integration
UnDySPuTeD : pulsar
•Coherent dedispersion
•Folding / Integration
SETI Machine
NenuFAR Standalone Beamformer

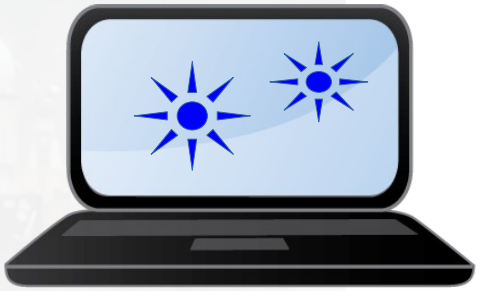
On-site mini-arrays and computing facilities



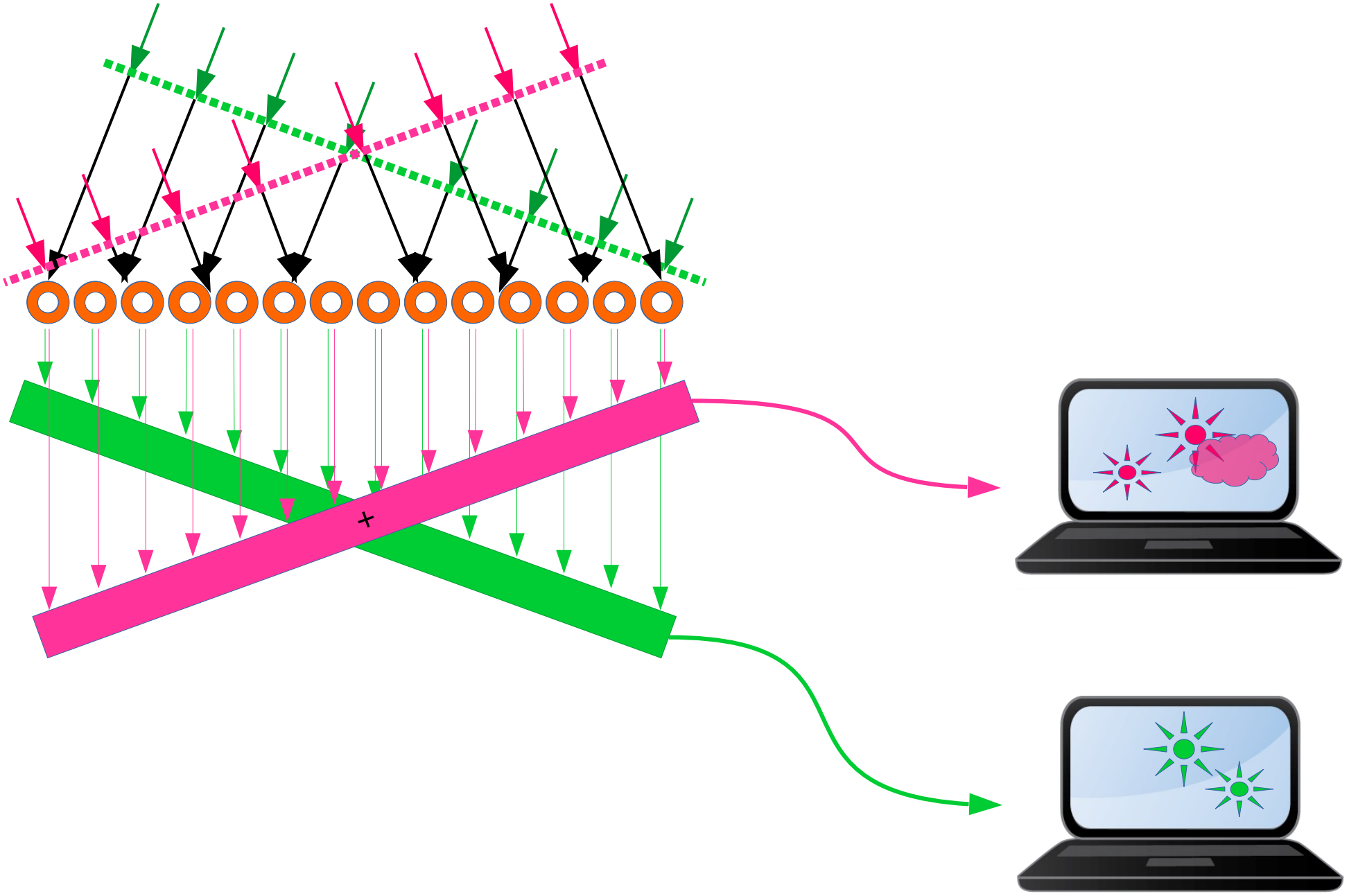


- Grande *surface* collectrice
  → sensibilité $\propto D^2$
- Grande extension
  → résolution spatiale $\propto \frac{\lambda}{D}$





NenuFAR : Presentation & updates on the system



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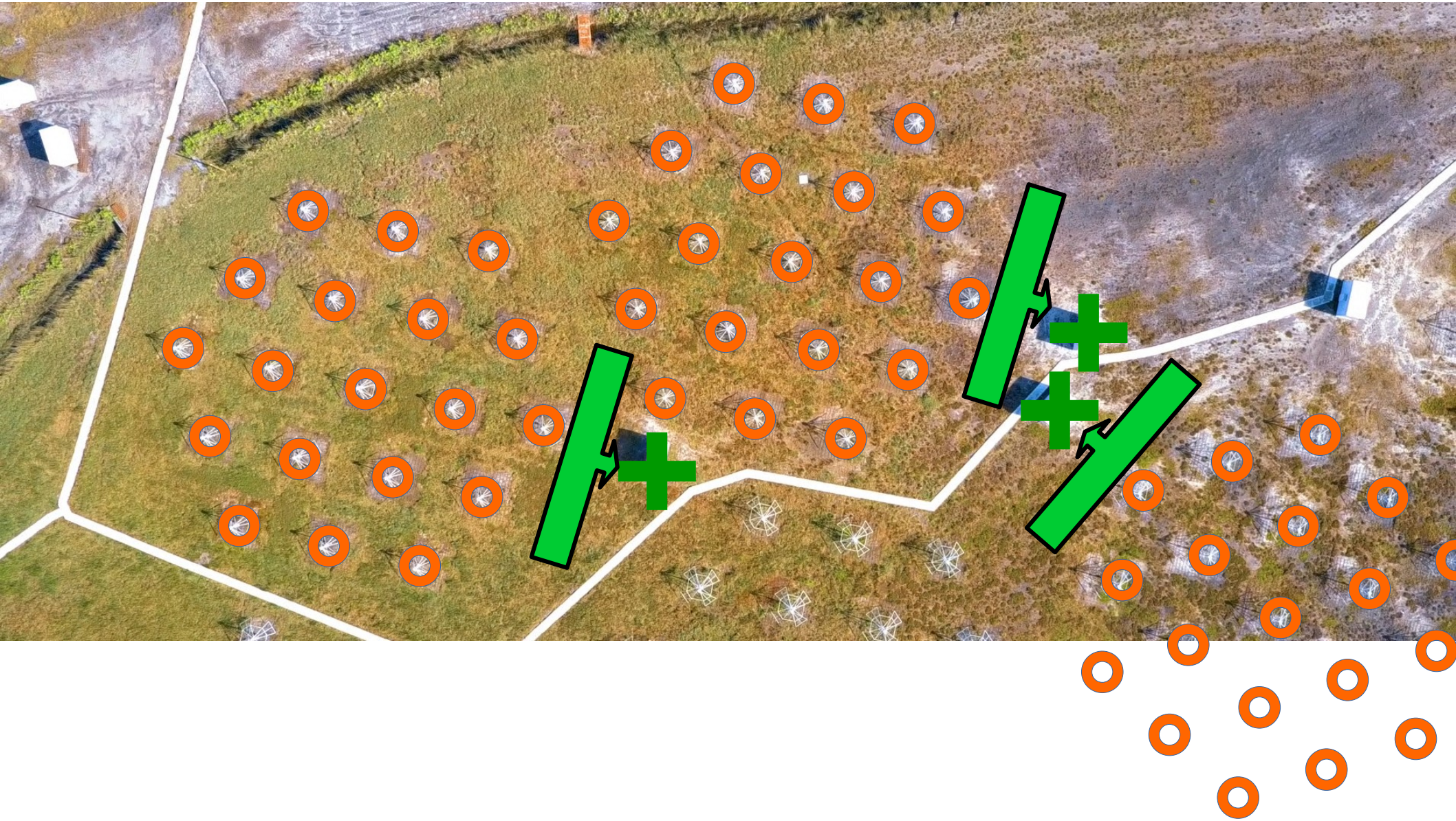

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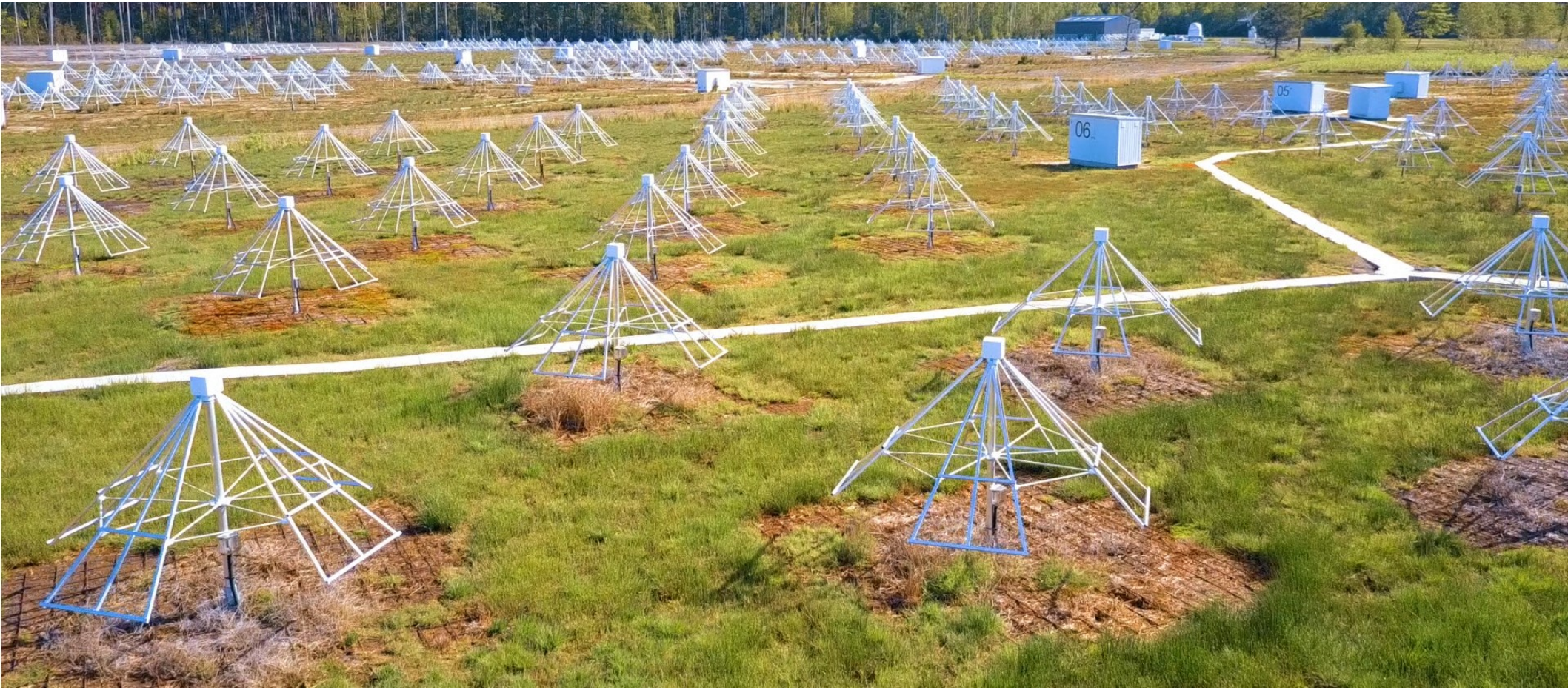

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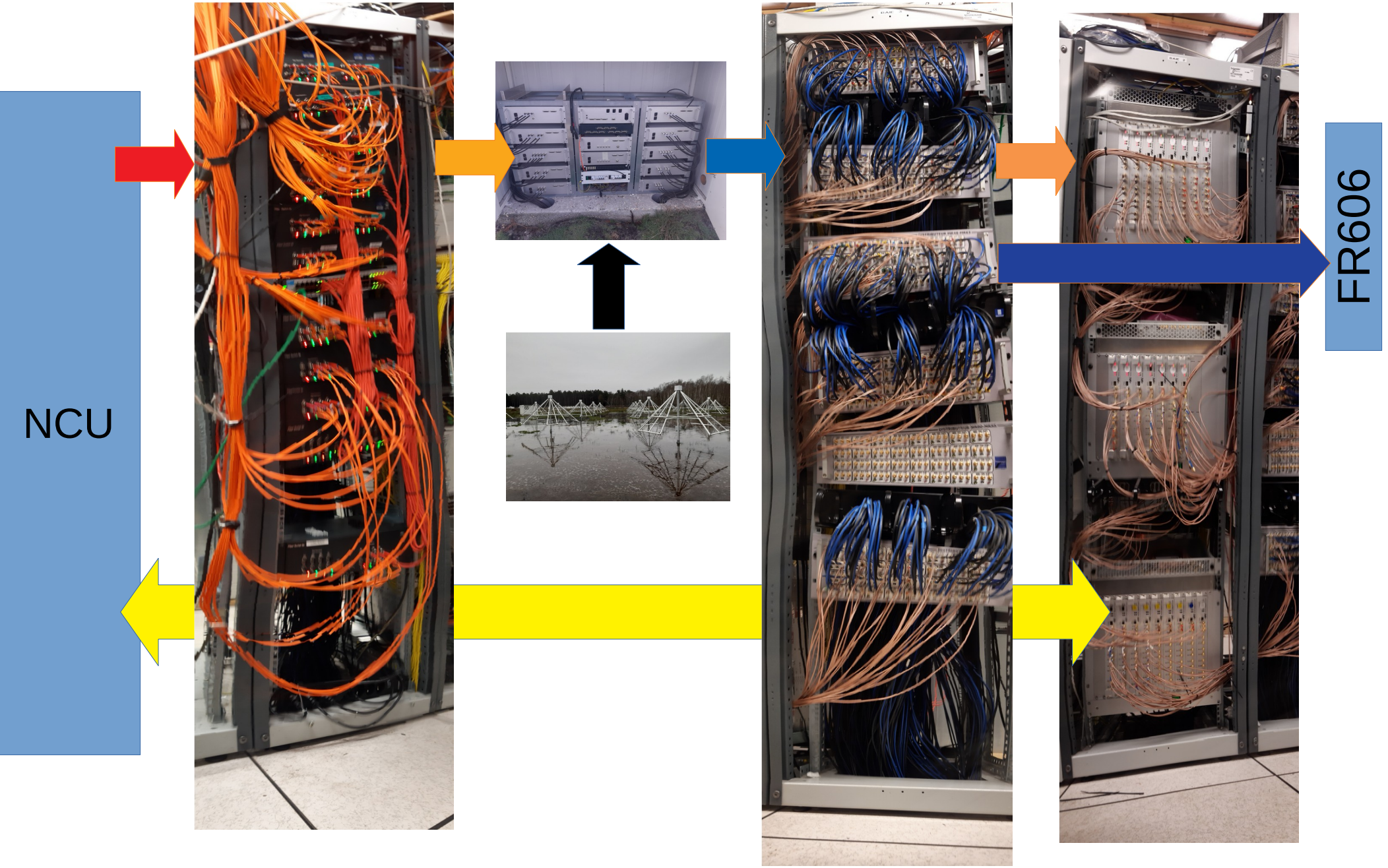
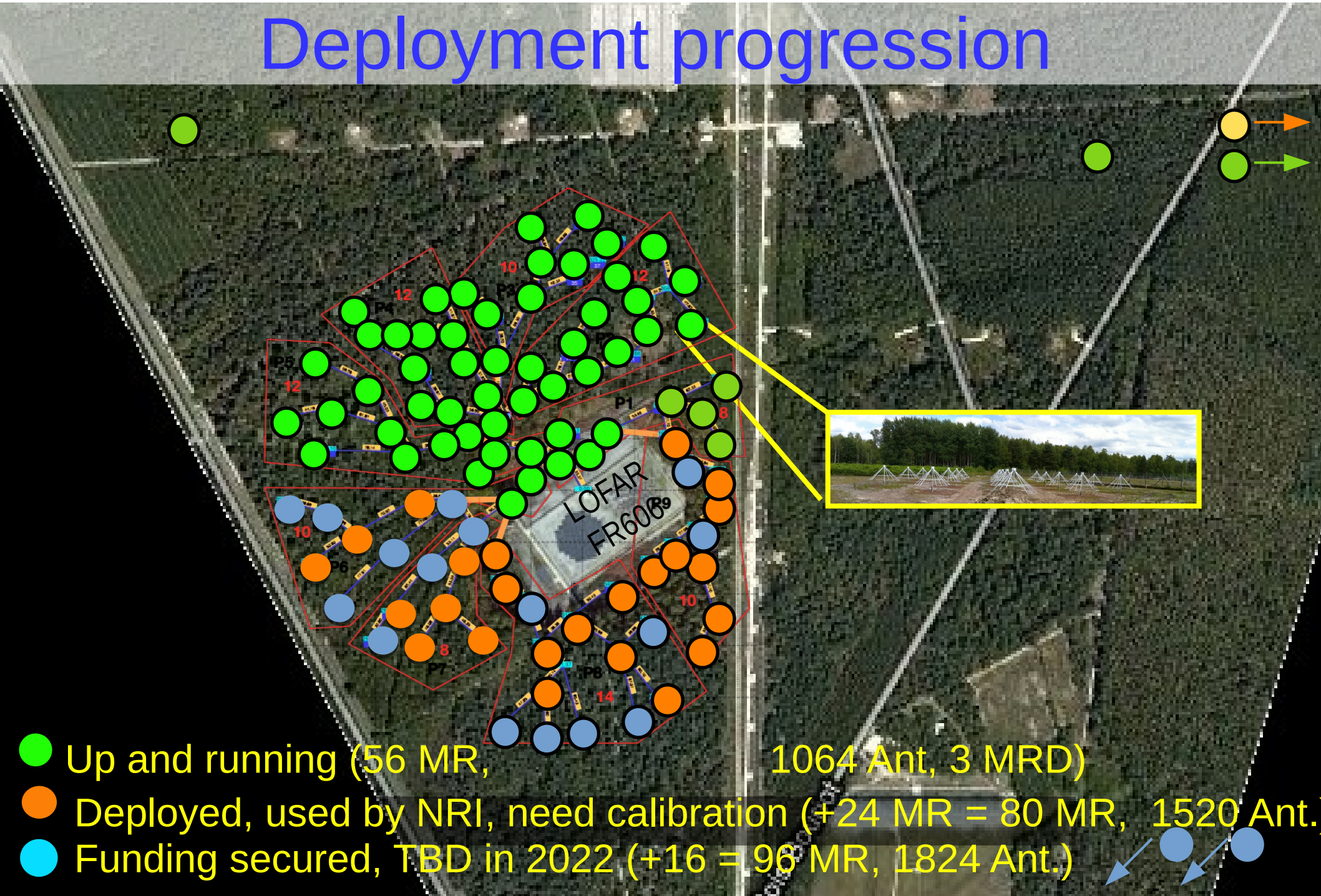
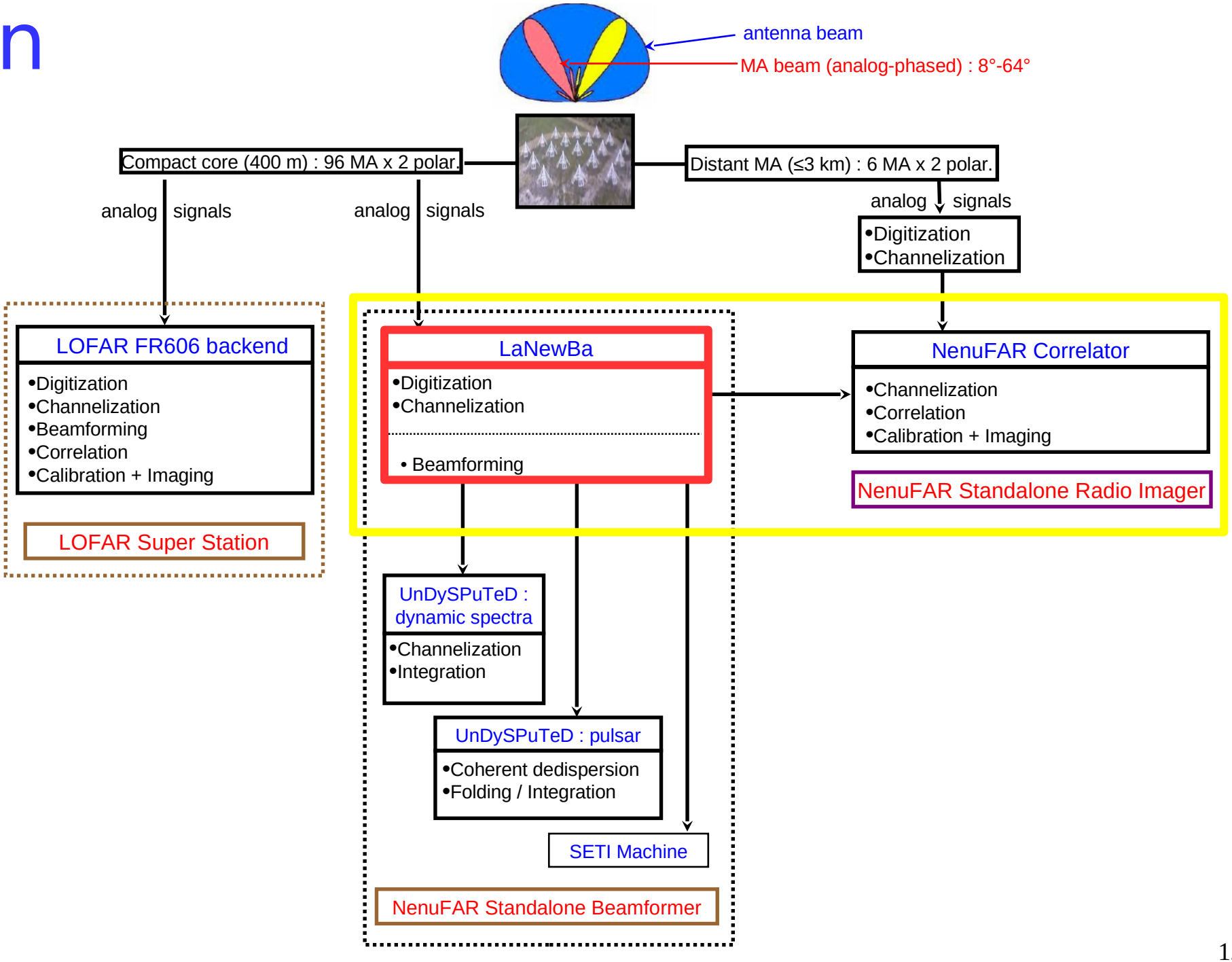


Deployment progression



- Up and running (56 MR, 1064 Ant, 3 MRD)
- Deployed, used by NRI, need calibration (+24 MR = 80 MR, 1520 Ant.)
- Funding secured, TBD in 2022 (+16 = 96 MR, 1824 Ant.)

Plan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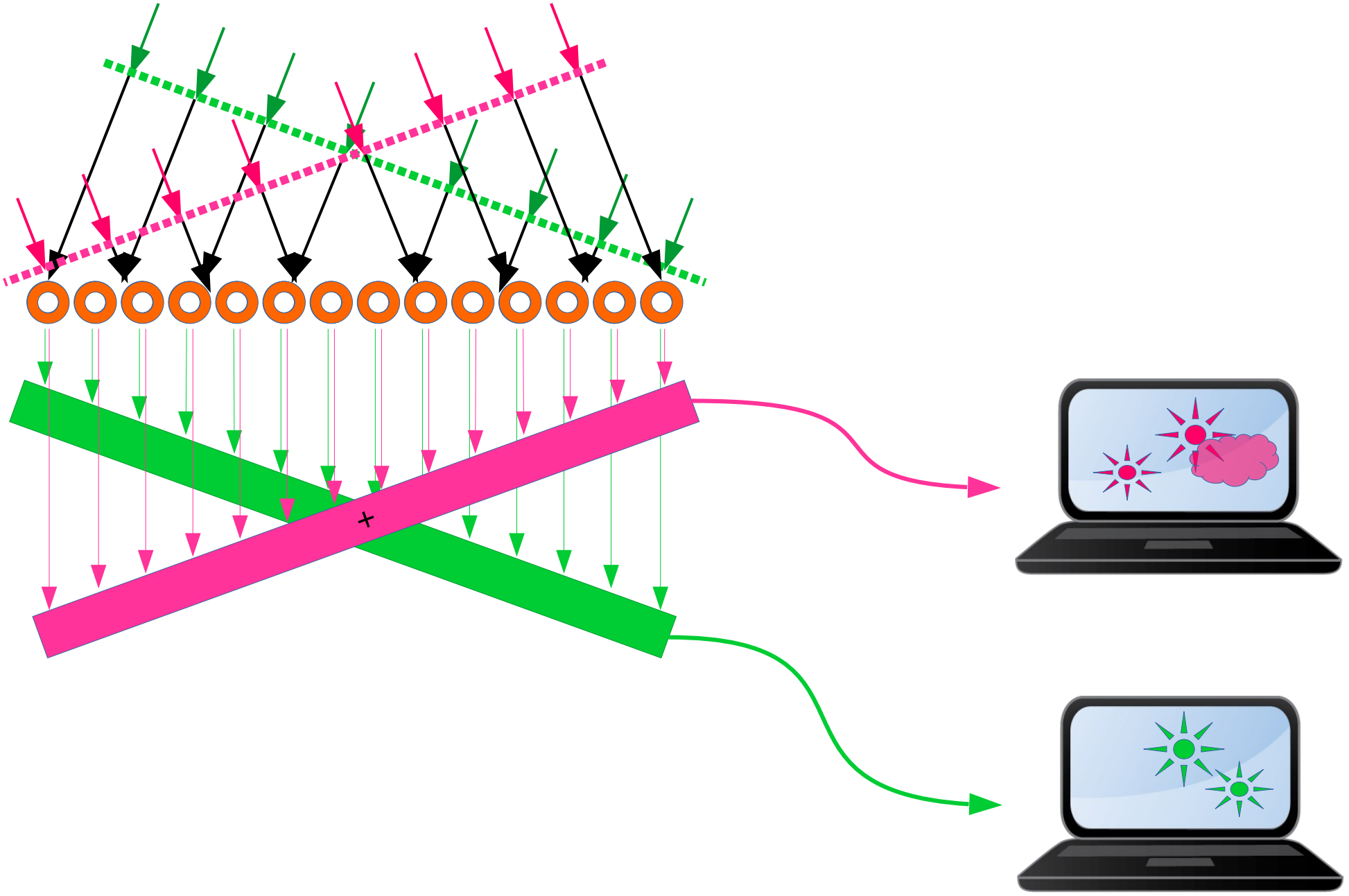
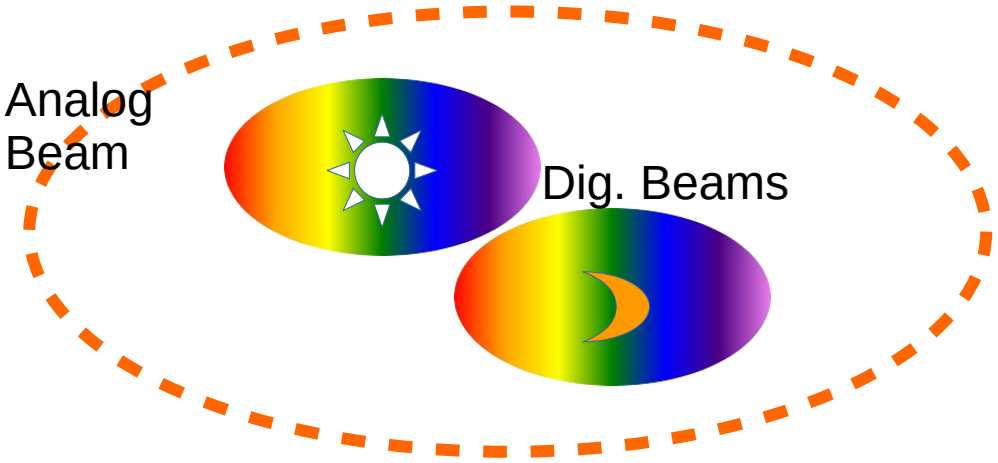
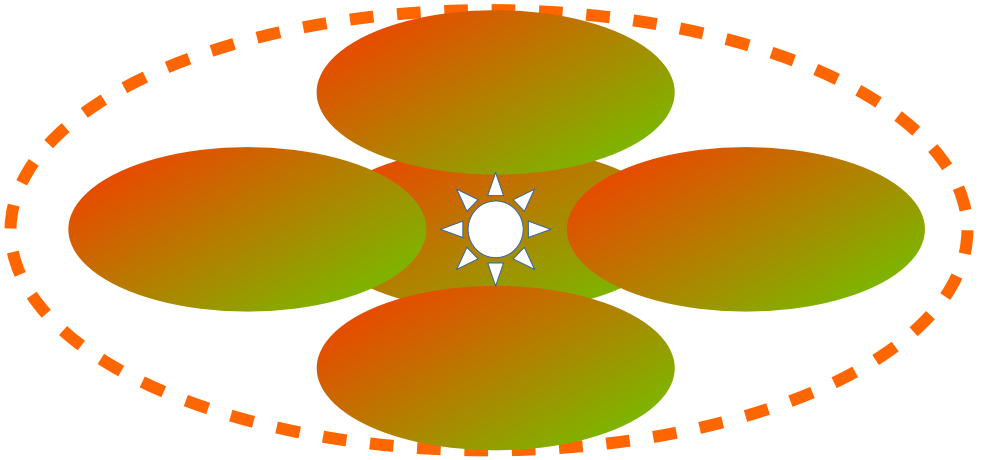
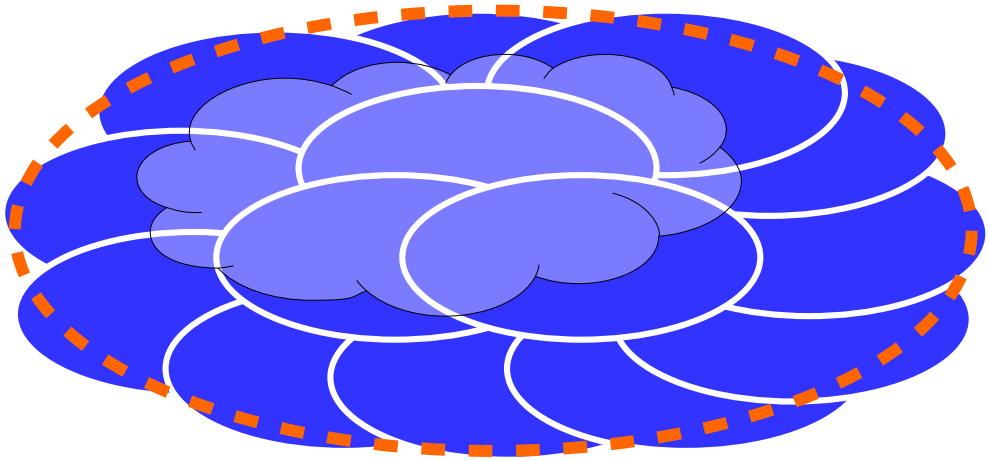


Possible configuration of beamforming







Your config

768 sb / 16 bits

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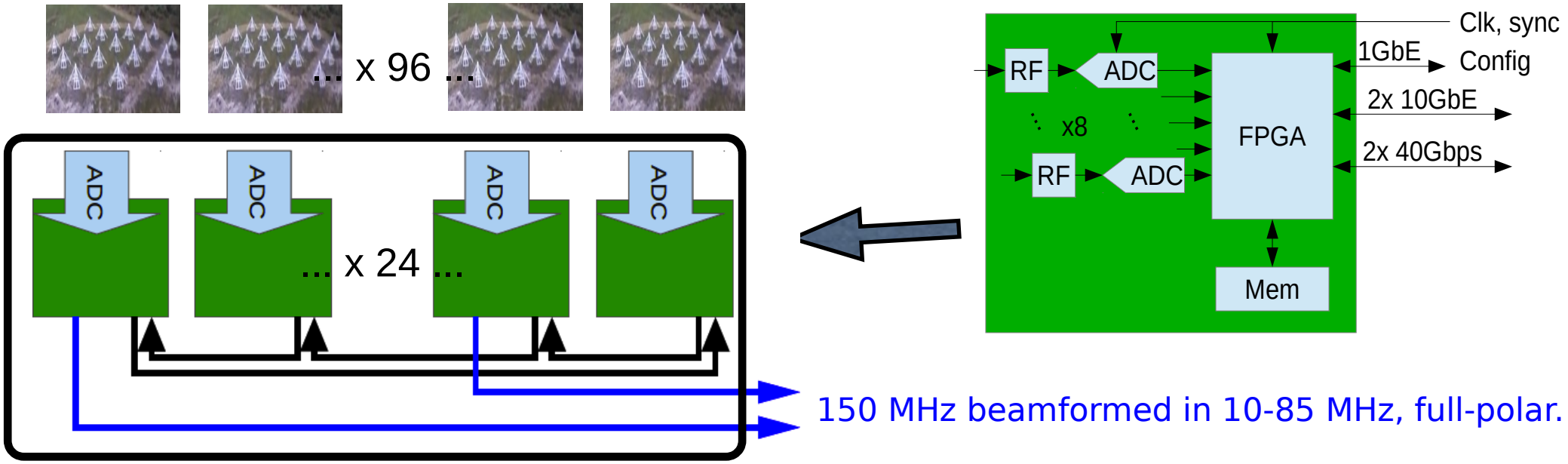

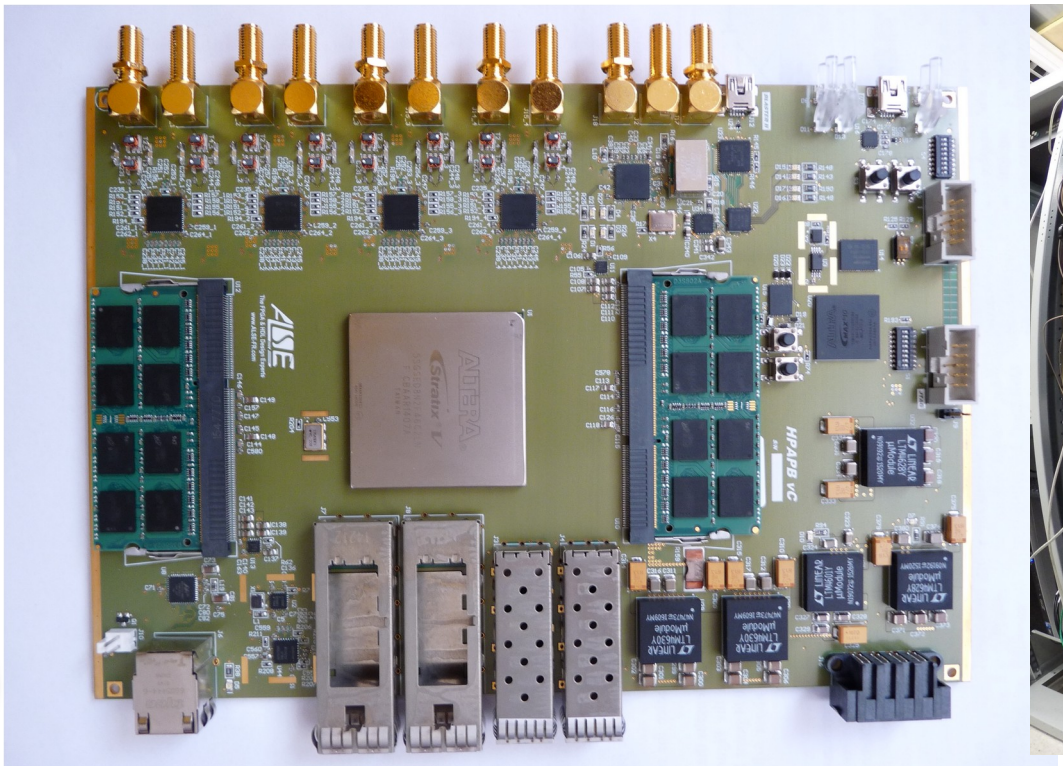

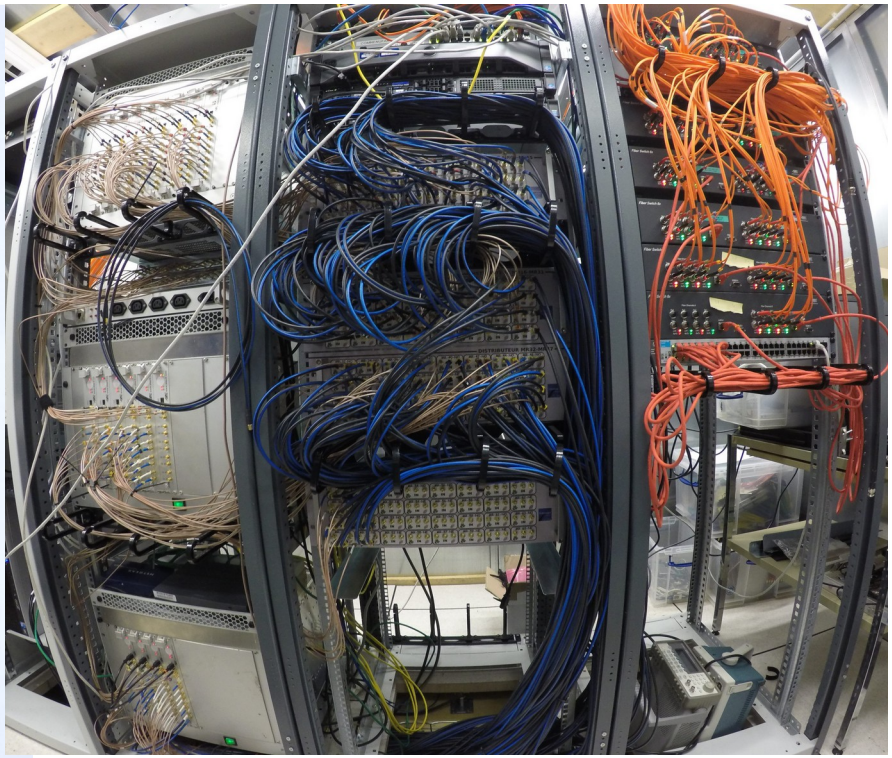

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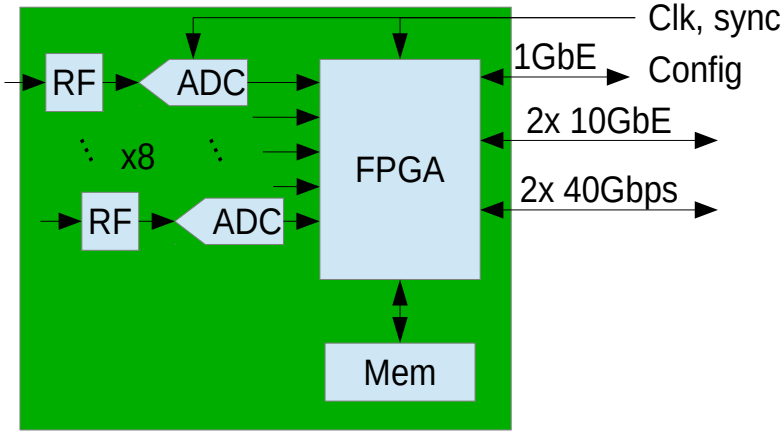
LANewBa

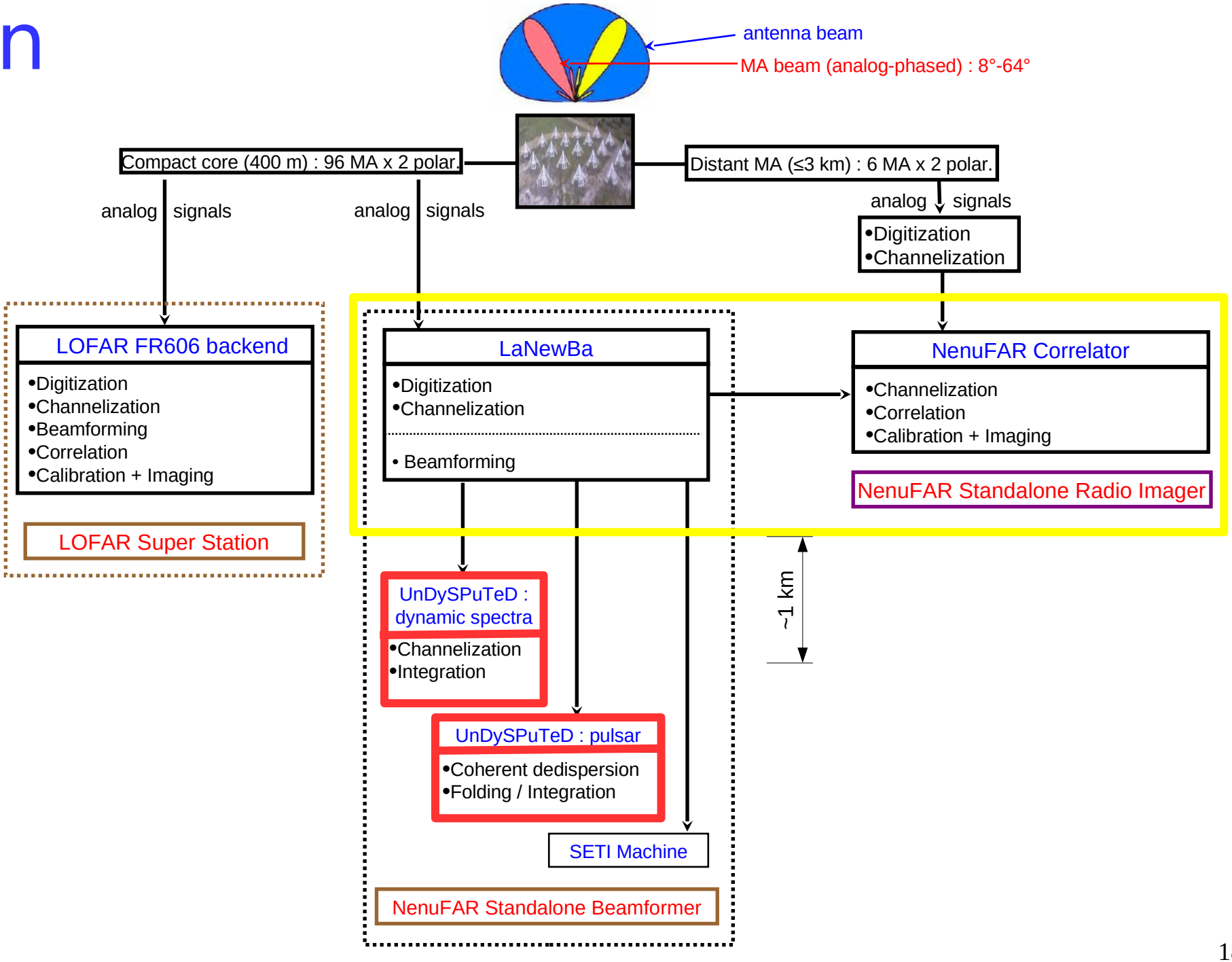
- Sampling
  - (96x2) x 200 MS/s - 14-bits ADCs (~400 MB/s/chan)
  - 64 GB/s today, 77 GB/s for full instrument, continuously 24/7
  - Synch < 0.1 ns
- Signal processing implemented on FPGA (Stratix V Altera/Intel)
  - HW interfaces subcontracted to ALSE (ADC, mémoire, 1G, 10G, 40G,...).
  - Signal processing based on VHDL code from RSP LOFAR
  - 1300 GMAC/s distributed over 24 FPGA boards
- Channelization :
  - 512 x 0.195 kHz subbands
  - 16-taps PFB + 1k-FFT (614+192 GMAC/s)



LANewBa

- Beamforming
  - Subband selection (768 from 512)
  - Delays by exp(i.phi) multiplication
  - Summation in a double ring (14 Gb/s, 58 GAcc/s)
  - 10GbE Export (4x 150-300 MB/s)
- Calibration
  - XST (16 ssb/s -> 512 ssb/30s)
    - Reflet distribution over double ring (18 Gb/s)
    - MAC distributed over the 24 FPGA boards (90 MB/s x 2.2 GB/s)
    - 461 GMAC/s
- Monitoring and diagnostics
  - SST, BST recorded continuously 24/7
  - Continuous recording of physical parameters (T°C, U, I, flags)
  - Fed into a DB
- 1 cabinet, 3 RACKS, 1500 W

Plan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~1 km
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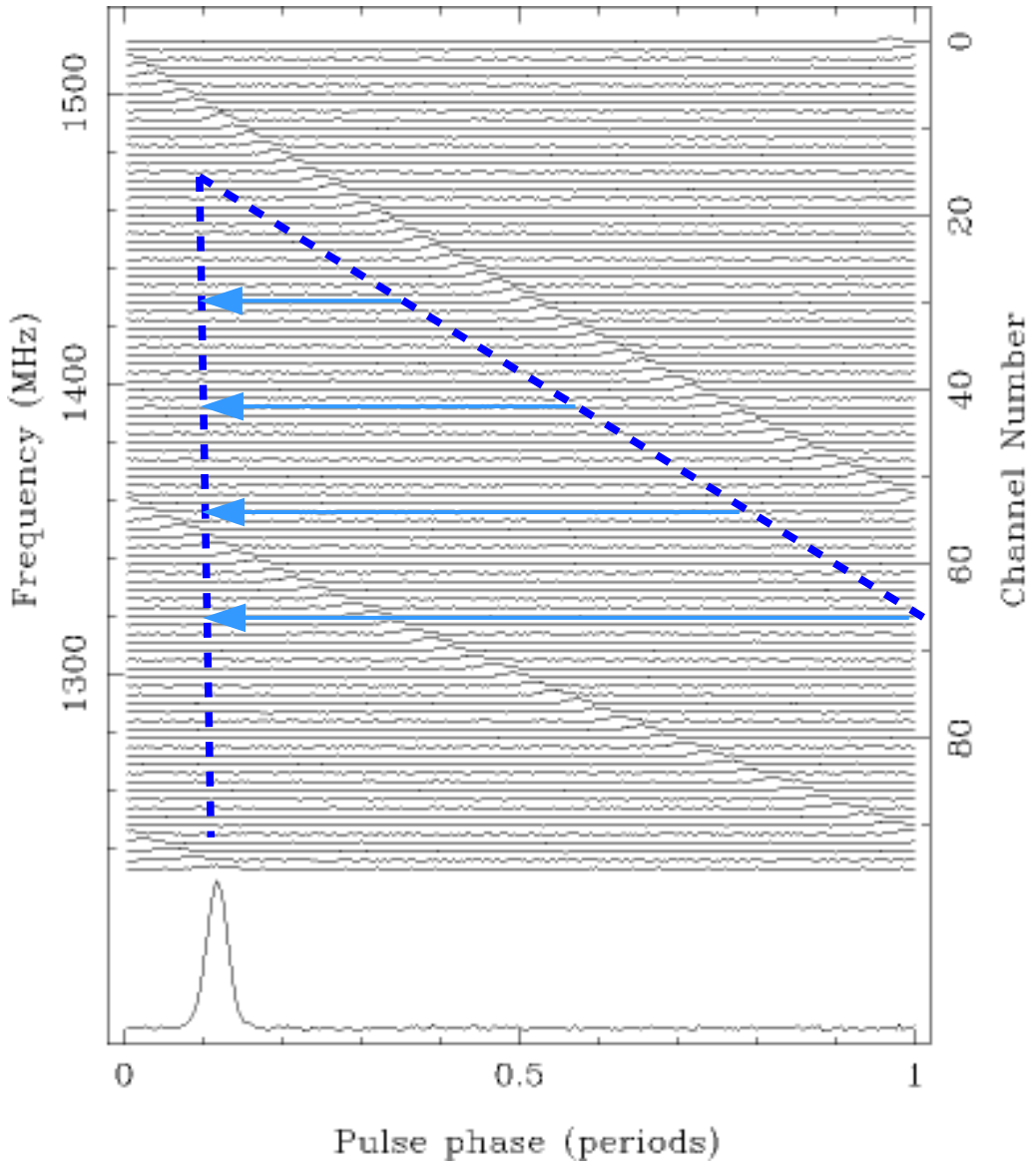
UnDySPuTeD

- 2x Servers :
  - 2x Intel Xeon E5-2620v4 8cores
  - 256GB DDR4
  - 2x GPU Nvidia GTX 1080

UnDySPuTeD dynamic spectra

- Dynamic Spectra
  - 1 à 2 streams each at 4.8 Gb/s, B=195 kHz, dt = 5.12 µs
  - win-FFT + $<|x_i.x_j|^2>$ to produce 4 Stokes, continuous, real-time
    - B_{min} = 762 Hz, dt_{min} = 1 ms
    - B_{max} = 195 kHz, dt_{max} = 1 s
  - Flux à traiter : 4x 150-300 Mo/s (int8-int16) → 1.2 Go/s (float32)
  - Calcul FFT : ~ 2 GFLOPS

UnDySPuTeD pulsar : LUPPI



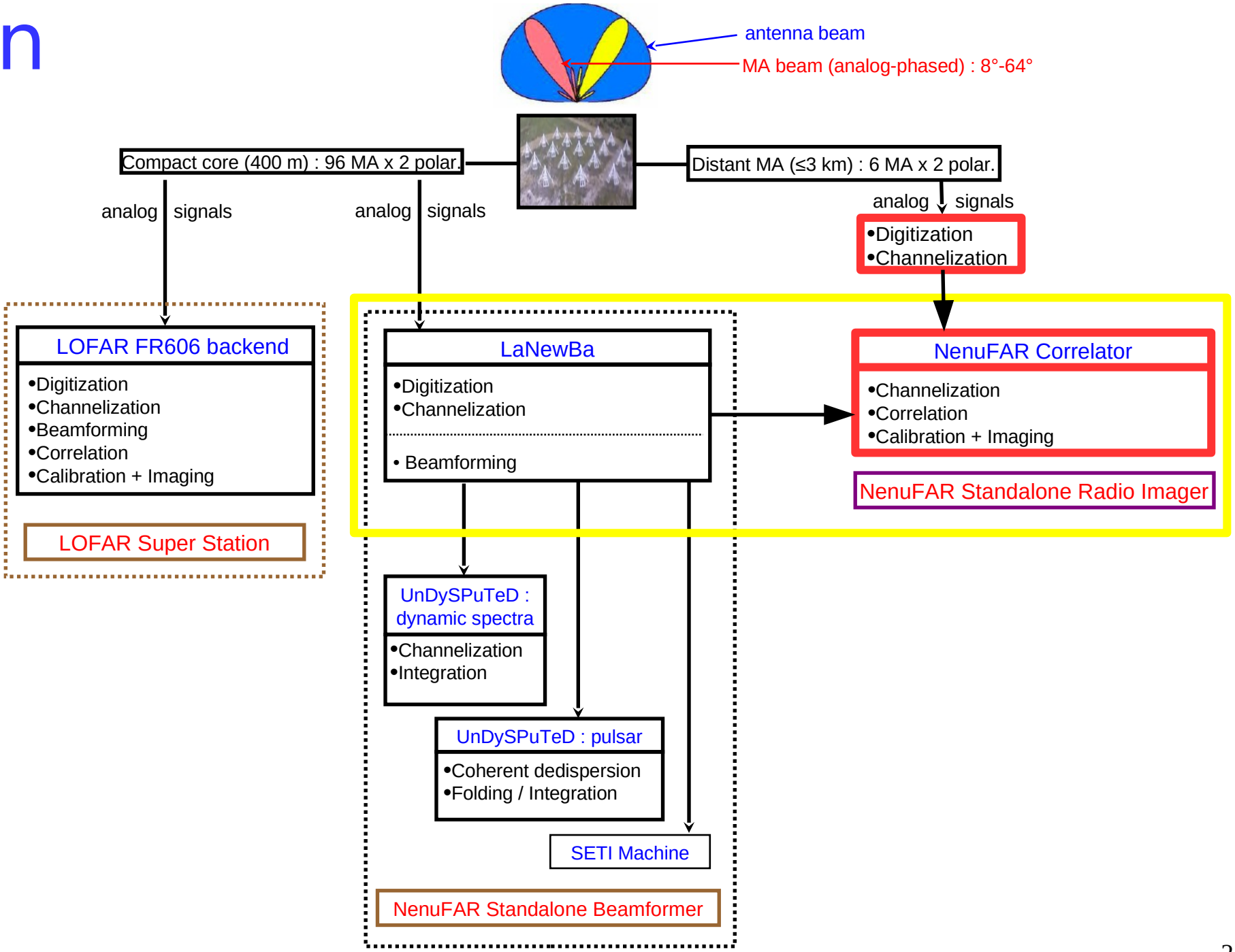
- Dedispersion code from luppi/guppi running on NRT

$$H(\nu+\nu_0)=\exp\left(i\,2\pi\,D\,\frac{\nu^2}{\nu_0^2(\nu+\nu_0)}\right)$$

- Modes :
  - Accumulation
  - Single pulse
  - Polarisation dedispersion

From the Handbook of Pulsar Astronomy, by Lorimer & Kramer

Plan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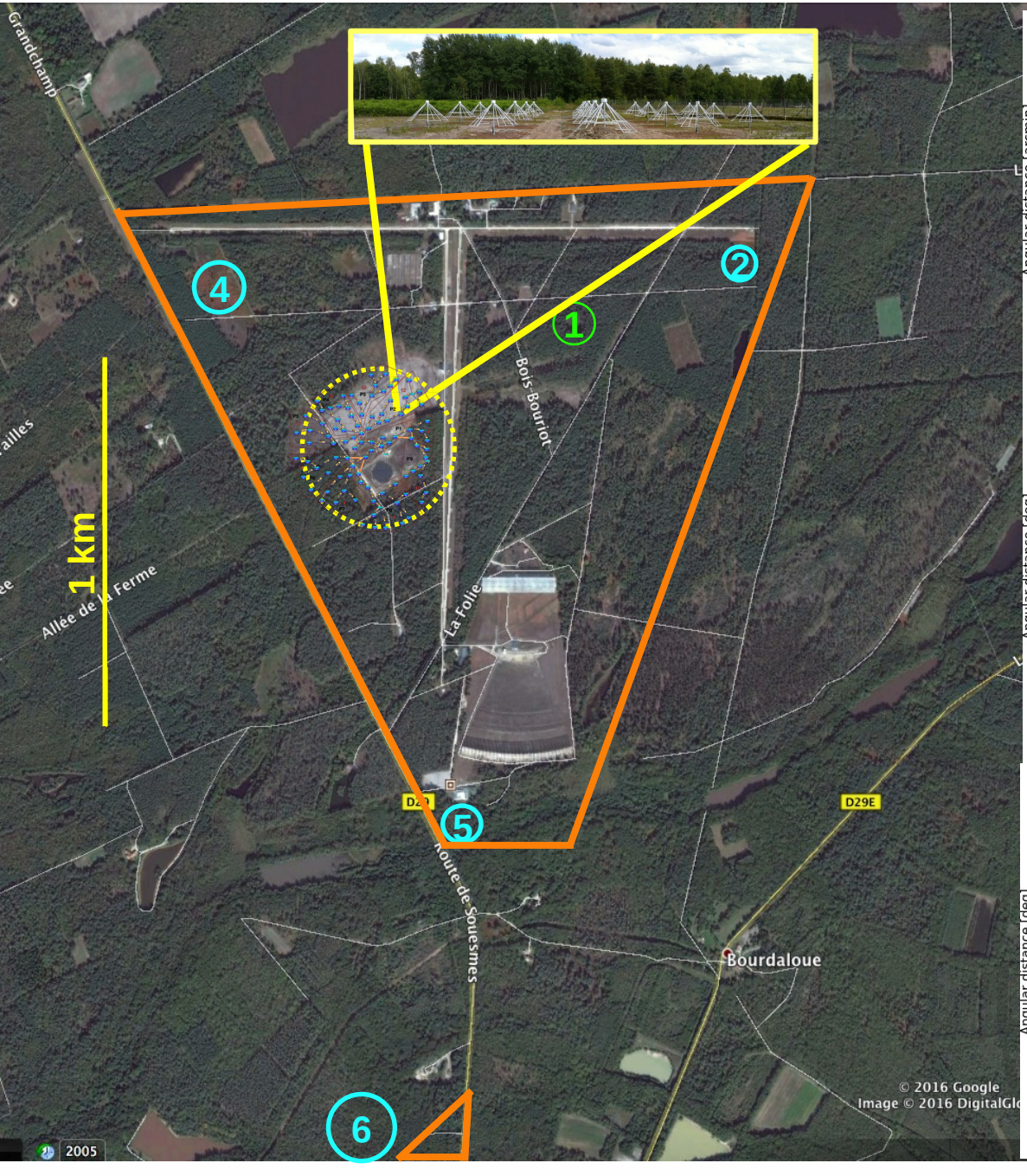
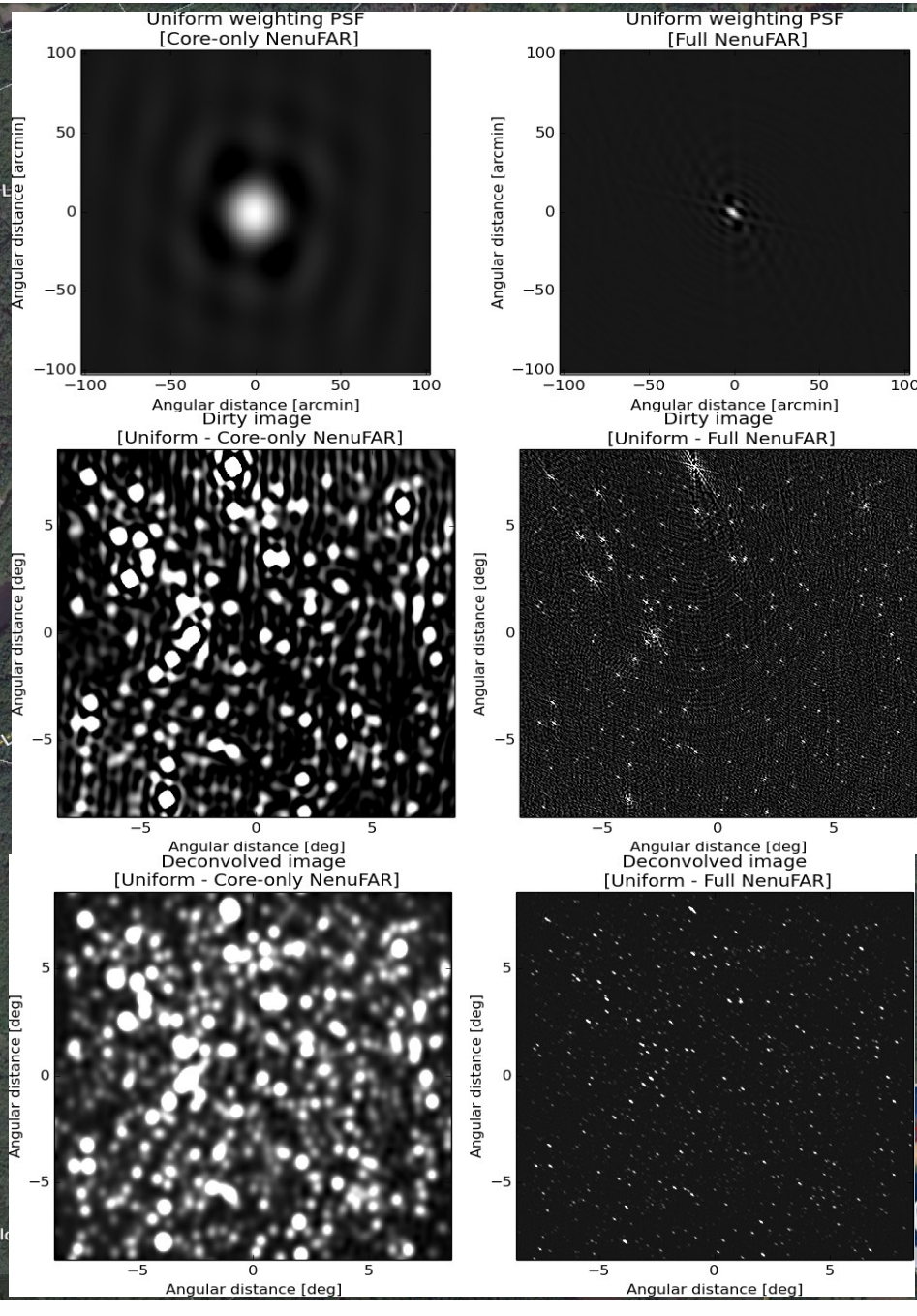
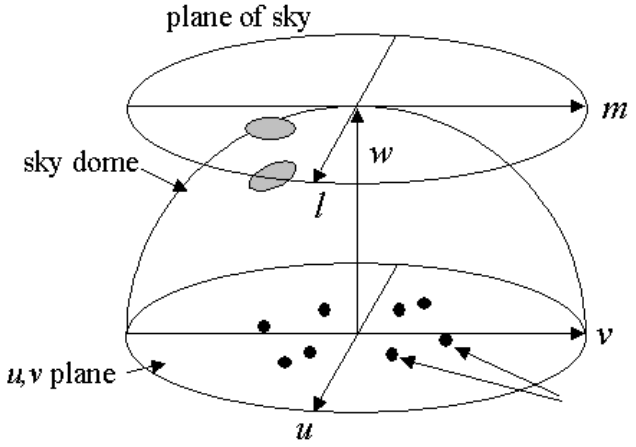
NenuFAR-Radio-Imager

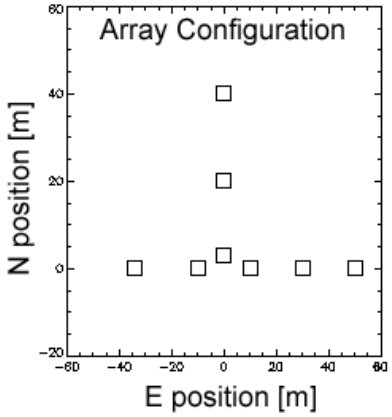
ANR «NRI» 2017-2019

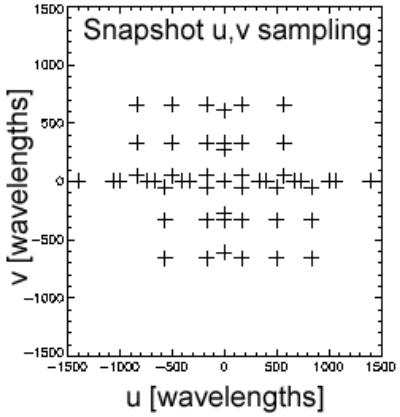


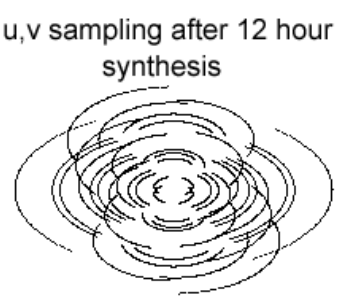


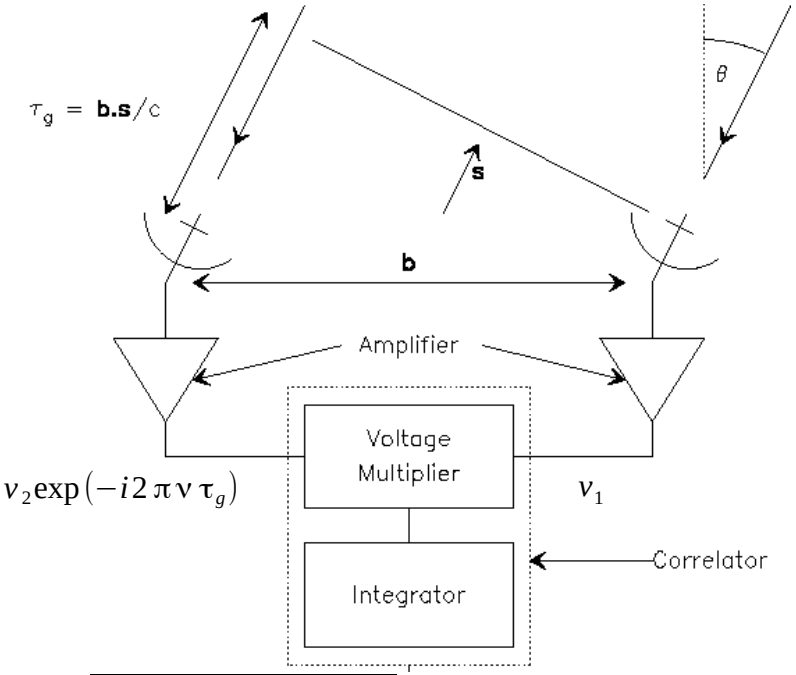
Imagerie par interférométrie radio









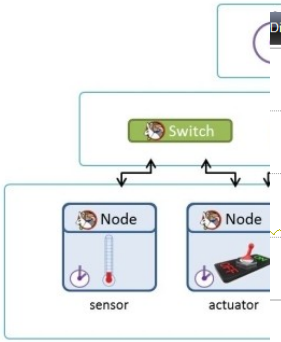


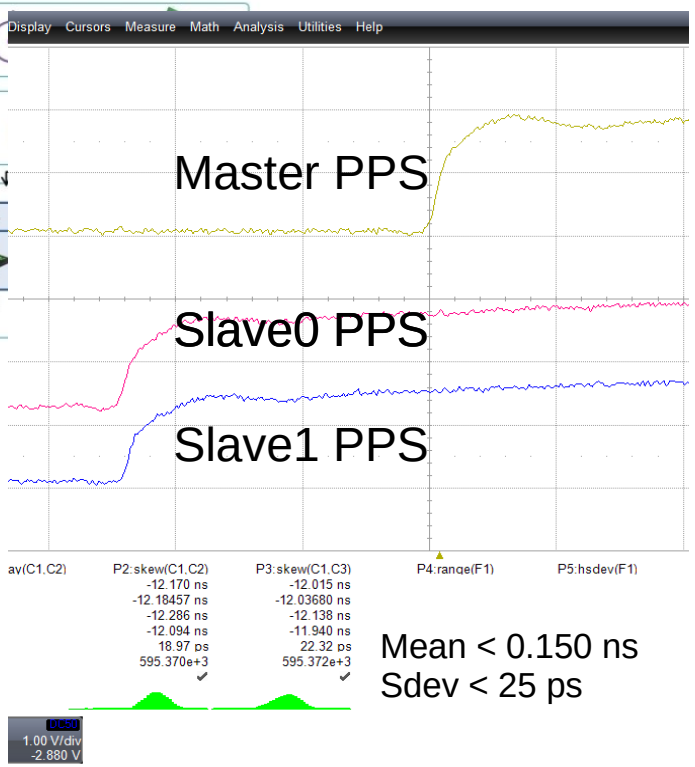
$$V = \langle v_1 \overline{v_2 \exp(-i 2\pi \nu \tau_g)} \rangle = |v_1 v_2| \exp(i 2\pi \nu \tau_g)$$

- Instrumental stability required for MRDs (remote mini-arrays)
- N feeds → N(N+1)/2 visibilities
  - 96 MRs + 6 MRDs polarisés → 20k visibilities
- Antennae/Freq transpose is costly

NenuFAR-Radio-Imageur

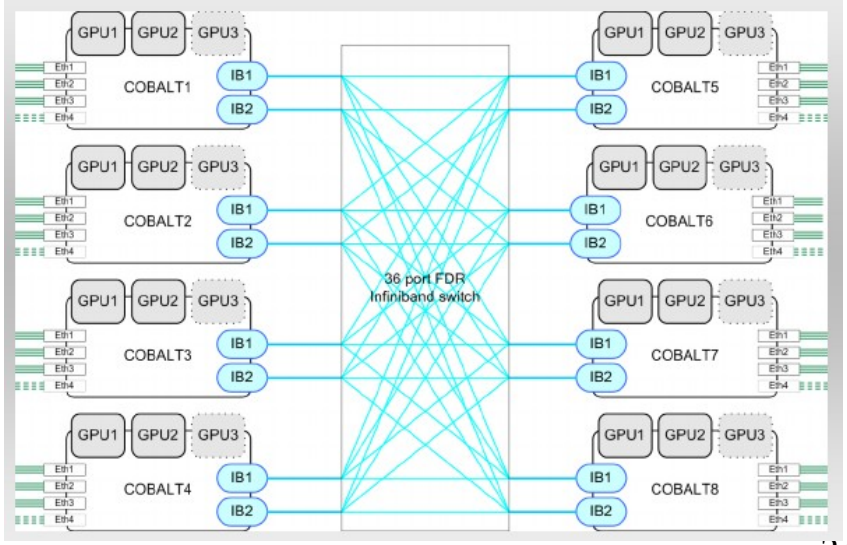
- Remote Digitization
  - WhiteRabbit network
    - Sub-ns fiber-based timing distribution (next IEEE 1588)
    - PPS and 10 MHz refclock regenerated on-site
  - 10GbE streams of beamlets towards the correlator
  - On-field constraints (cooling, RFI shielding,...)
  - 3 in production, 1 in deployment





Mean < 0.150 ns
Sdev < 25 ps

- Correlator → NICKEL
  - LOFAR-COBALT2.0 based
  - 102 antenna fields
  - 384 subbands (75 MHz) (only 244 now)
- Storage → COPPER
  - Real-time recording of MS
  - Automatic pre-processing (under dev)



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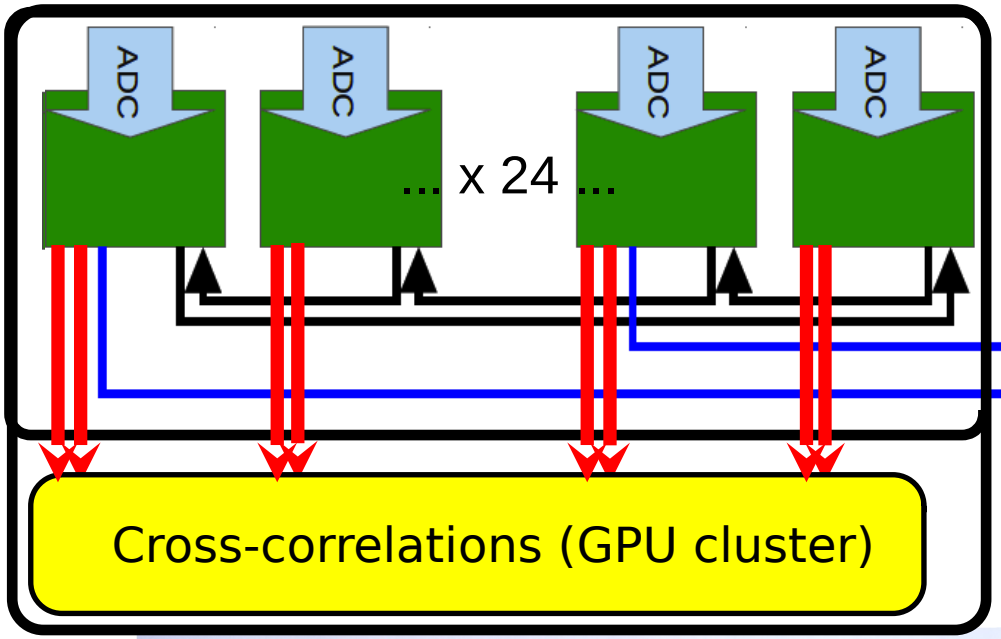
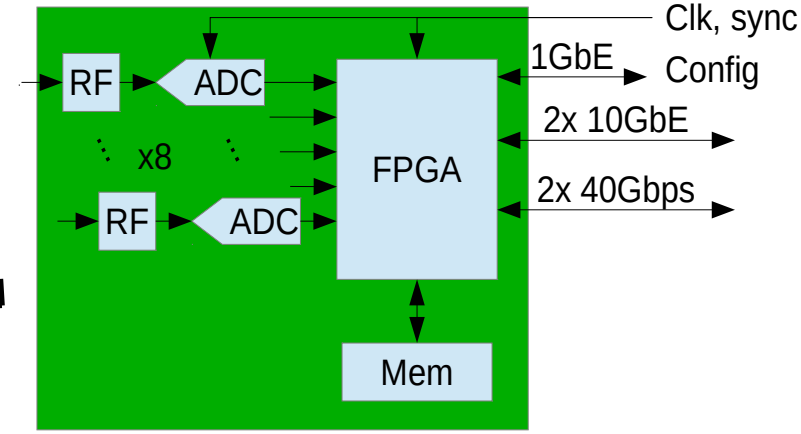
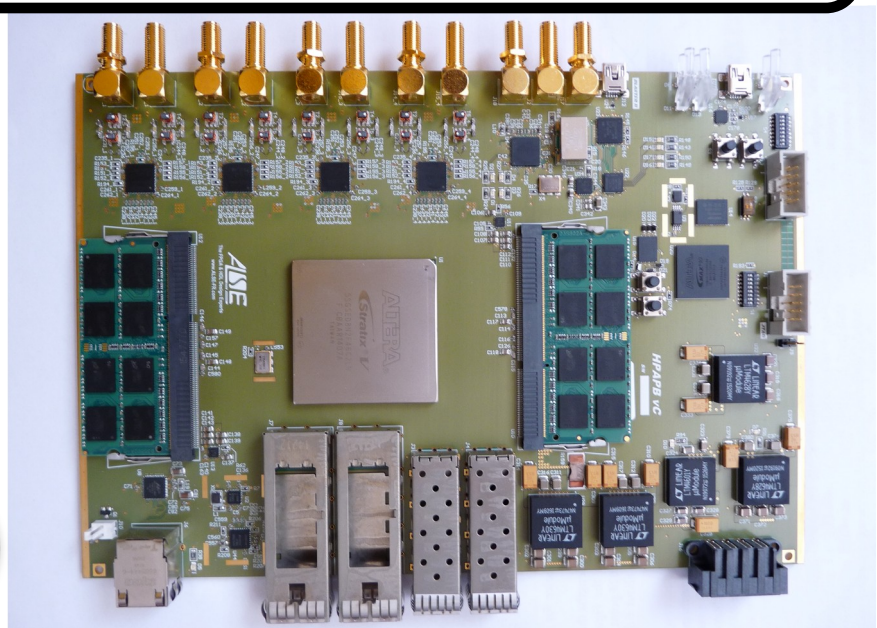




2 beams full-band (~10-85 MHz), full-polar.



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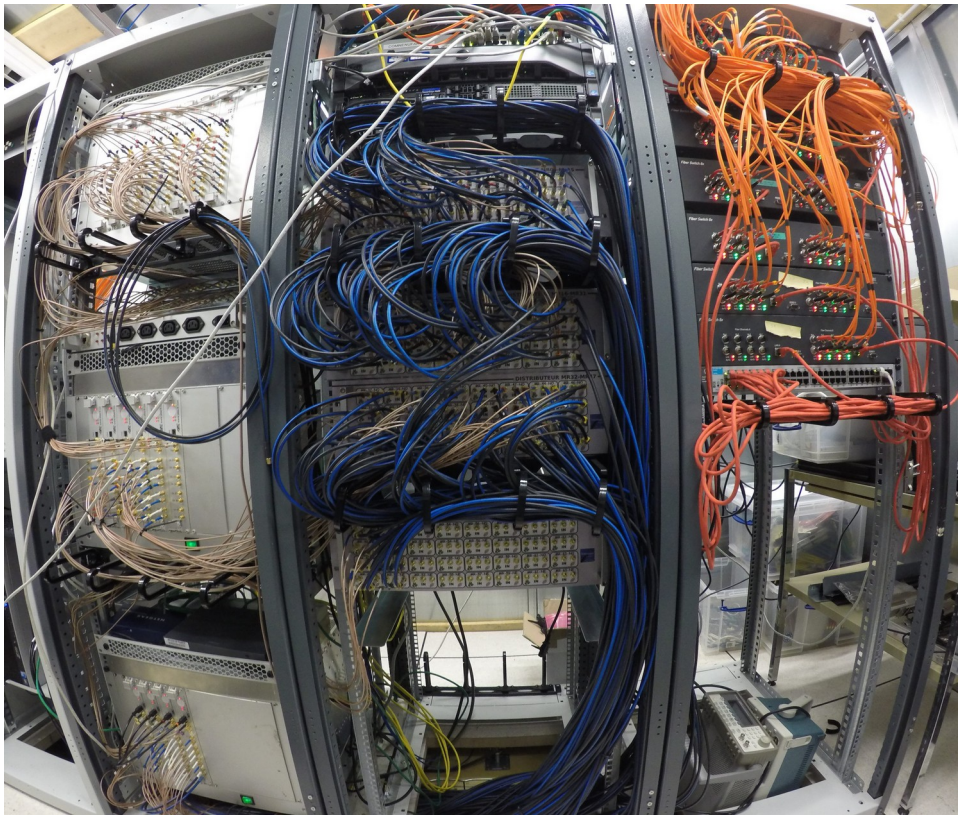
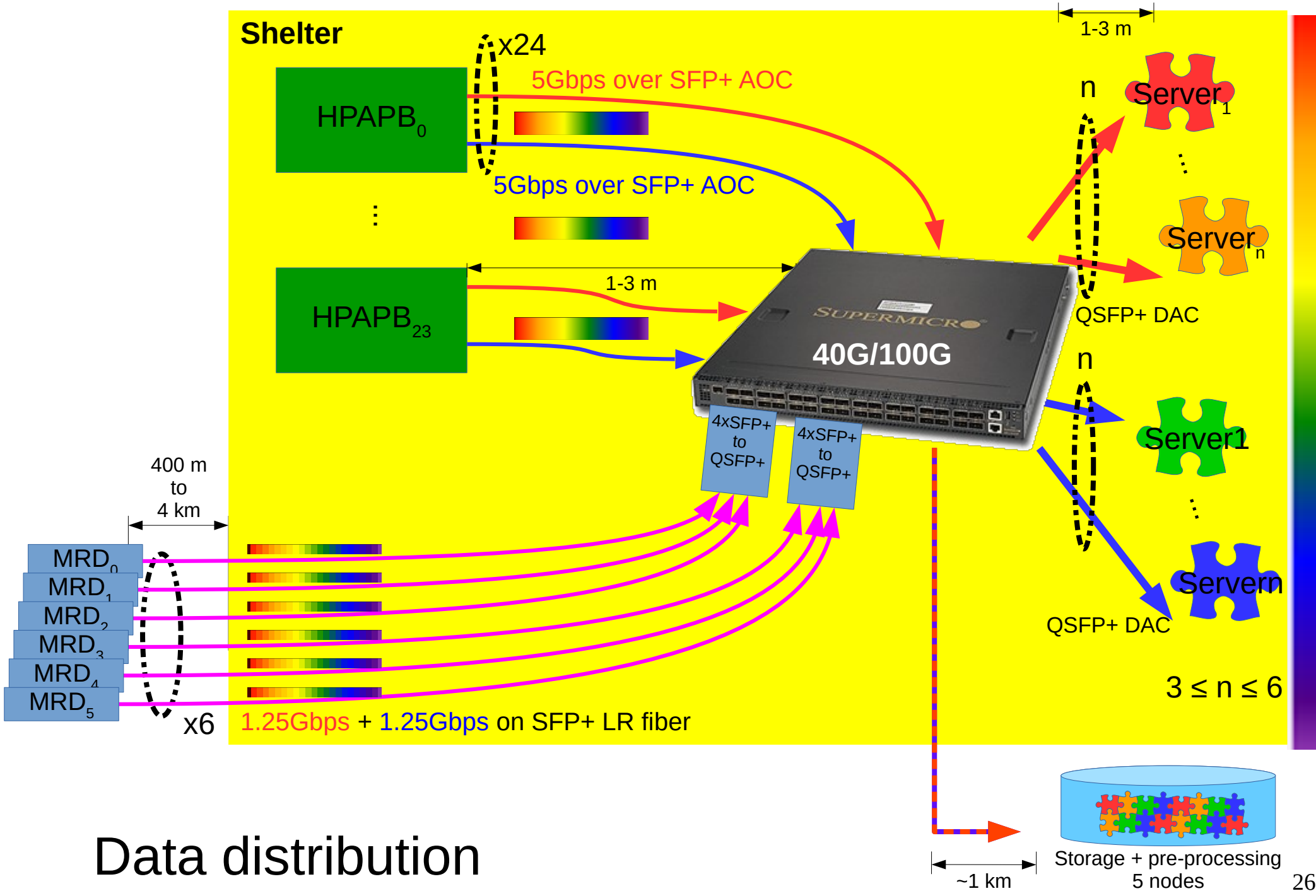
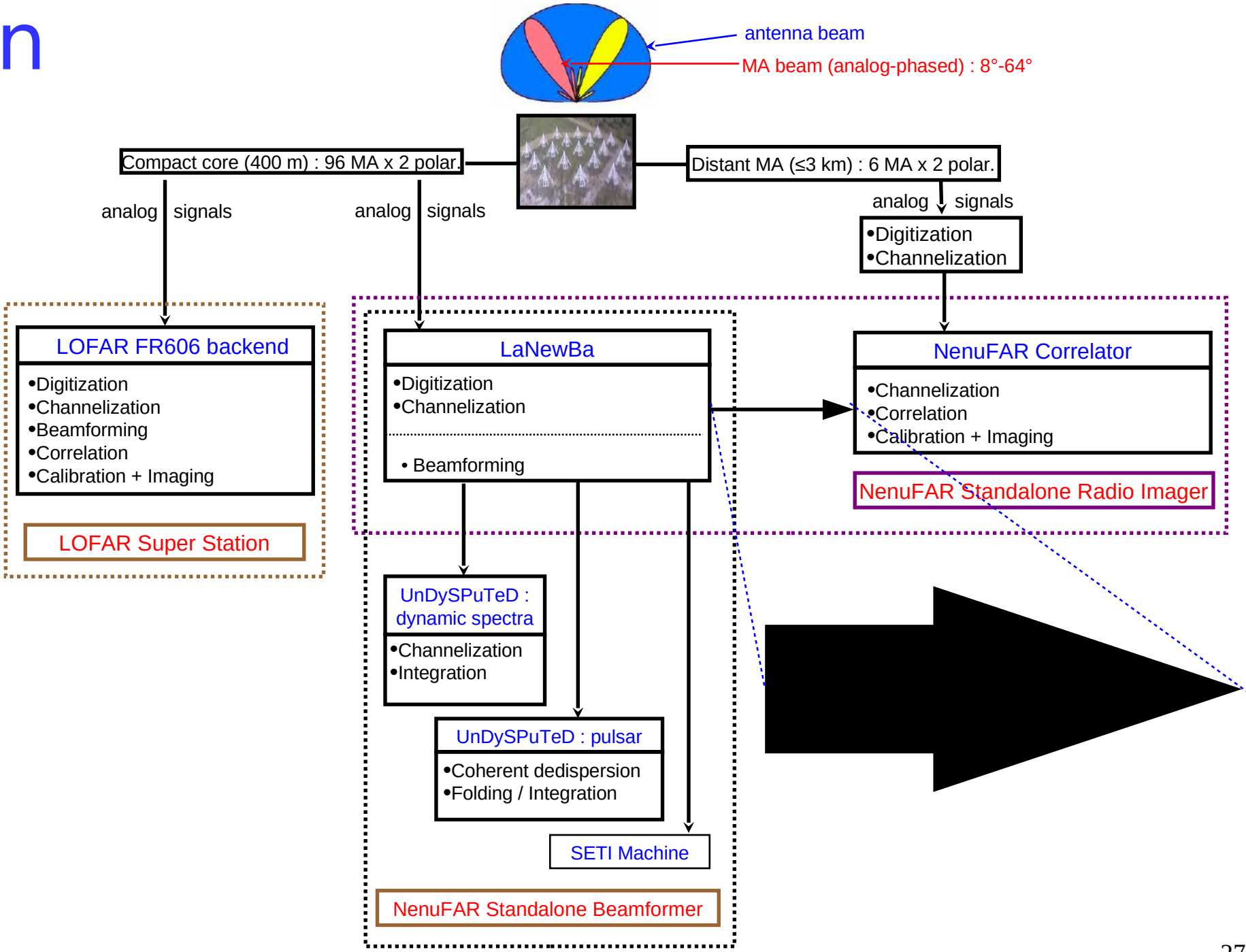




Data distribution

Plan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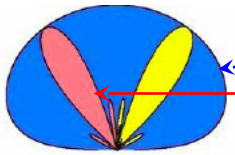

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- Beamforming
- Correlation
- Calibration + Imaging

LOFAR Super Station

LaNewBa

- Digitization
- Channelization

- Beamforming

NenuFAR Correlator

- Channelization
- Correlation
- Calibration + Imaging

NenuFAR Standalone Radio Imager

UnDySPuTeD : dynamic spectra

- Channelization
- Integration

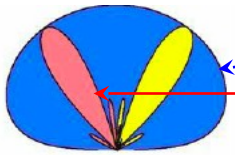
UnDySPuTeD : pulsar

- Coherent dedispersion
- Folding / Integration

SETI Machine

NenuFAR Standalone Beamformer

Plan



Compact core (400 m) : 96 MA x 2 polar.

Distant MA (≤3 km) : 6 MA x 2 polar.

analog signals

analog signals

analog signals

- Digitization
- Channelization

LOFAR FR606 backend

- Digitization
- Channelization
- Beamforming
- Correlation
- Calibration + Imaging

LOFAR Super Station

× 8

LaNewBa

- Digitization
- Channelization

- Beamforming

NenuFAR Correlator

- Channelization
- Correlation
- Calibration + Imaging

NenuFAR Standalone Radio Imager

RadioGaGA

- Digitization
- Incoherent beamforming

- Gamma detection

UnDySPuTeD : dynamic spectra

- Channelization
- Integration

UnDySPuTeD : pulsar

- Coherent dedispersion
- Folding / Integration

SETI Machine

NenuFAR Standalone Beamformer

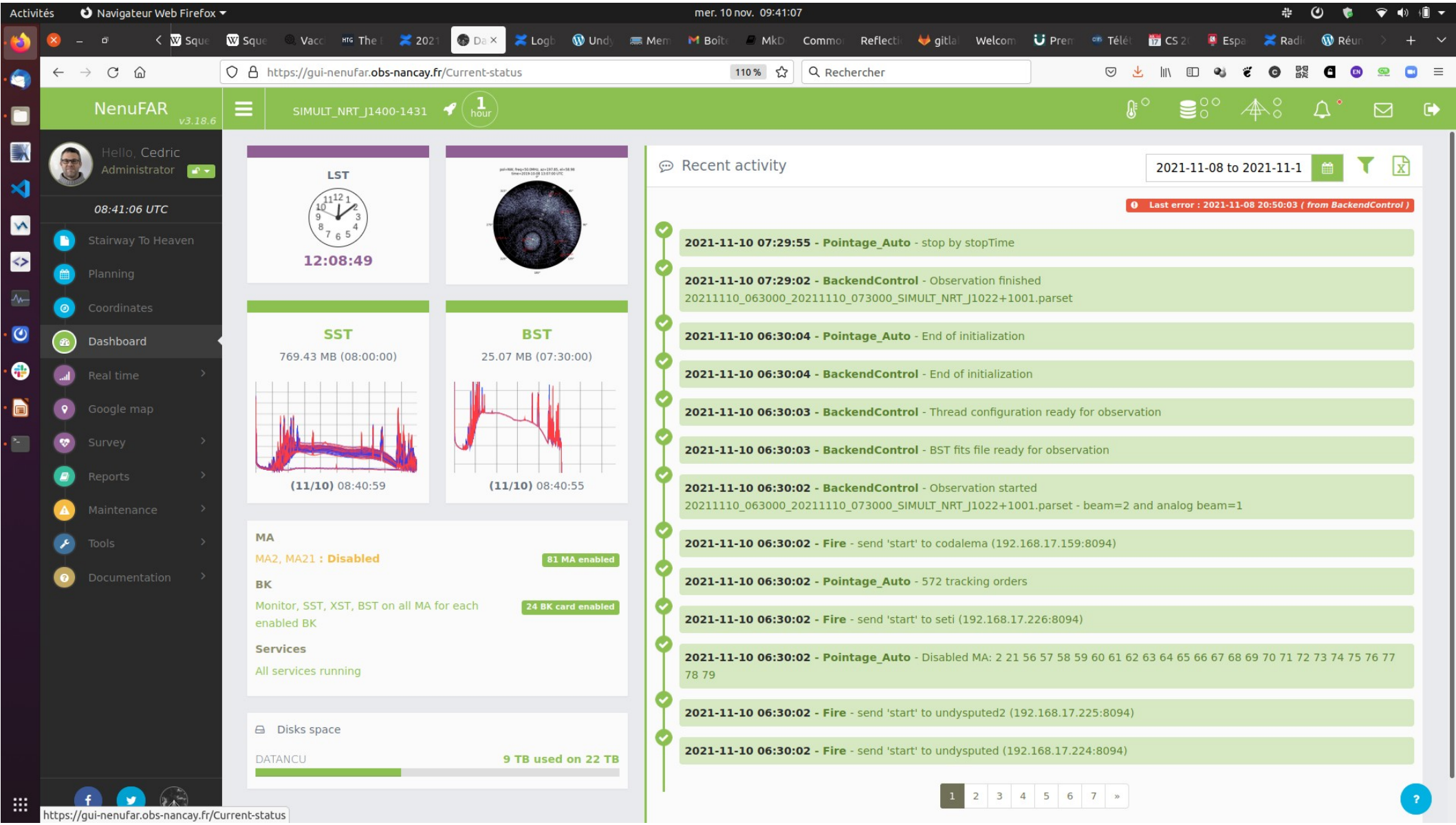
DARK ERA ANR

- Realtime imaging pipeline

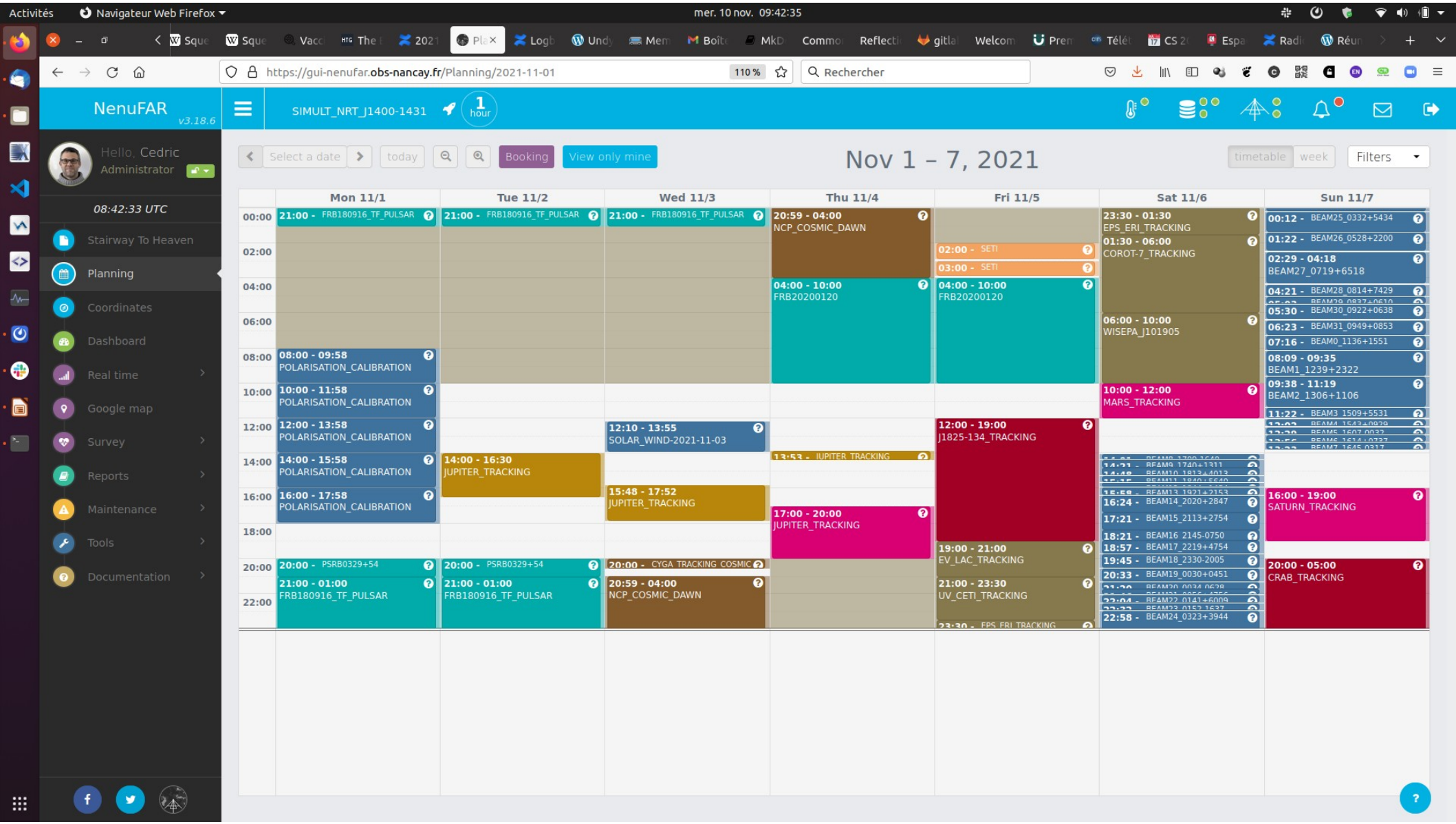
COSMIC@NENUFAR

- Automatic detection of transients

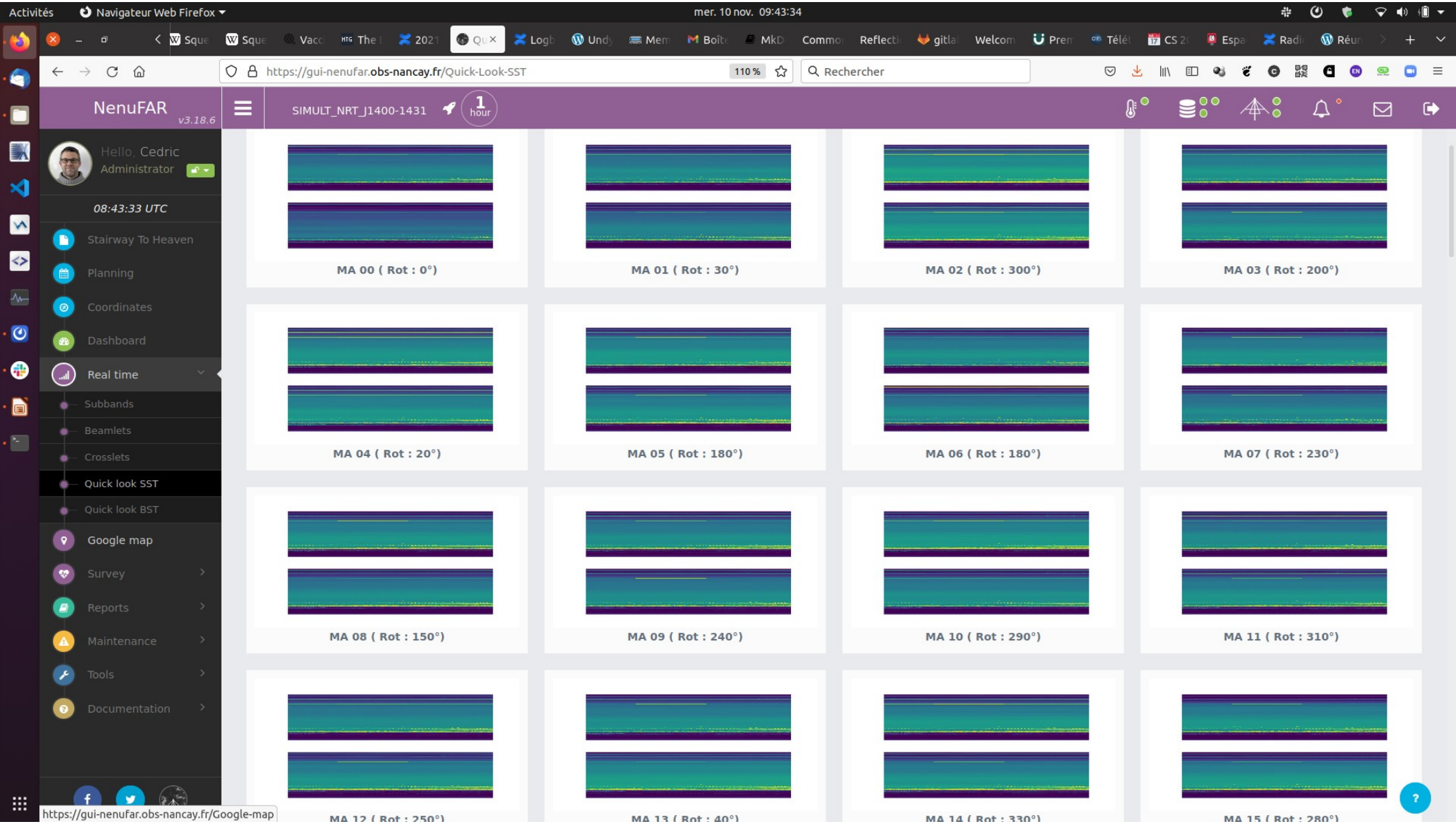
NenuFAR : Presentation & updates on the system



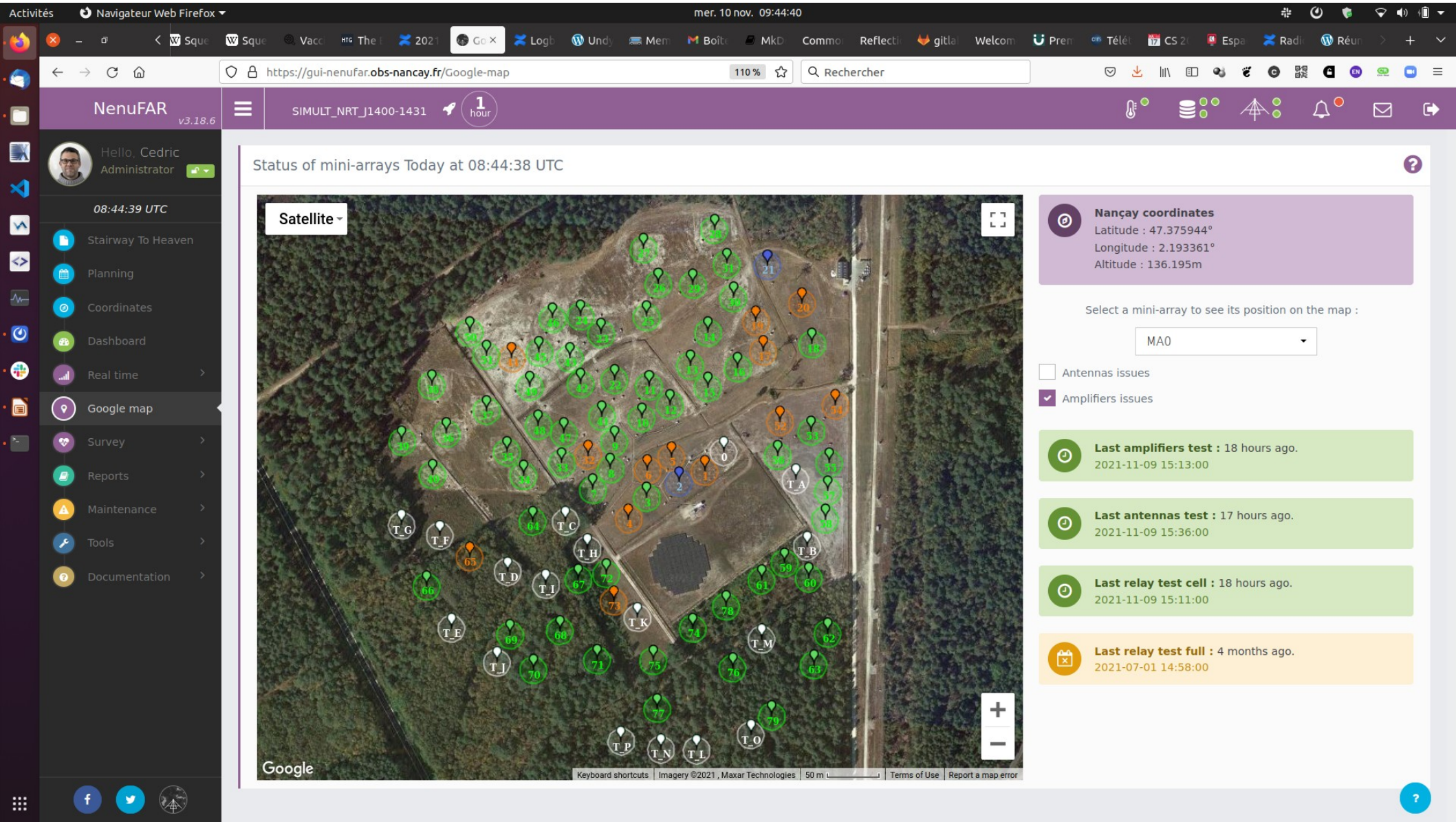
NenuFAR : Presentation & updates on the system



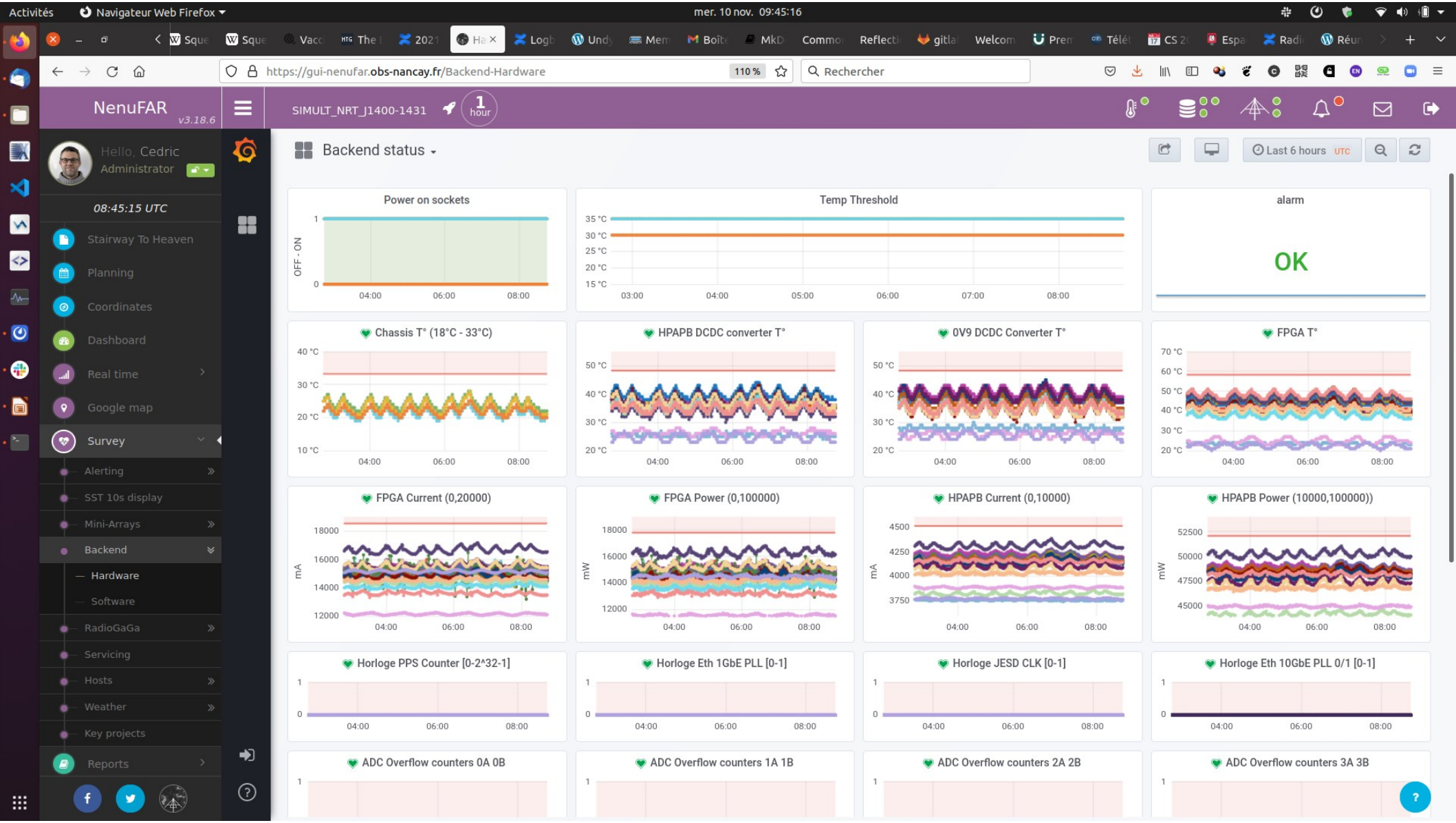
NenuFAR : Presentation & updates on the system



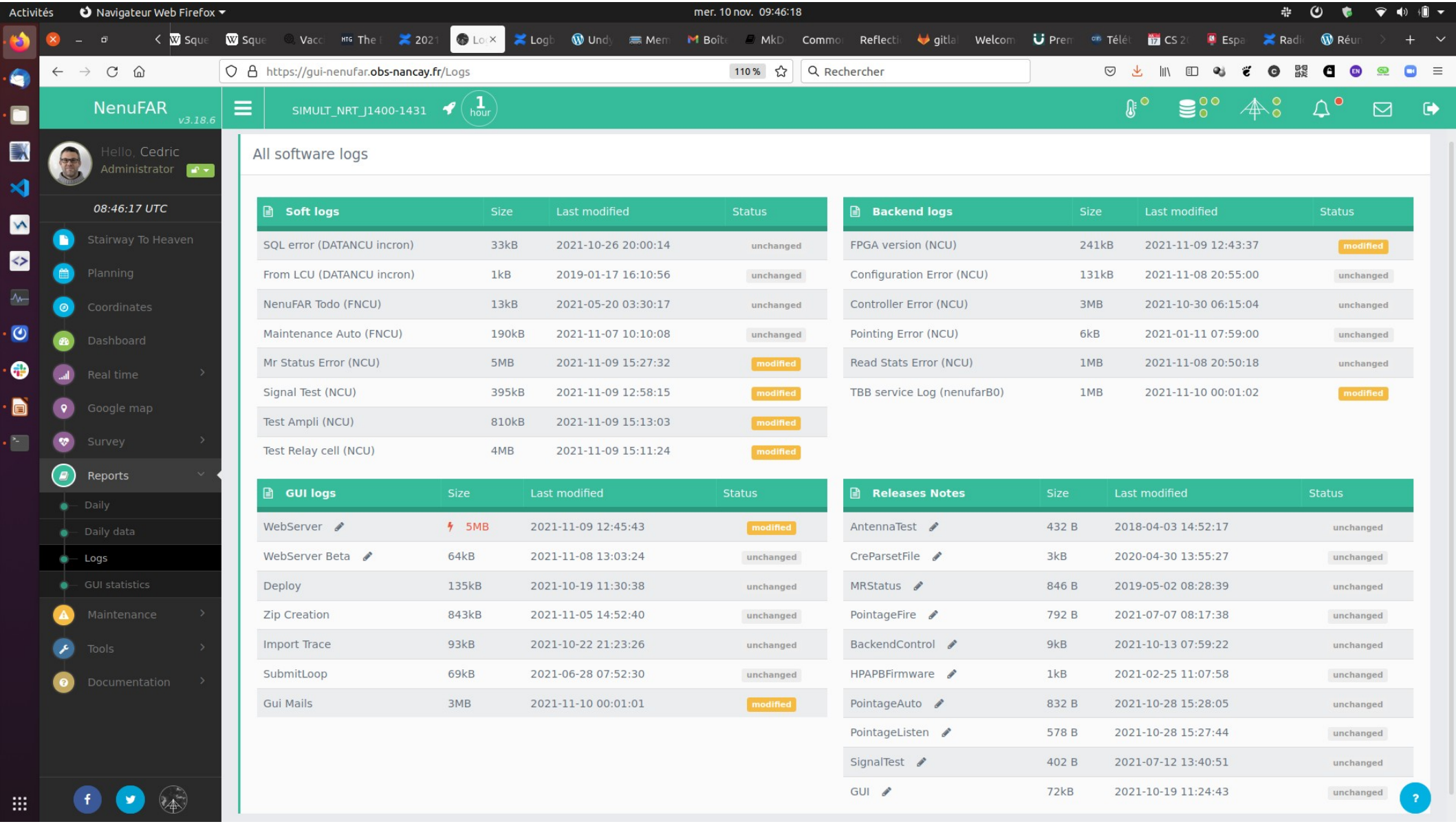
NenuFAR : Presentation & updates on the system



NenuFAR : Presentation & updates on the system



NenuFAR : Presentation & updates on the system



Questions ?