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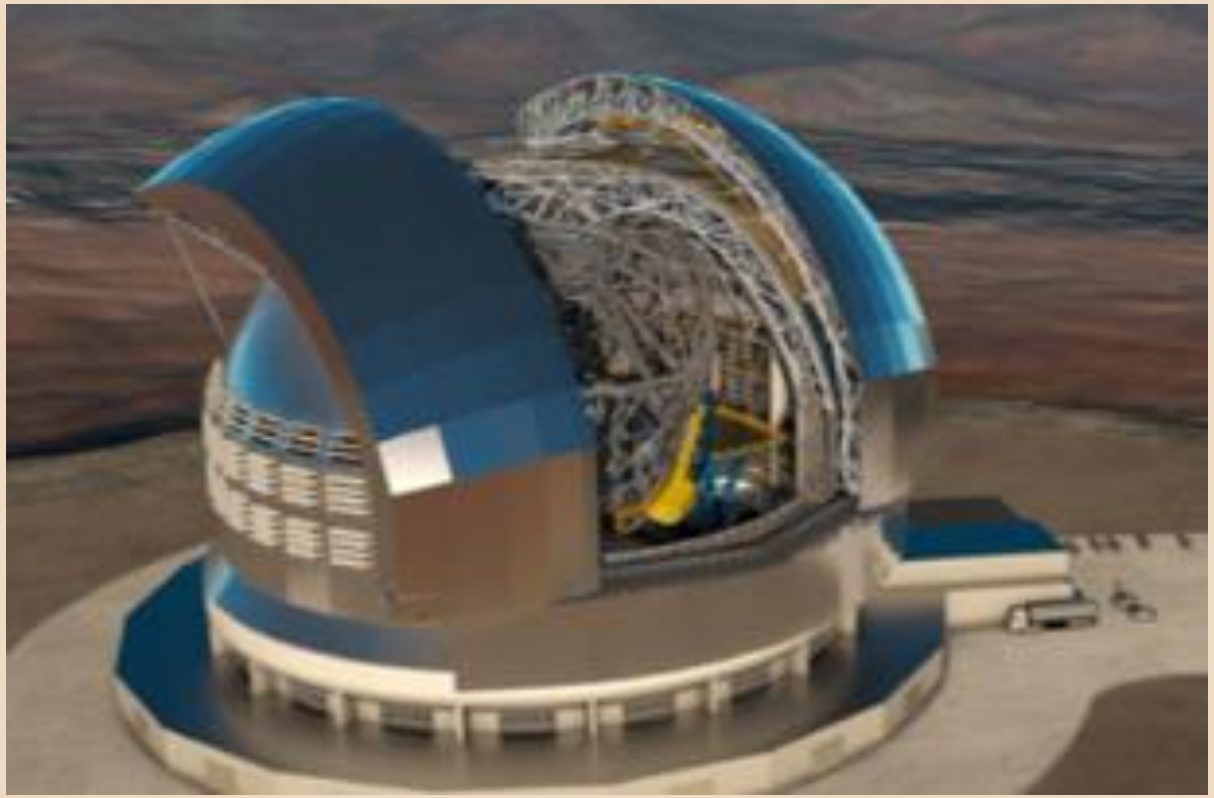
# STILES

## MeerKAT Band 5 Project

**Maria Grazia Labate**
(MK Band 5B Systems Engineer), INAF
**on behalf of the Band5B team**

Napoli, 17 March 2026



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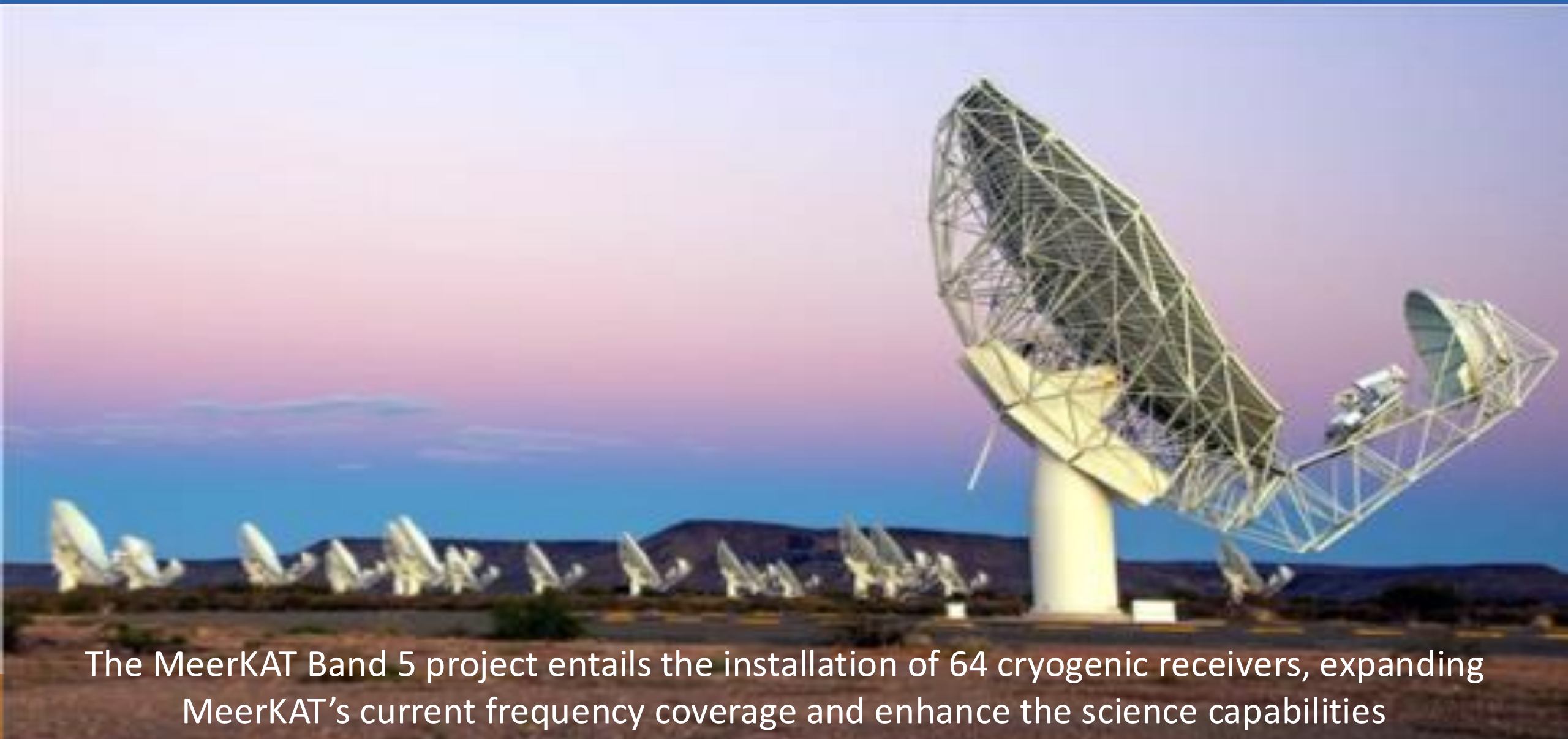

The MeerKAT Band 5 project entails the installation of 64 cryogenic receivers, expanding MeerKAT's current frequency coverage and enhance the science capabilities

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- ✓ Operating in the 8.3–15.4 GHz range, **corresponding to SKA-Mid Band 5b**, this upgrade will make **MeerKAT the most sensitive centimetre-wave interferometer in the southern hemisphere** until SKA-Mid—into which MeerKAT will be integrated—begins full operations
  - This will **enhance and enable** relevant **studies** in **cosmological surveys**, galaxy formation and evolution, **star formation** and the **interstellar medium**, **galactic** and **extragalactic transients**, **planet formation**, and the **search for biomolecules**.
  - Moreover, exploring a new parameter space with sub-mJy **sensitivity** and sub-arcsecond angular **resolution** could lead to **new and unexpected discoveries**.


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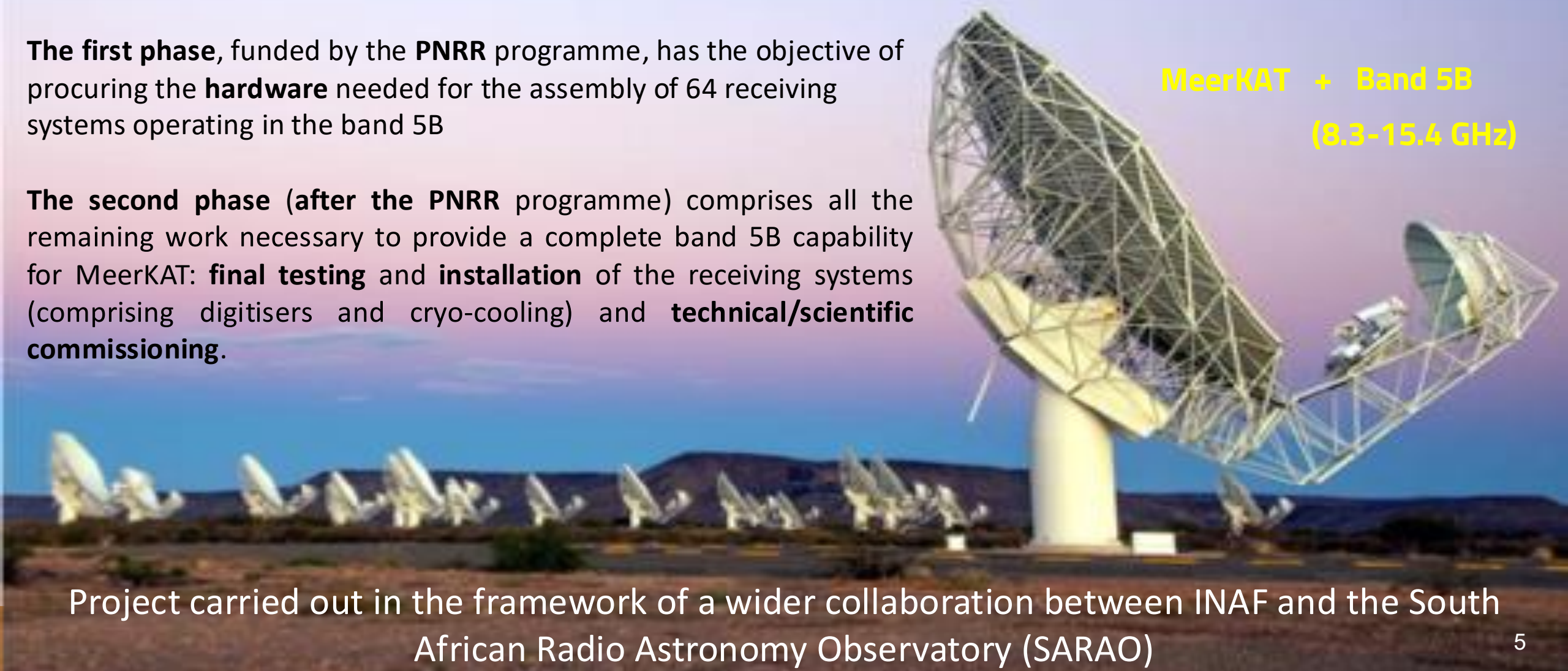
- ✓ An operational MeerKAT in Band 5 would offer two immediate **benefits for SKA** as well:
  - The additional 64 receivers will significantly increase SKA's sensitivity in Band 5b (Area +30%).
  - The additional short baselines provided by MeerKAT will substantially improve the mapping of extended emission.


The MeerKAT Band 5 project entails the installation of 64 cryogenic receivers, expanding MeerKAT's current frequency coverage and enhance the science capabilities

The MeerKAT Band 5B project is composed of two phases:

**The first phase**, funded by the **PNRR** programme, has the objective of procuring the **hardware** needed for the assembly of 64 receiving systems operating in the band 5B

**The second phase** (**after the PNRR** programme) comprises all the remaining work necessary to provide a complete band 5B capability for MeerKAT: **final testing** and **installation** of the receiving systems (comprising digitisers and cryo-cooling) and **technical/scientific commissioning**.




Project carried out in the framework of a wider collaboration between INAF and the South African Radio Astronomy Observatory (SARAO)

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Procurement of
**Cryogenic Receivers**
(SPF)

MAX PLANCK INSTITUTE FOR RADIO ASTRONOMY

Kick off meeting July 2024

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Procurement of
**Down-converting Digitisers,**
**Compressors upgrade,**
**Time and Frequency Reference,**
**Receptor Fibre Network,**
**Array Data Network,**
**Antenna Structures**

NRF National Research Foundation | SARAO South African Radio Astronomy Observatory

Project carried out in the framework of a wider collaboration between INAF and the South African Radio Astronomy Observatory (SARAO)

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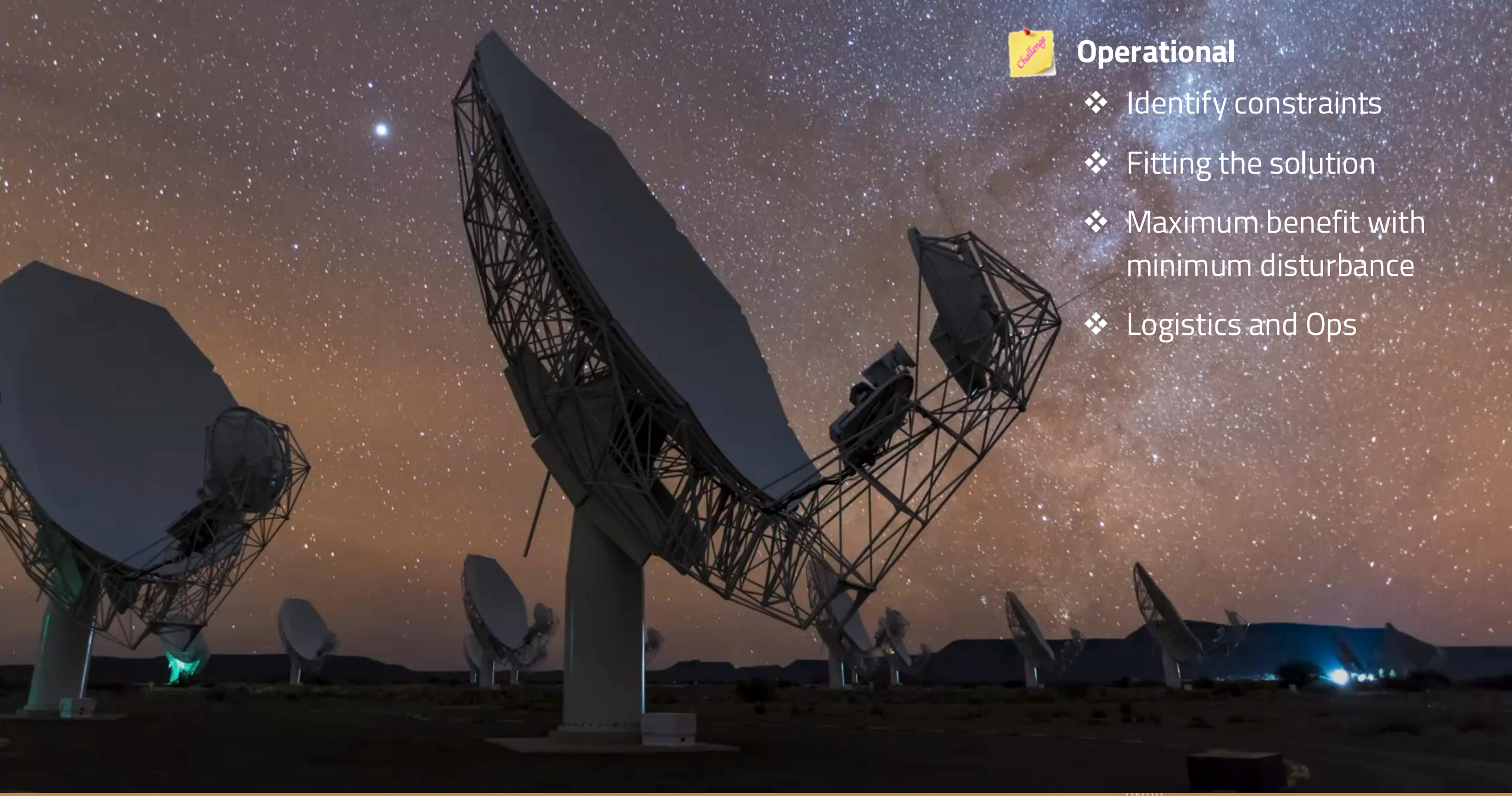
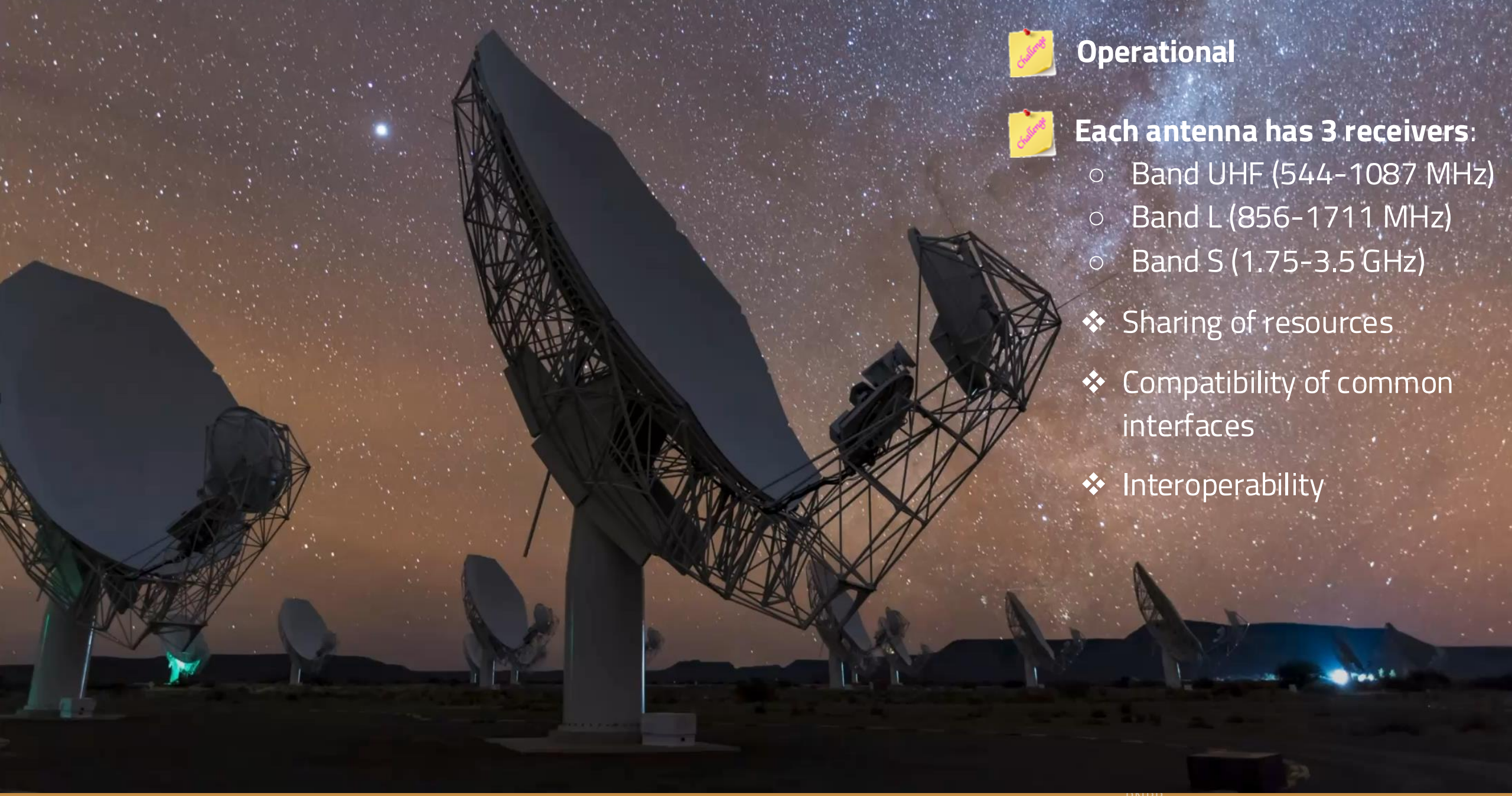


## Operational

- Identify constraints
- Fitting the solution
- Maximum benefit with minimum disturbance
- Logistics and Ops

# The Band5B Project in the MeerKAT context



**Operational**

**Each antenna has 3 receivers**:

- Band UHF (544-1087 MHz)
- Band L (856-1711 MHz)
- Band S (1.75-3.5 GHz)

- Sharing of resources
- Compatibility of common interfaces
- Interoperability

# The Band5B Project in the MeerKAT context

**Operational**

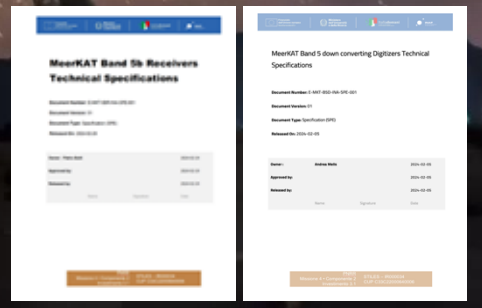
**Each antenna has 3 receivers**:

- Band UHF (544-1087 MHz)
- Band L (856-1711 MHz)
- Band S (1.75-3.5 GHz)

**To be integrated in SKA-Mid** (Band UHF and Band L)

MeerKAT Band **5B:**

- **SKA 5b Frequency Band,**
- **SKA 5b Requirements**
- **Challenging Timeline**
- **and more…** SKAO




# The Band5B Project in the MeerKAT context


The Band 5B receiver will be installed in the **X-Band slot**, which is currently **not populated**



PNRR
Missione 4 • Componente 2
Investimento 3.1

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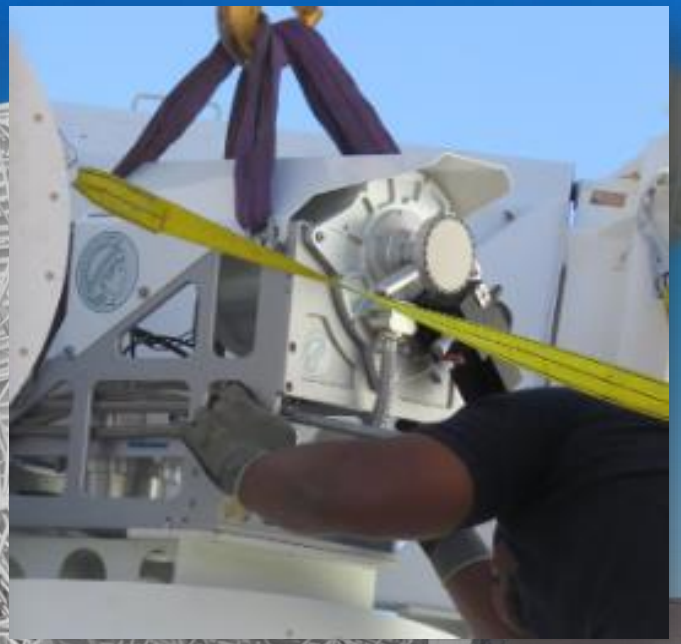
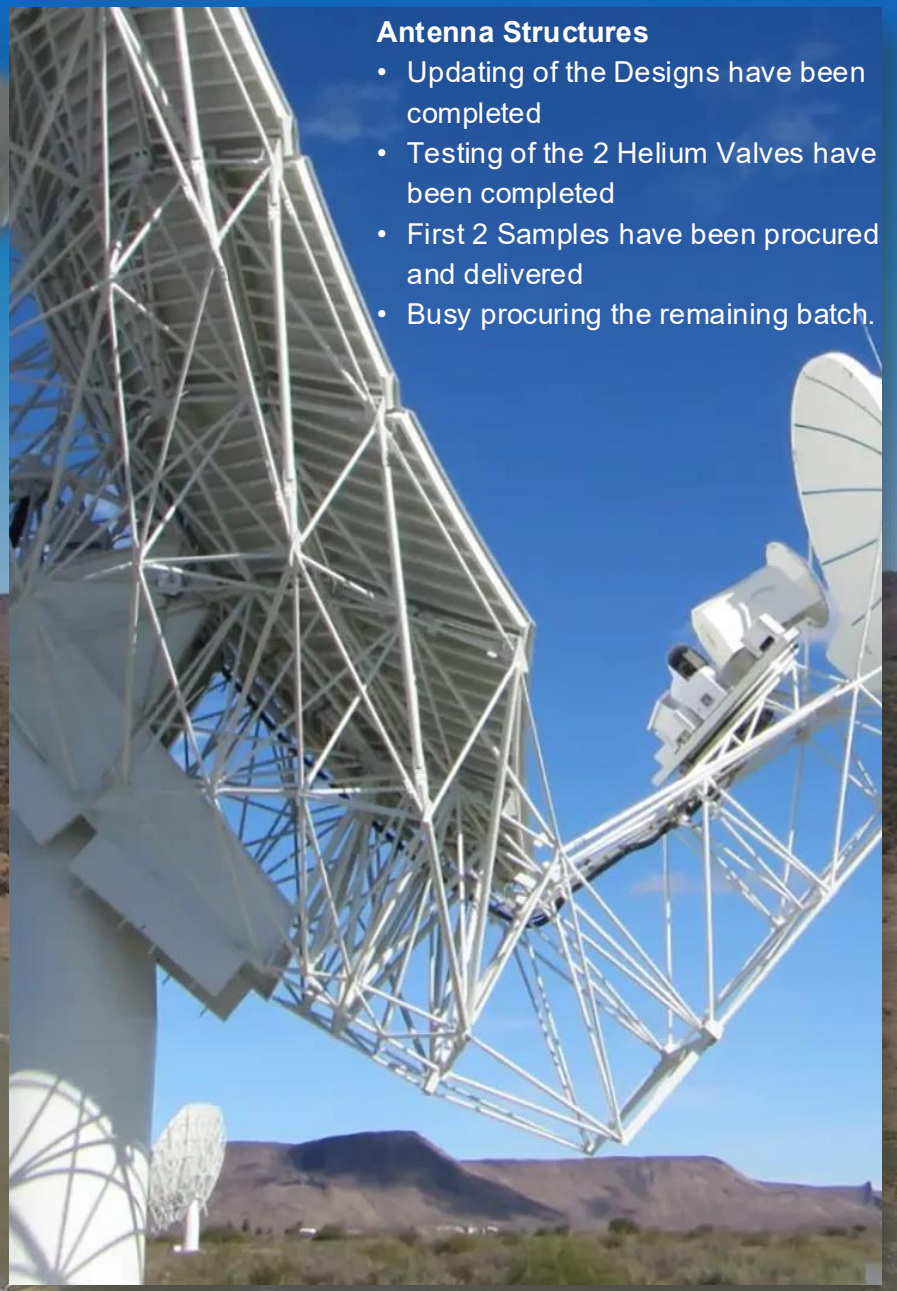
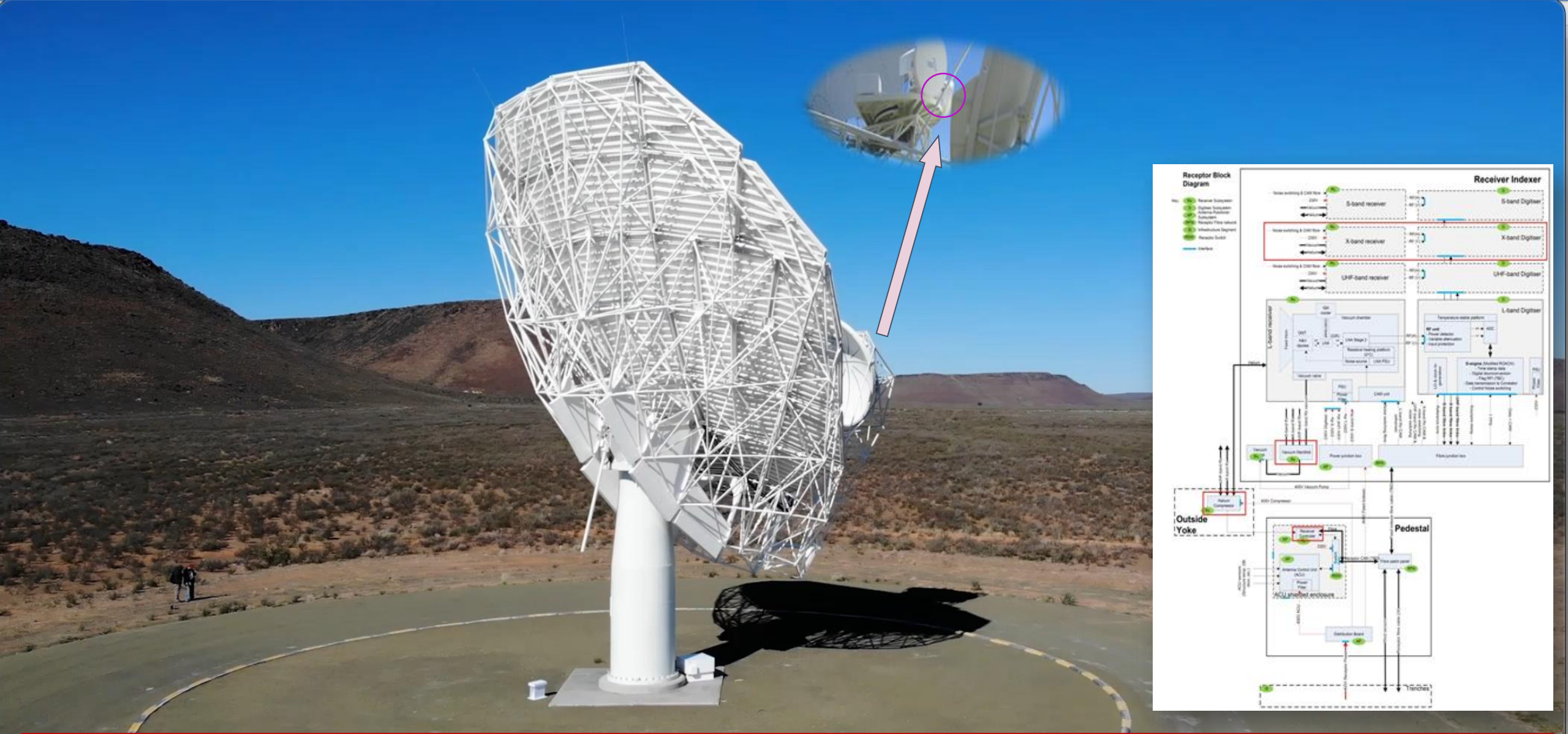




**Antenna Structures**

- Updating of the Designs have been completed
- Testing of the 2 Helium Valves have been completed
- First 2 Samples have been procured and delivered
- Busy procuring the remaining batch.




Areas **where the addition of a Band 5B receiver will impact the current configuration of MeerKAT.**



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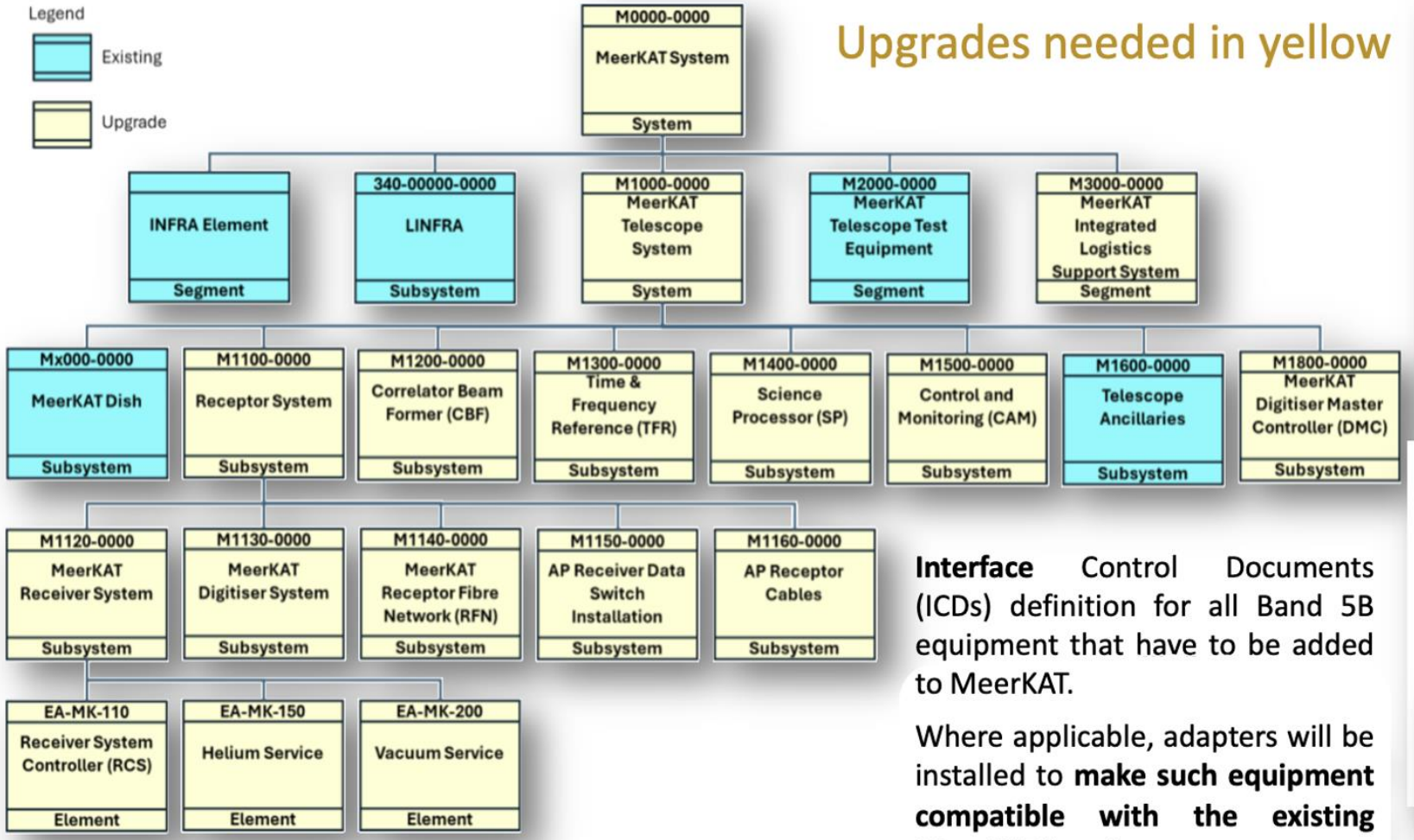
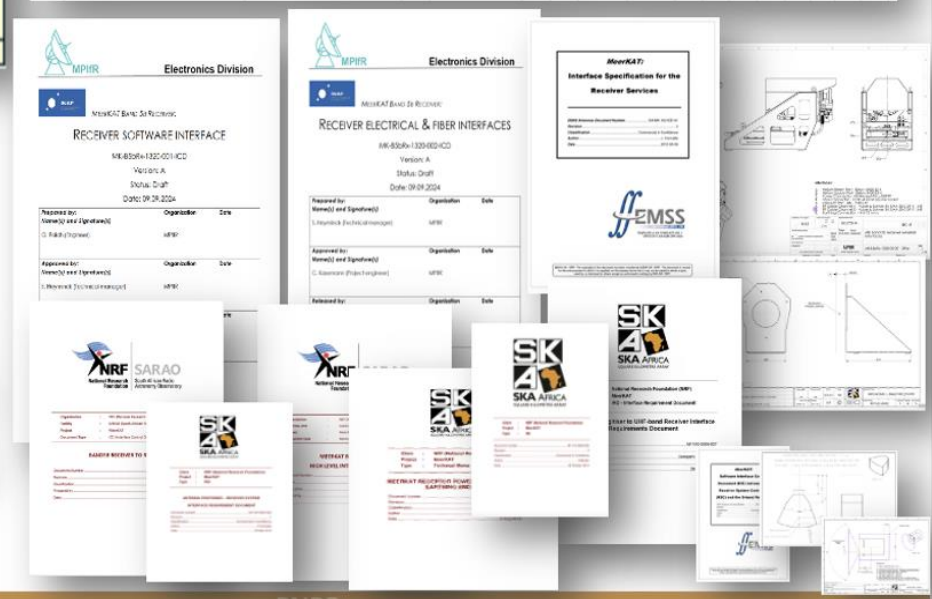



# Upgrades needed in yellow

| | | | Antenna Structure | Band 5 Feed Package | RSC | He service | Vacuum Service | Band 5 DC & Digitiser | Receptor Fibre Network | Receptor Switch | Receptor Cables | Digitiser Master Controller | CAM | TFR | CBF | SP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Receptor | | | | | | | | | | Array Central subsystems | | | |
| | | | Receiver System | | | | | | | | | | | | | |
| Receptor | Antenna Structure | | | S/M2/M9/M5 | | S | | S | | | | | S | | | |
| | Receiver System | Band 5 Feed Package | | | M1 | S4 | S4 | S2/S6 | M2 | | S | | M1 | | | |
| | | RSC | | | | S | S | | | | | | S | | | |
| | | He service | | | | | | | | | | | | | | |
| | | Vacuum Service | | | | | | | | | | | | | | |
| | Band 5 DC & Digitiser | | | | | | | | S | S | S | S8 | S | S | S7 | |
| | Receptor Fibre Network | | | | | | | | | | | | | | | |
| | Receptor Switch | | | | | | | | | | | | | | | |
| | Receptor Cables | | | | | | | | | | | | | | | |
| Array Central subsystems | Digitiser Master Controller | | | | | | | | | | | | S | | S | |
| | CAM | | | | | | | | | | | | | S | S | |
| | TFR | | | | | | | | | | | | | | S | S |
| | CBF | | | | | | | | | | | | | | | S |
| | SP | | | | | | | | | | | | | | | |




**Interface** Control Documents (ICDs) definition for all Band 5B equipment that have to be added to MeerKAT.

Where applicable, adapters will be installed to **make such equipment compatible with the existing MeerKAT interfaces.**

# The Band5B Project in the MeerKAT context

PNRR
Missione 4 • Componente 2
Investimento 3.1

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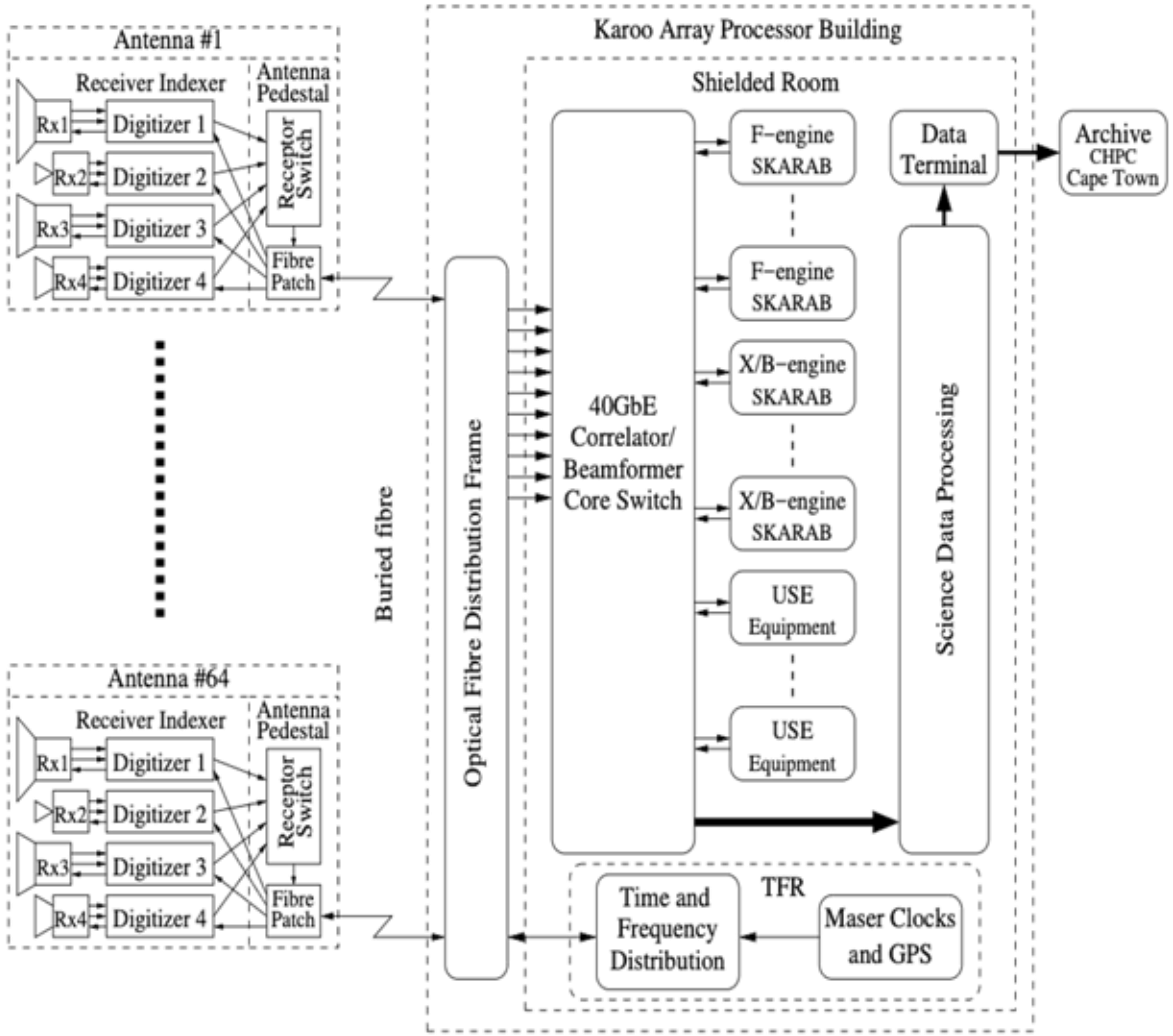
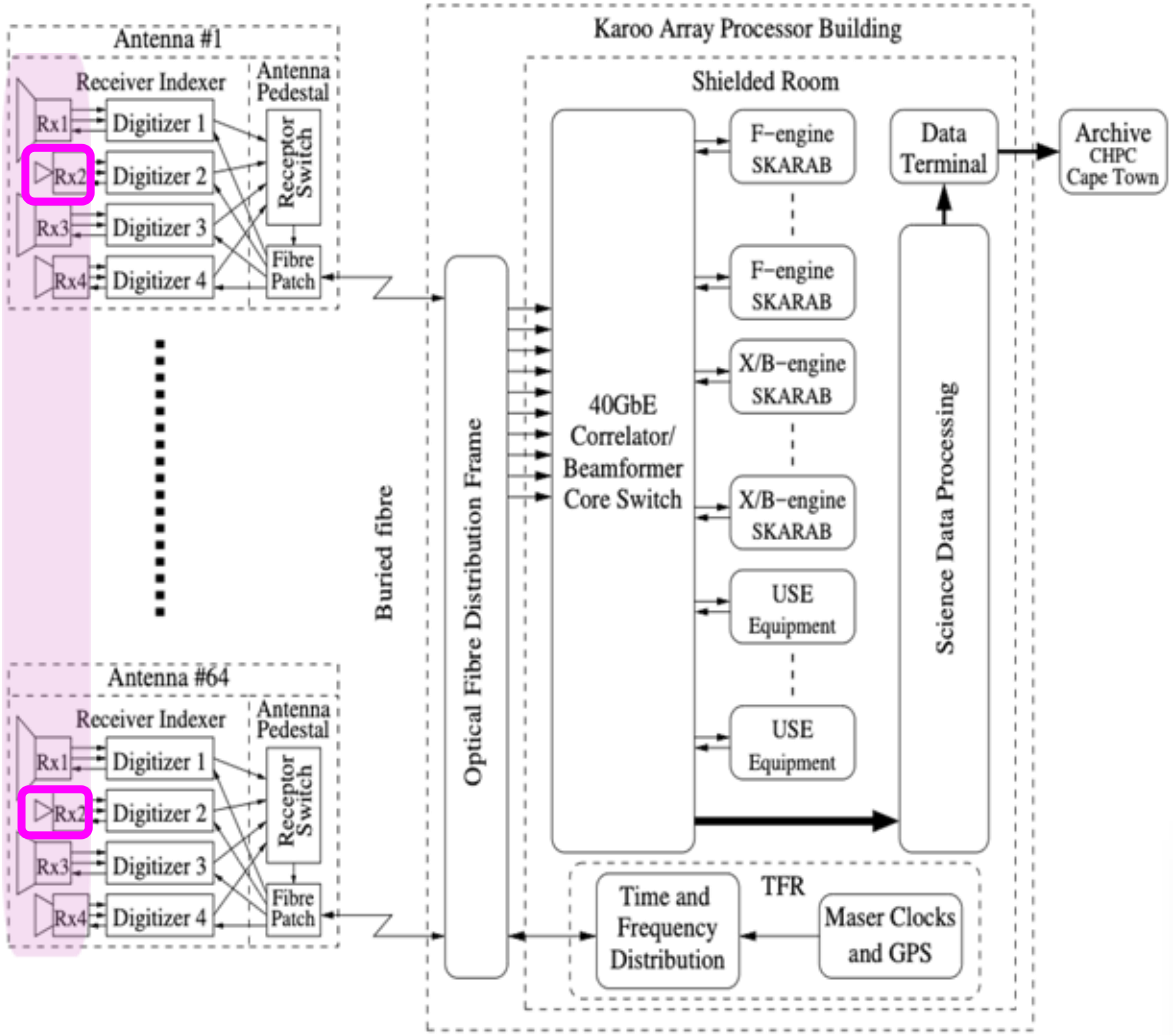
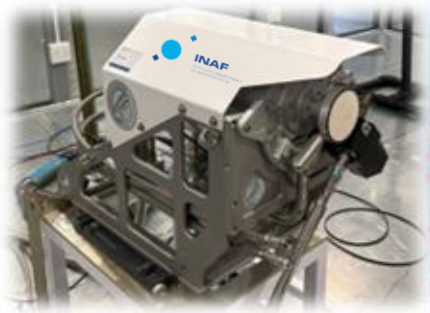
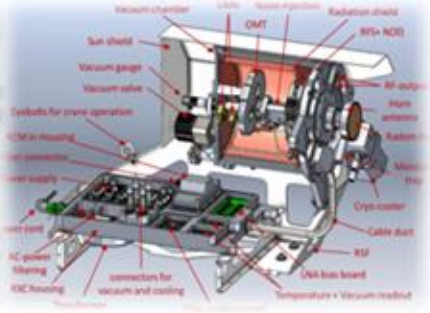



* Note: MK+ GPU based CBF is not shown here.




## Band 5B Receivers (64 + spares)



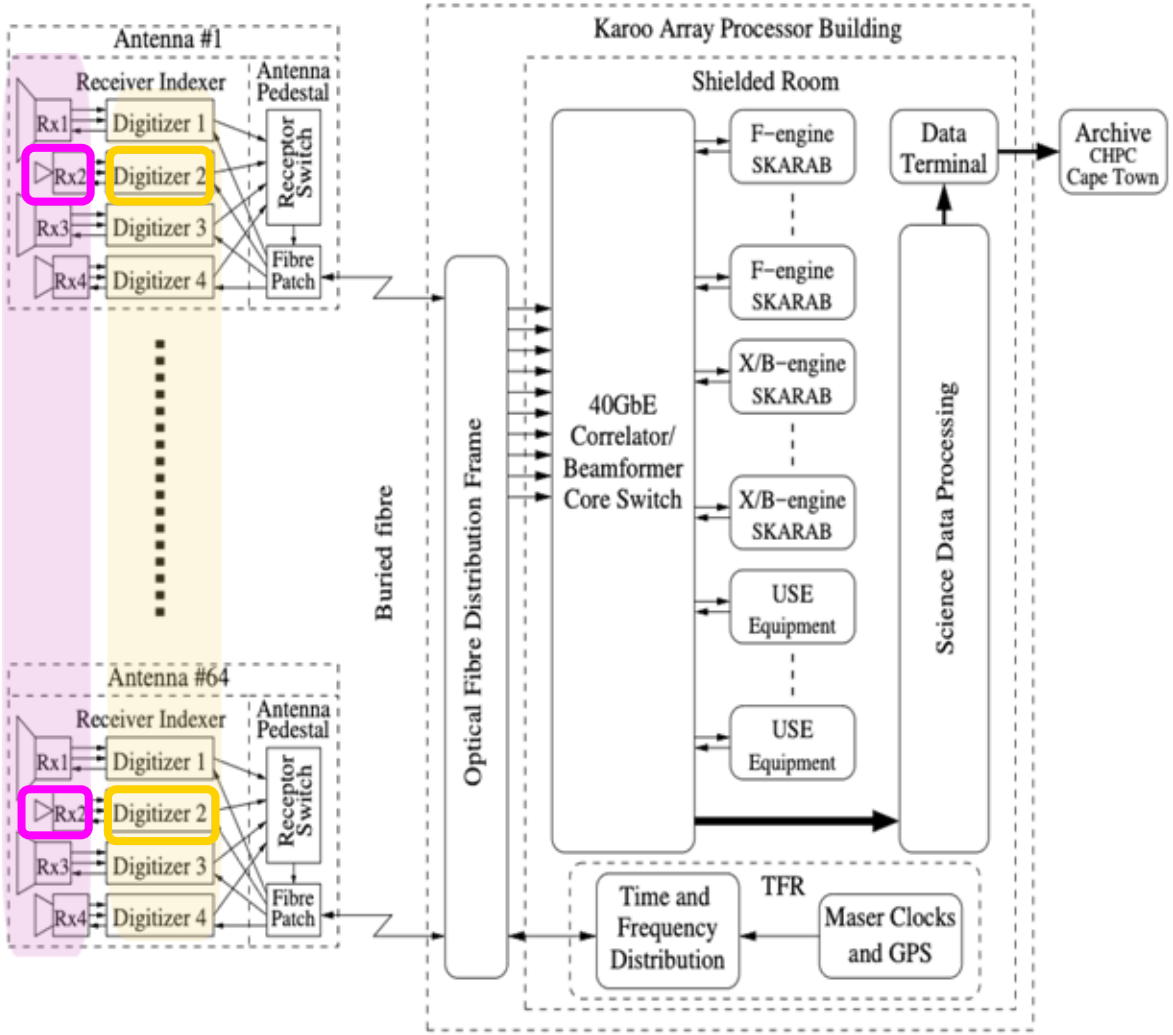


- **2** linear **polarizations**
- **cryogenic cooled LNA and OMT** <20K / horn
- **antenna** at room temperature
- Rx noise temperature: <10.6+0.633*($\nu$-8.41)
- **analogue RF and noise diode** temperature controlled

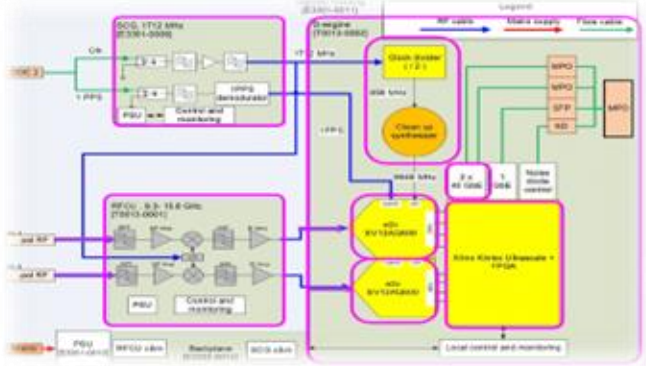
- **SKAO based requirements**
- **Compact** and **modular** design (36.5 kg, 35 x 86 x 50 cm)
- Based on **MPIfR** experience with **S-Band** receiver and on an existing design.

**1° FAT** Nov 2024 → **1° SAT** Dec 2024 → **52 on site** Nov 2025 → **All receivers on site** March 2026

# The Band5B Project: Receivers




# Band 5B Digitisers (64 + spares)



| Parameter | Specification |
|---|---|
| RF frequency range | 8.3 – 15.4 GHz |
| IF | 4.5 GHz |
| Bandwidth | 2.5 GHz |
| Nominal input power level | -132 dBm/Hz |
| ADC nominal power level | -12 dBFS |
| Gain flatness | ≤ 1.8 $dB_{p-p}$ over Bandwidth |
| Gain stability | ≤0.05 % rms |
| Adjustable gain | + 3 to – 8dB in 1 dB steps -37 dB max adjustment |
| Phase stability | ≤ 3.5 ° p-p ≤ 0.5 ° rms |

Receive amplified RF signals and down convert sub-bands within the Band 5B frequency range to an intermediate frequency (IF) of ~ 4.5 GHz (2.5 GHz bandwidth)

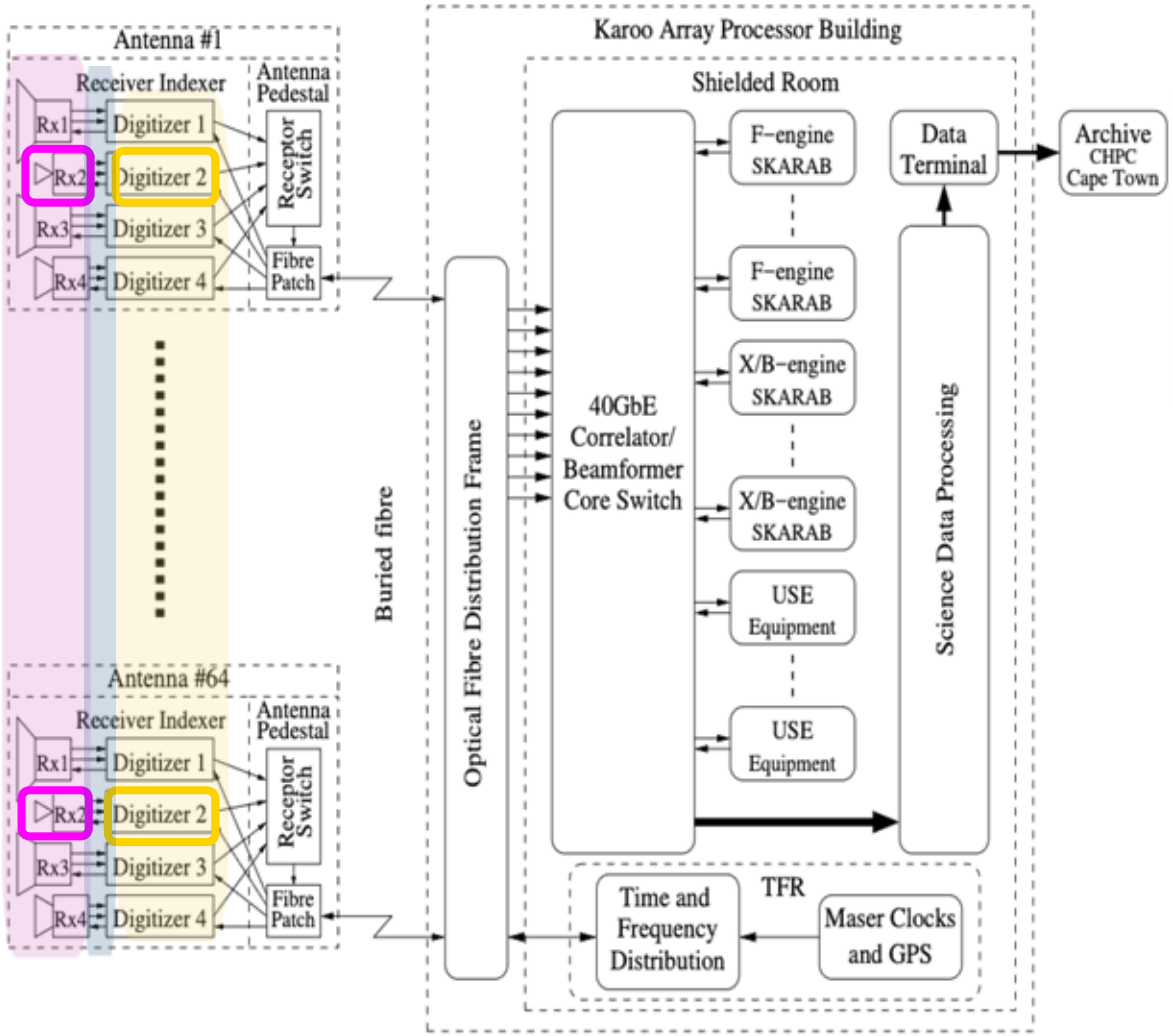
- **Maximise the re-use of MeerKAT extension** Digitiser.
- **D-Engine** and **RF and Clock module** (RFCM) modules **modified** to provide the Band 5B specific functionality.

1° D-Engine FAT **Jul 2025** → 64 + D-Engines FAT **Nov 2025** → RFCUs completed → First digitiser system ready

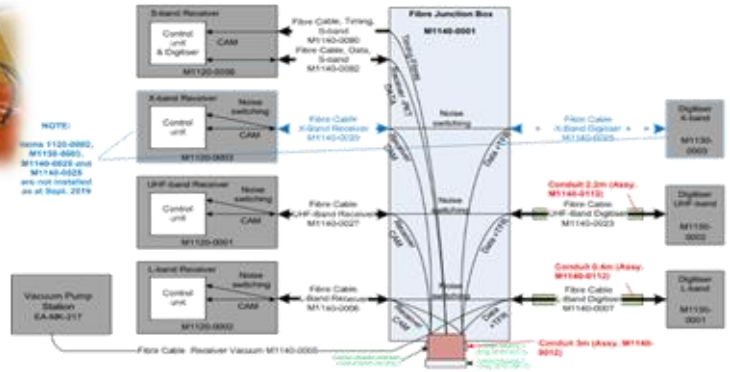




# The Band5B Project: Receivers



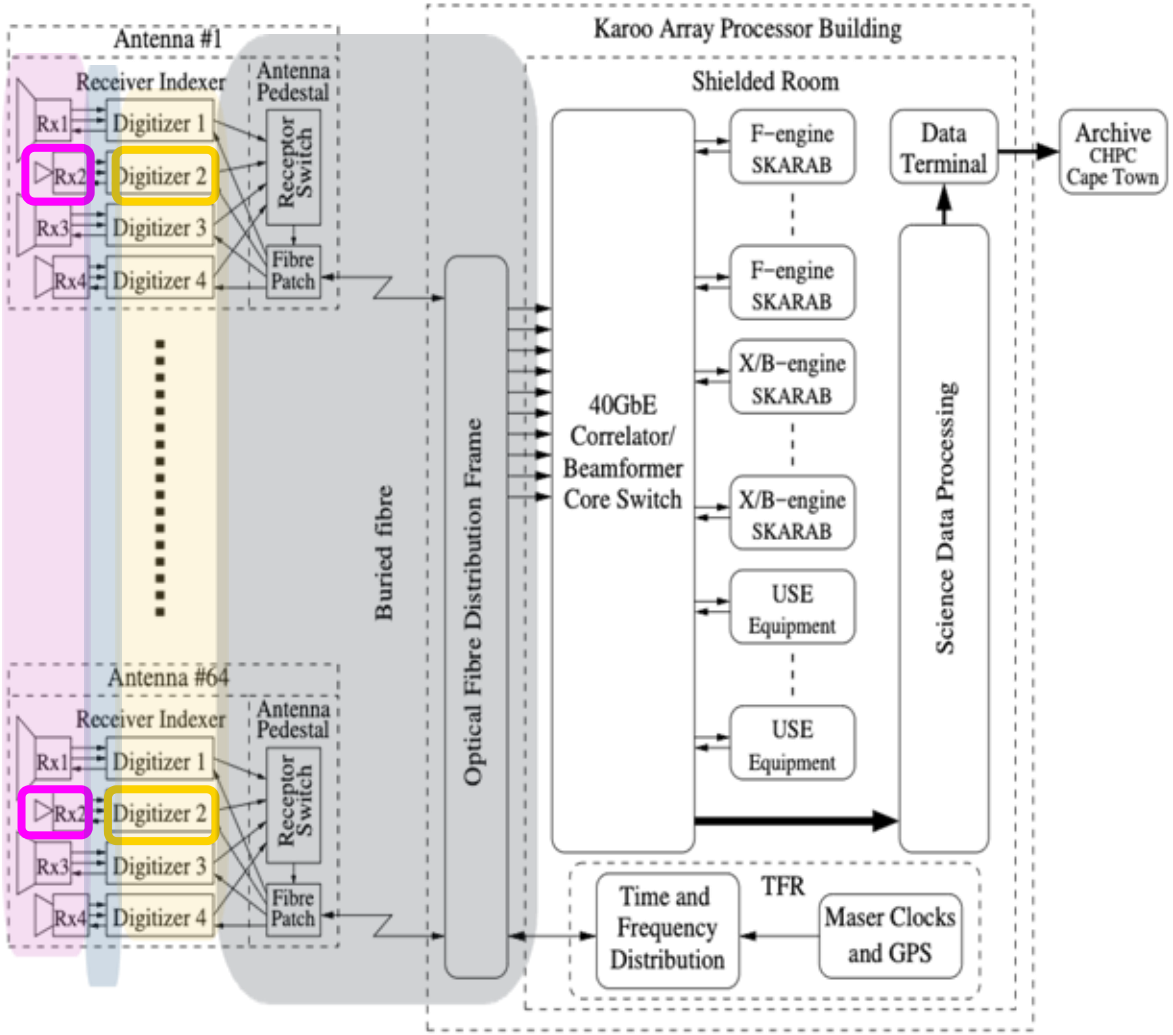

# Receptor Fibre Network (Upgrade)



Optical **inter-connection between different receptor** subsystems

- Transports Data & Control and Monitoring (CAM)
- Transports Timing signals

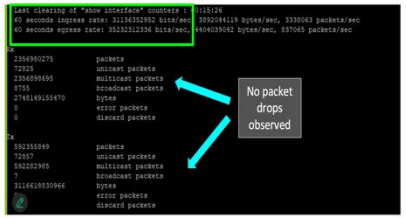
Purchased and tested **Q2 2025** → Docs & Plans **Nov 2025** → First batch ready for installation → Finalise last batch procurement


## Array Data Network (Upgrade)

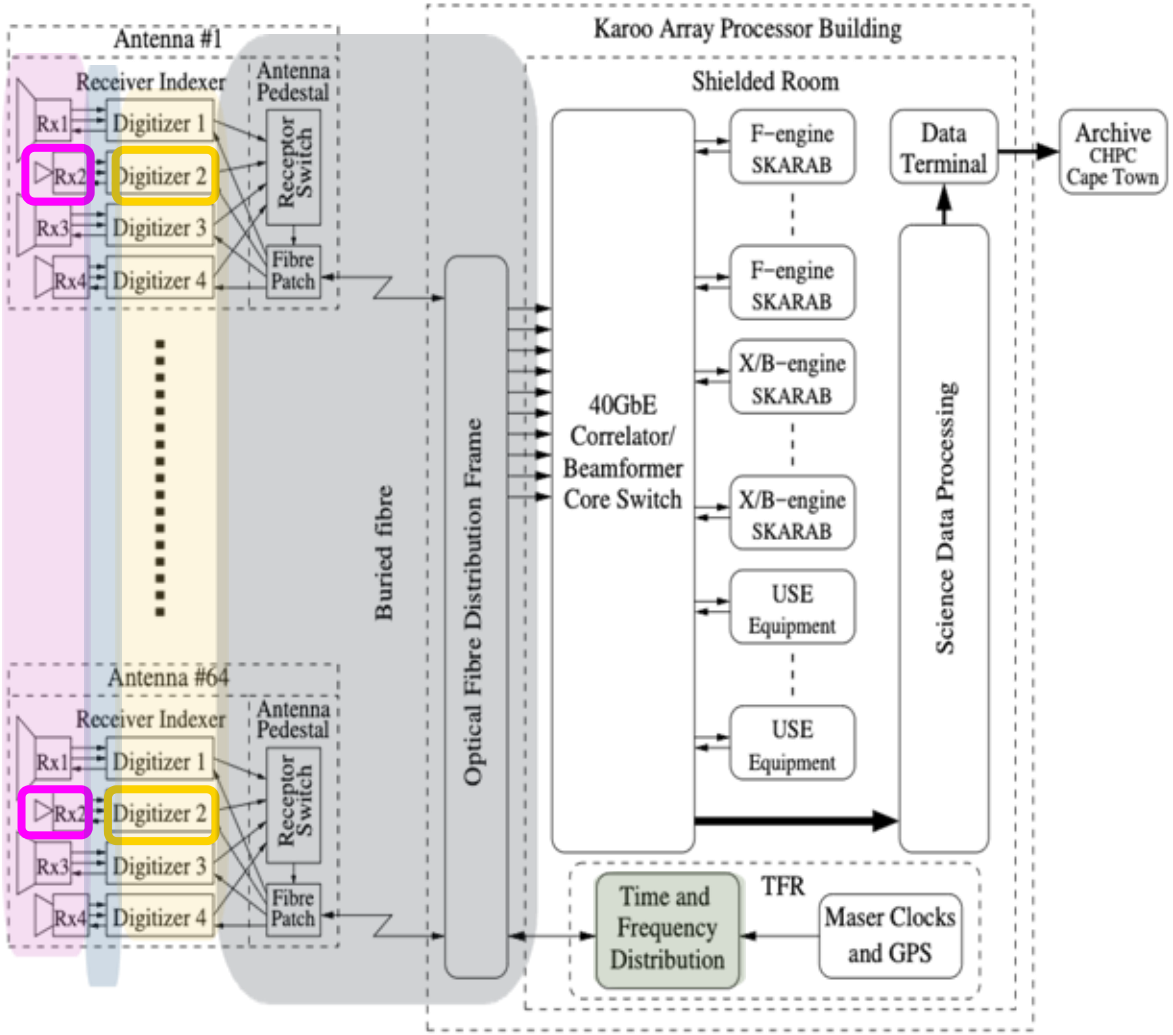







- 40 GbE transceivers for the AFN were evaluated and tested for compatibility with the existing MK data network and AFN
- Establishment of a lab setup for prototyping the configuration of and testing the upgraded AFN (to consist of two 40 GbE links) is in progress
- **Procurement**:
  - All AFN materials, additional 40 GbE Transceivers, have been procured and delivered
  - All 40 GbE transceivers were tested and confirmed to be fully functional

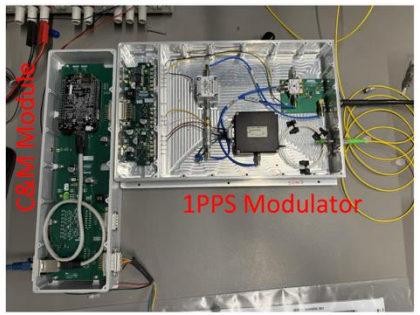
Tested **Q2 2025** → 110 LR4 Delivered **Q2 2025** → Finalise outstanding procurement **Jan 2026** → Testing on site and Installation

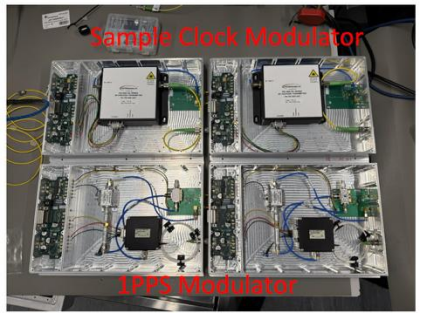


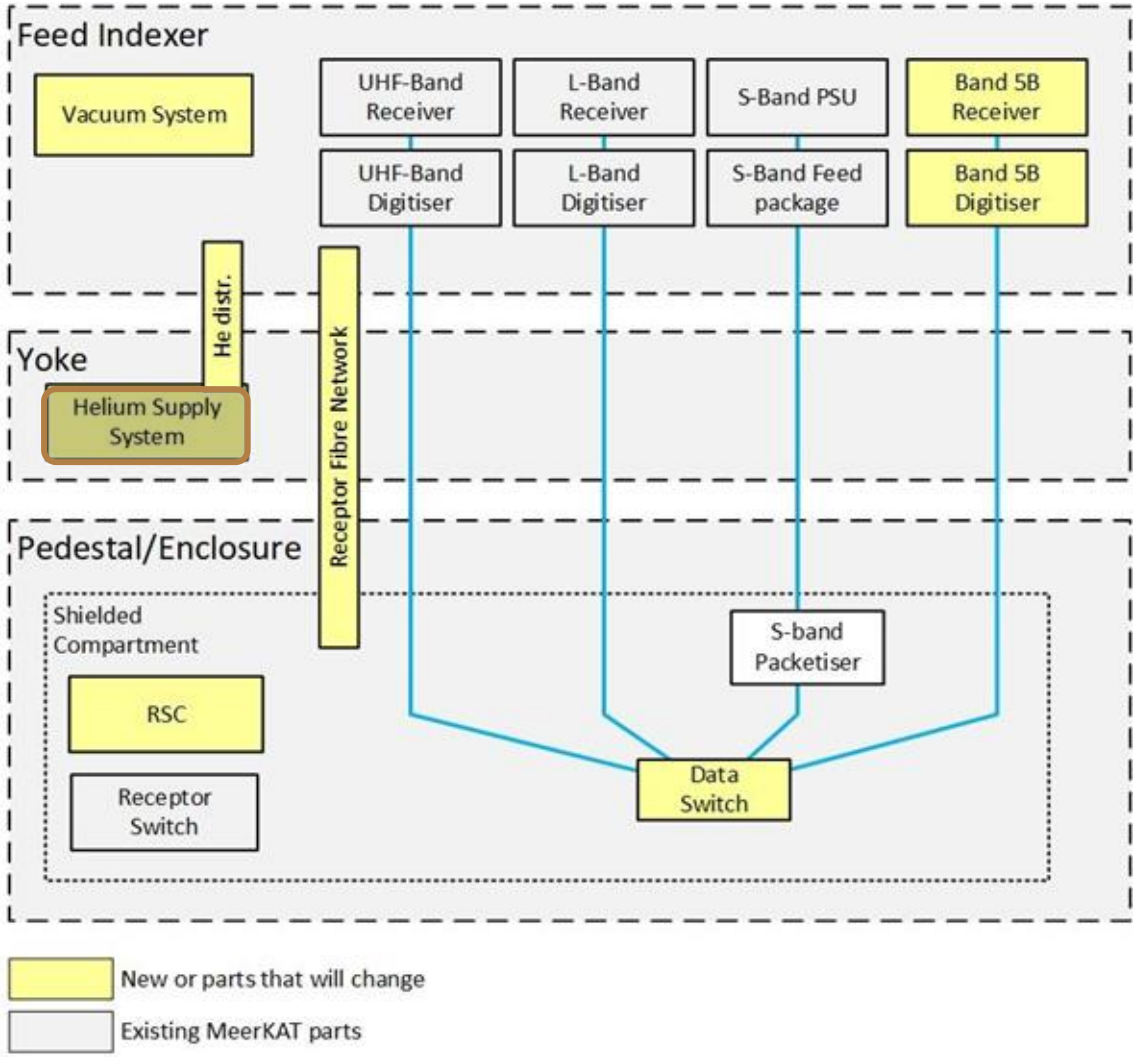

# Time and Frequency Distribution (Upgrade)

- Designs and testing on the TFR modules have been completed
- Integration of the rackmount TFR units in progress.
- Acceptance testing and deployment to site will be next.
- All materials for the TFR have been procured and delivered.

Purchase **Q2 2025** → Testing **2025** → Assembly **In progress** → Acceptance and deployment



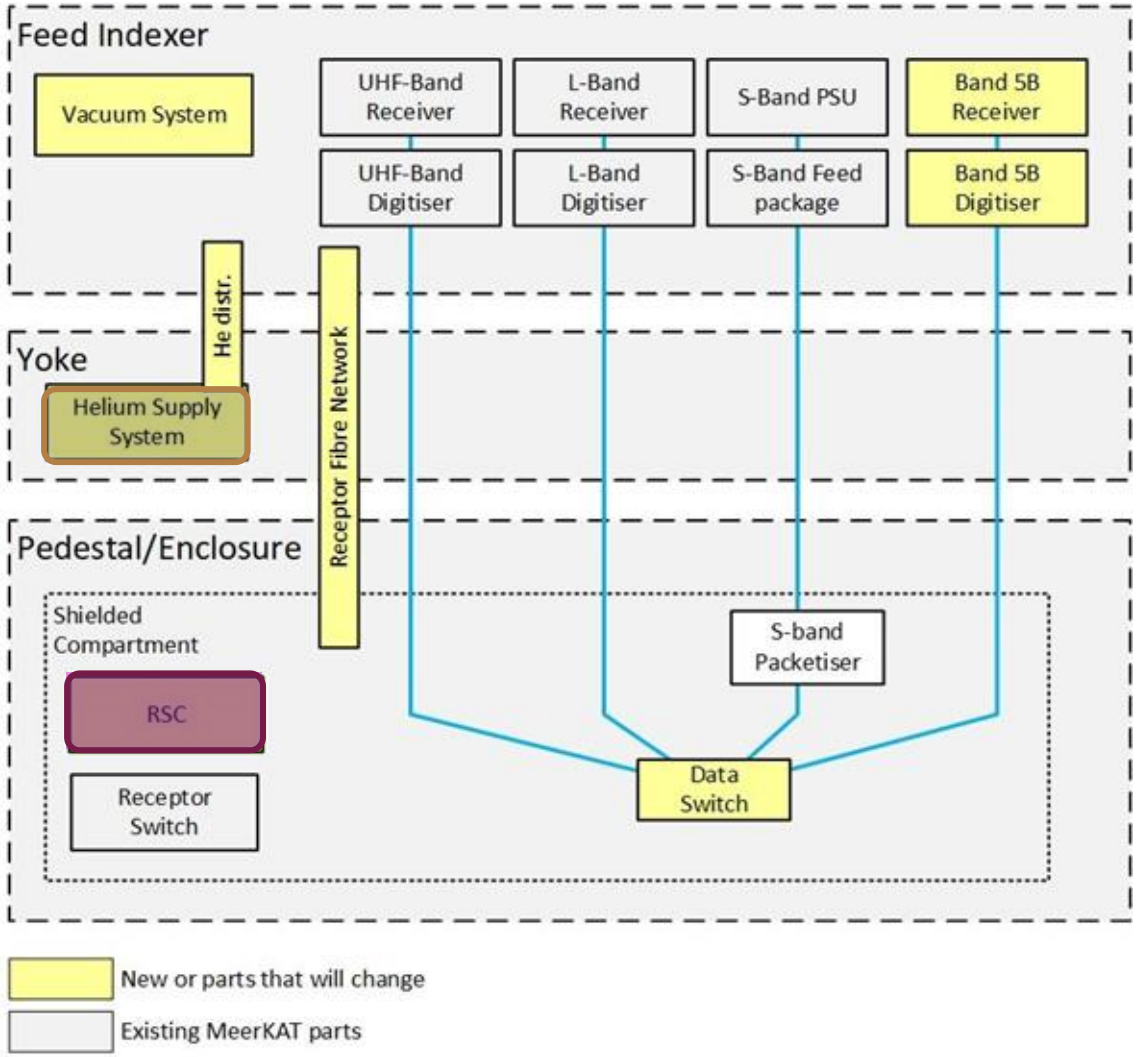

# Helium Supply System (Upgrade)

Helium compressor refurbishment

Replacement of the scroll capsule (also referred to as the capsule), PN: ZCH48C3G-TFD-235, of the M500RT helium compressor (Trillium)

- Helium compressor tradeoff study completed: not possible to run 4x coldheads from one compressor
- 3 x manual valves per receiver indexer
- Select two receivers from pool: UHF band, S-band and Band 5B
- Scheduling: 3 month minimum and 6 month maximum time that a receiver can be disconnected from Helium.

First capsule received Q2 2025 → 64 compressor capsules received Q3 2025 → Replacement caps received Q4 2025

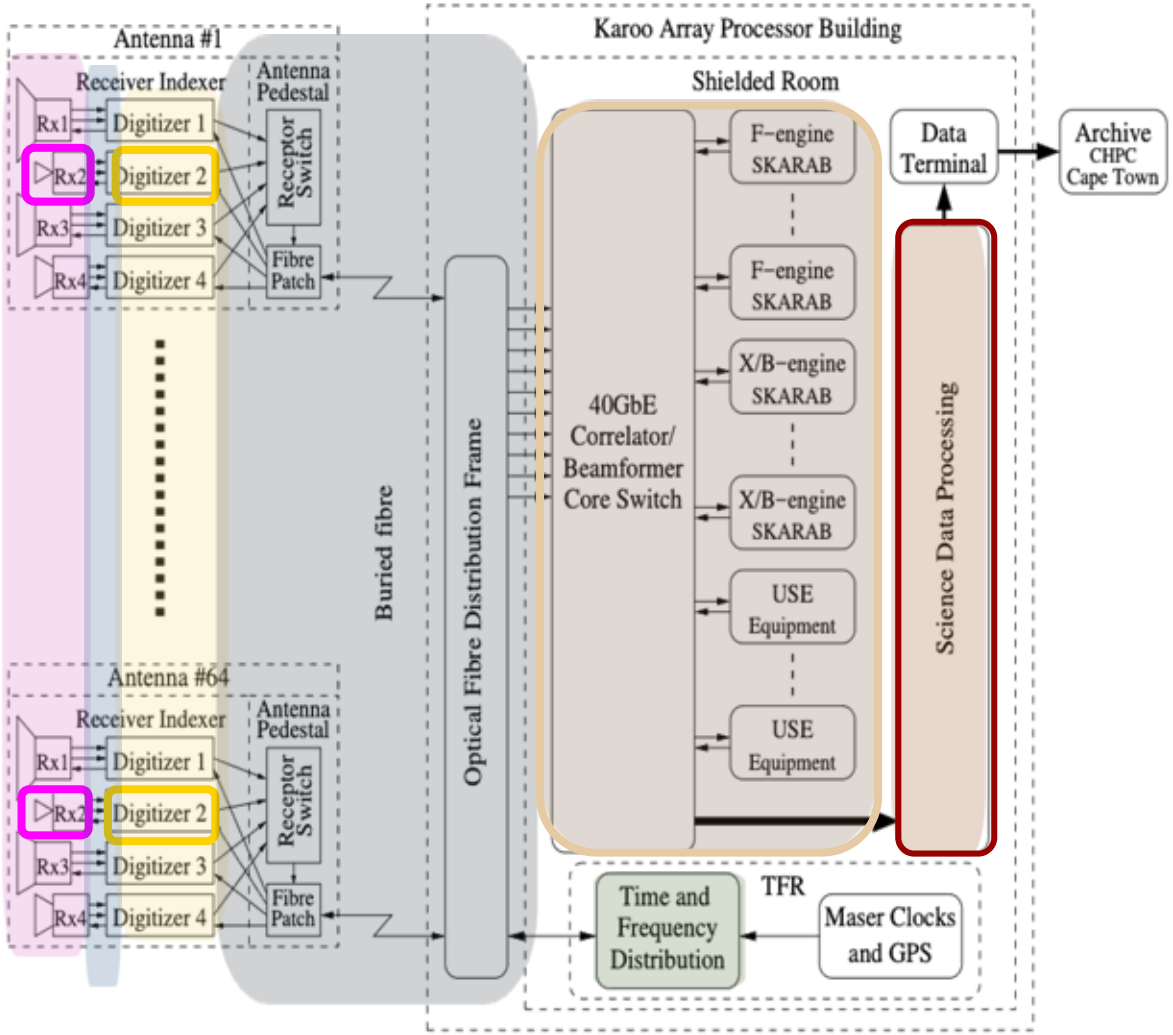



# Receiver Systems Controller

Work ongoing on the **Receiver-RSC integration**

- Trade off between 5 options – done
- Proposing to pursue the following two options:
  - SARAO team to test the switching of the two libraries on a receptor
  - MPIfR be tasked to develop their proposed solution whereby it will be possible to keep both the Band 5B and the S-Band operational at the same time.
- Feasibility, architectural design, interface definition and adherence, initial testing and roll out to be agreed.

Trade off Study **Q2 2025** → Way Forward Evaluation **In progress** → Development



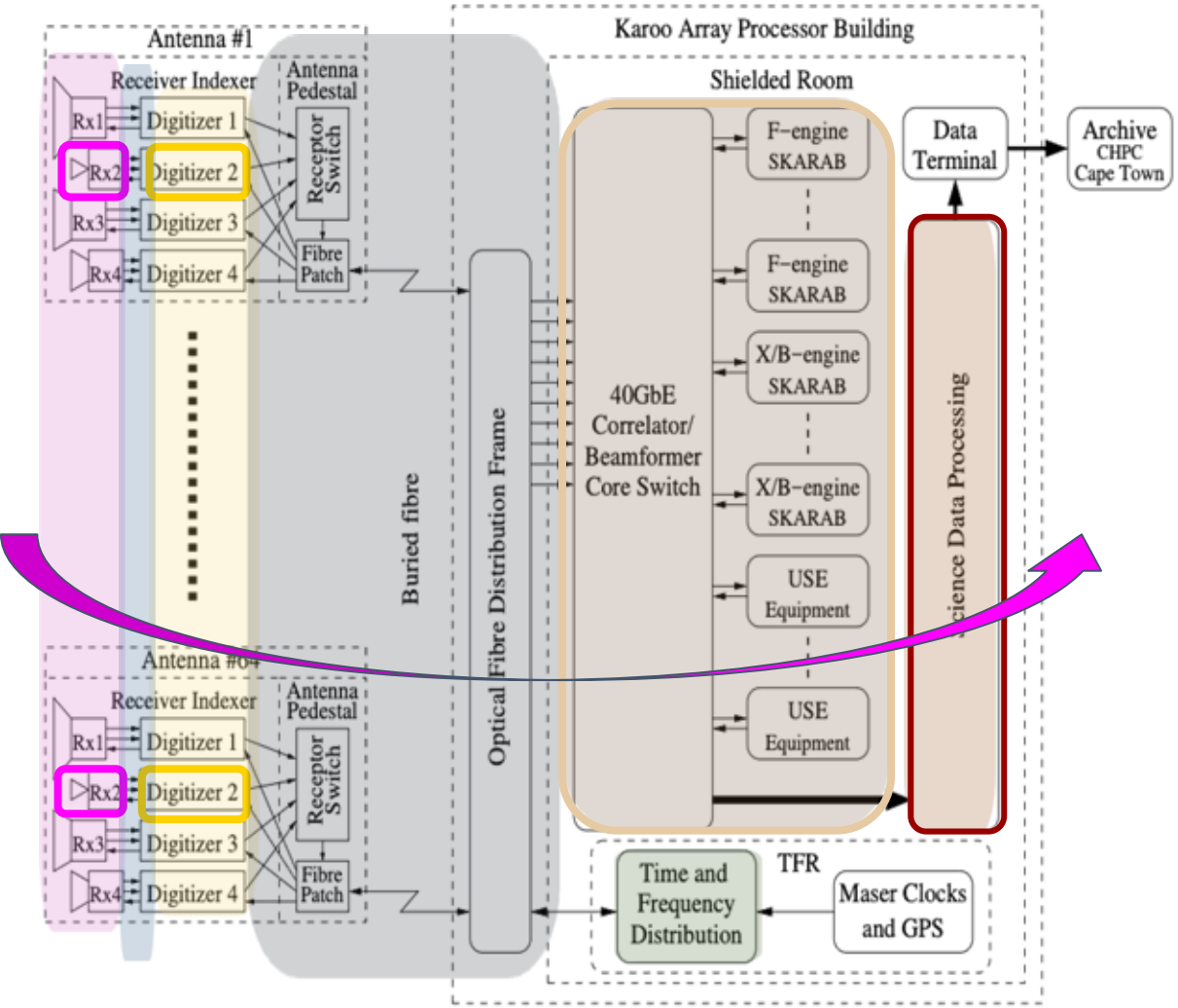

## Correlator & Beamformer

- Trade off between several options
- Science Working Groups consulted
- Analysis and Evaluation is ongoing
- The full extent of the capability of the B5B backend is still subject to funding and the science requirements
- Formally finalise by March 2026:
  - **Science capabilities of B5B**
  - **Funding commitment from SARAO and INAF**
  - **Technical solution for B5B backend**

Trade off Q2 2025 → Science consultation Q2 2025 → Design finalisation Q1 2026 → Development 2026

## Science Data Processing

Full extent of the capability of the B5B backend (CBF and SDP) is subject to funding and the science requirements




Band 5B Receivers (64 + spares)

Band 5B Digitisers (58 + spares)

Receptor Fibre Network (Upgrade)

Array Data Network (Upgrade)

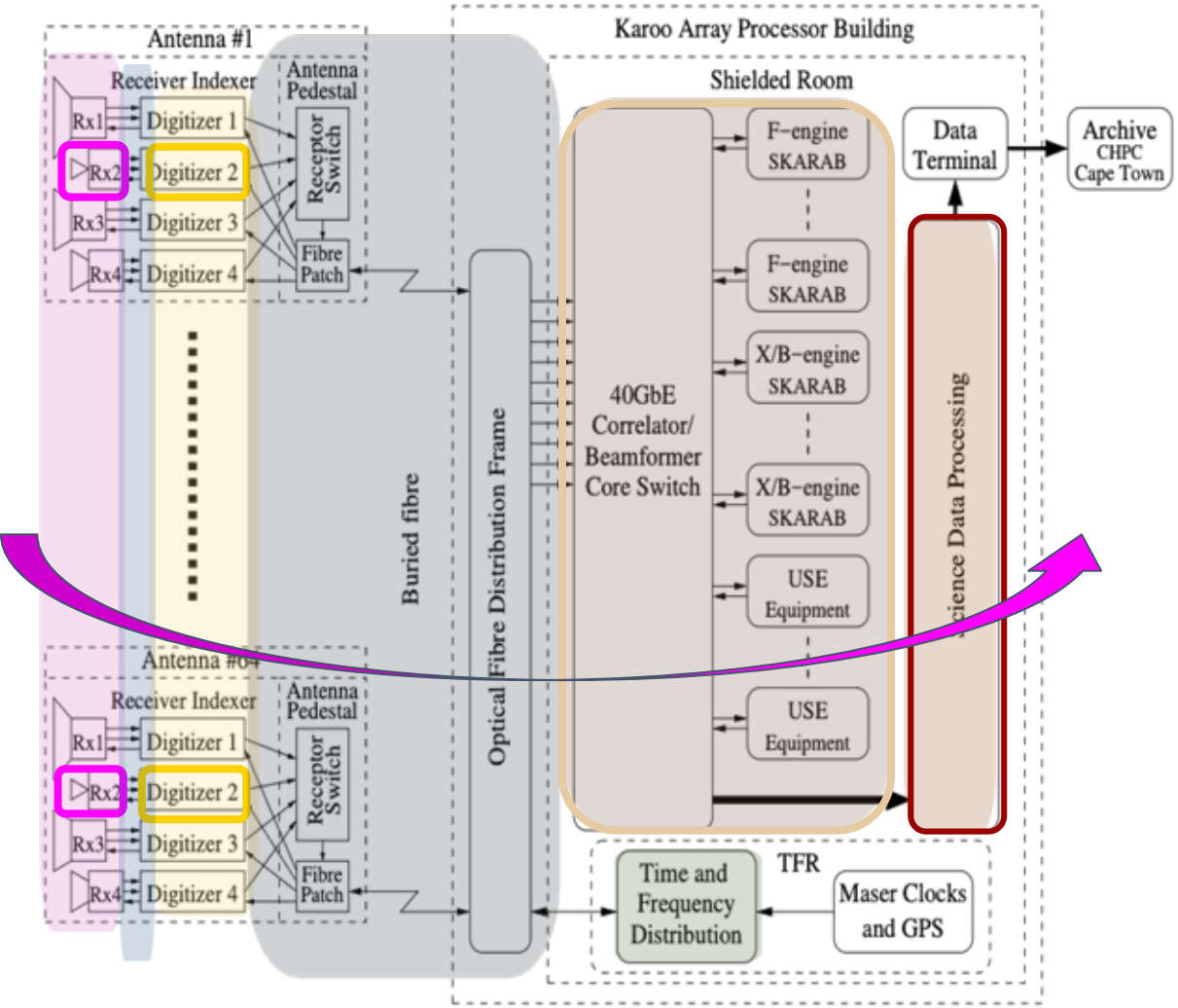
Time and Frequency Distribution (Upgrade)

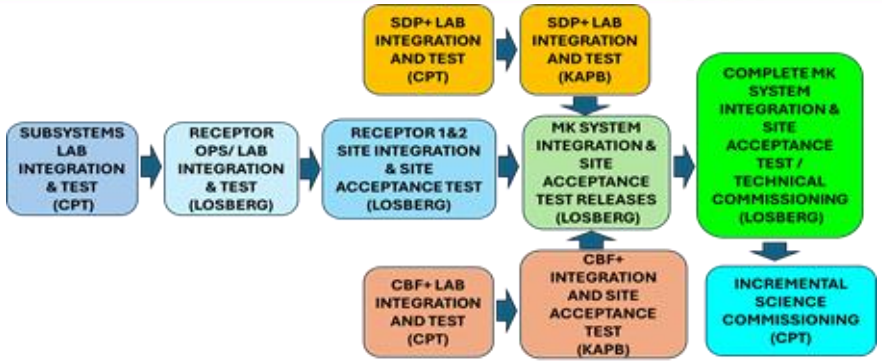
Helium Supply System (Upgrade)

Receiver Systems Controller

Correlator & Beamformer

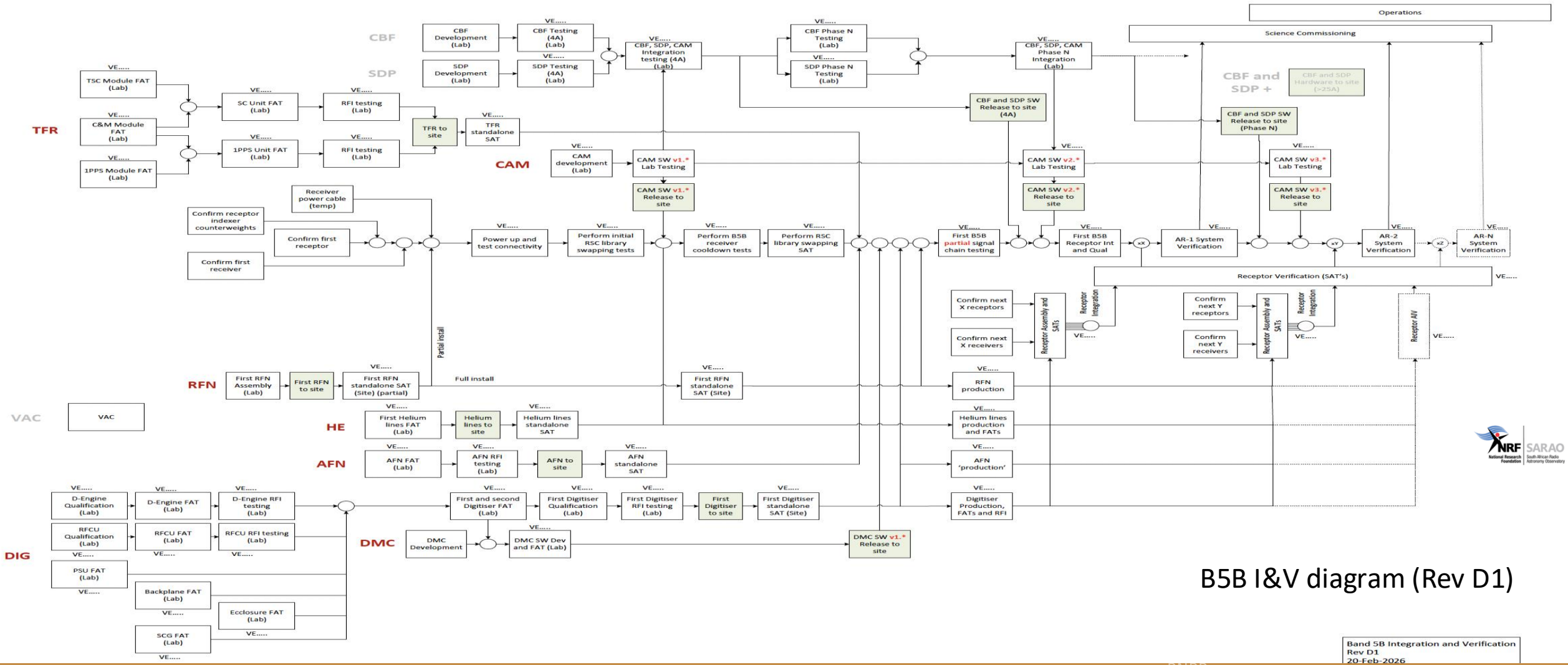
Science Data Processing





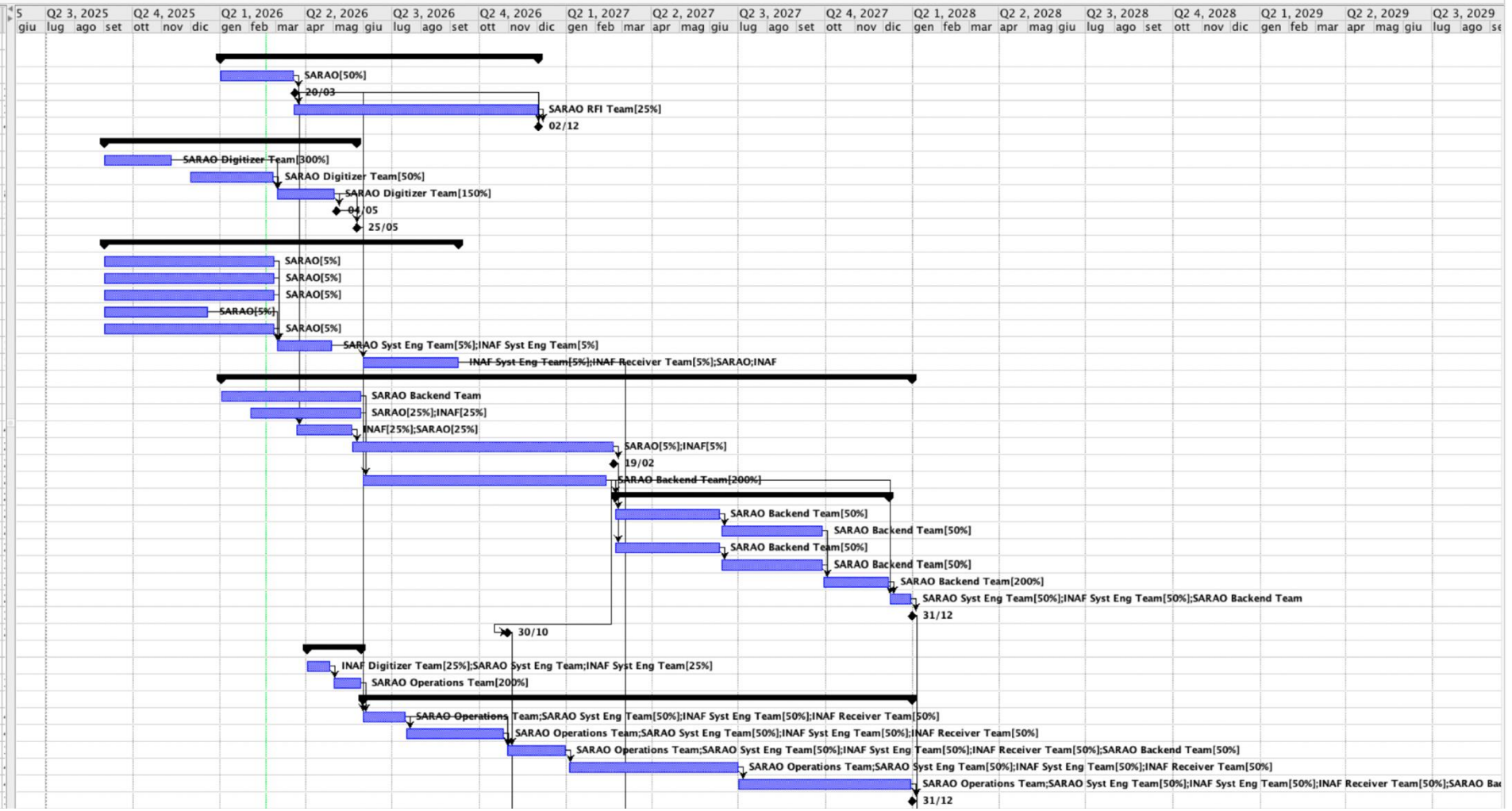
Systems Engineering
AIV
Engineering Commissioning
Science Commissioning
Operations
Maintenance

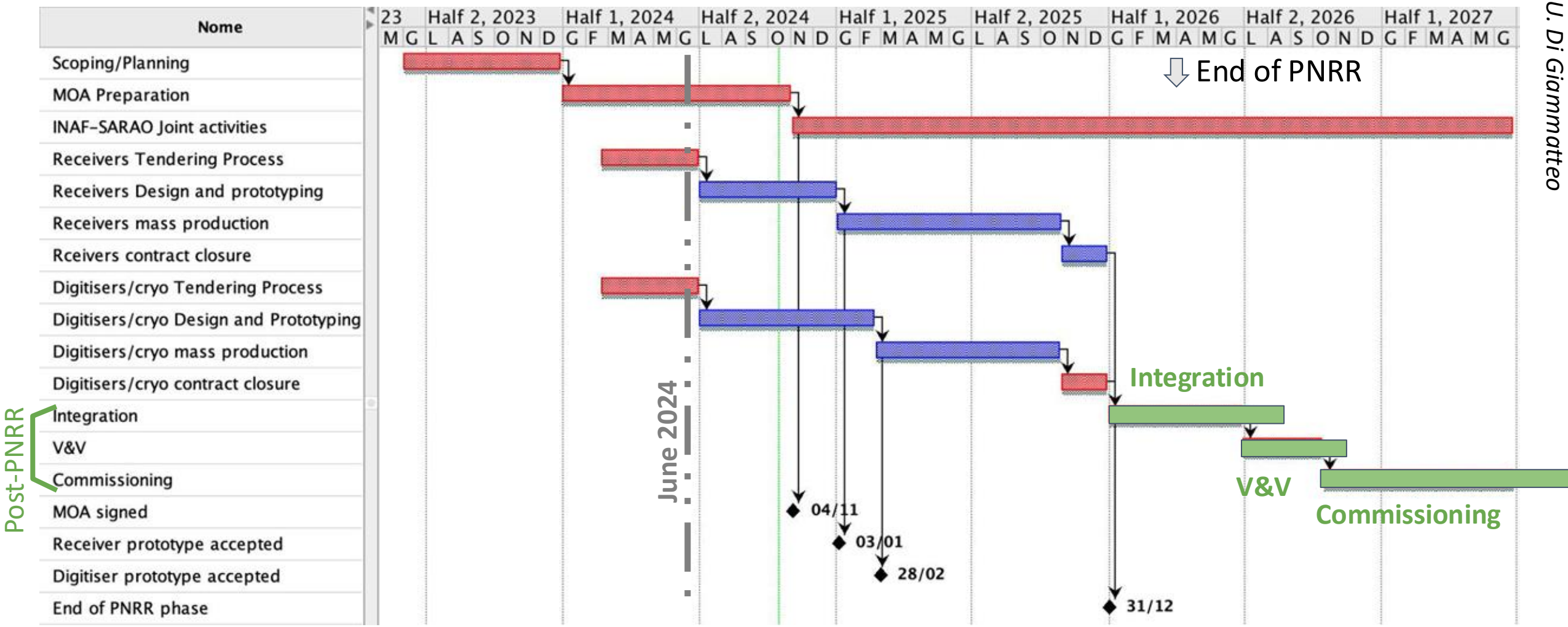

B5B I&V diagram (Rev D1)

# Band 5B Integration & Verification diagram

| | Nome | Data di Avv... | Data di chi... |
|---|---|---|---|
| 2 | **B5B Receiver Development & Acceptance** | **01/01/26...** | **02/12/26...** |
| 3 | B5B Receivers Permit Procedure | 01/01/26... | 19/03/26... |
| 4 | B5B Receivers Permit Released (TBC) | 20/03/26... | 20/03/26... |
| 5 | B5B Receivers CoC Procedure | 20/03/26... | 02/12/26... |
| 6 | B5B Receivers CoC Released (TBC) | 02/12/26... | 02/12/26... |
| 7 | **B5B Digitiser Development & Acceptance** | **01/09/25...** | **25/05/26...** |
| 8 | D-Engine Acceptance | 01/09/25... | 11/11/25... |
| 9 | Digitiser other components | 28/11/25... | 26/02/26... |
| 10 | Digitiser Integration | 02/03/26... | 01/05/26... |
| 11 | Digitiser Accepted | 04/05/26... | 04/05/26... |
| 12 | Digitiser CoC | 25/05/26... | 25/05/26... |
| 13 | **MK B5B Supporting Sub-systems Developn** | **01/09/25...** | **09/09/26...** |
| 14 | B5B Receptor Fibre Network (RFN) Acceptanc | 01/09/25... | 27/02/26... |
| 15 | B5B Array Data Network (ADN) Acceptance | 01/09/25... | 27/02/26... |
| 16 | B5B Antenna Structure (AS) Acceptance | 01/09/25... | 27/02/26... |
| 17 | B5B Helium Supply System Acceptance | 01/09/25... | 19/12/25... |
| 18 | B5B Time and Frequency Upgrade (TFR) & Ac | 01/09/25... | 27/02/26... |
| 19 | B5B Receiver Systems Controller (RSC) Tempc | 02/03/26... | 29/04/26... |
| 20 | B5B Receiver Systems Controller (RSC) Upgra | 01/06/26... | 09/09/26... |
| 21 | **B5B Backend (CBF and SDP)** | **02/01/26...** | **31/12/27...** |
| 22 | Completion of MK/MK+ Work | 02/01/26... | 29/05/26... |
| 23 | Lab/Development System | 02/02/26... | 29/05/26... |
| 24 | Approval of funding | 23/03/26... | 20/05/26... |
| 25 | CBF-SDP HW Procurement | 20/05/26... | 19/02/27... |
| 26 | CBF-SDP HW Delivery | 19/02/27... | 19/02/27... |
| 27 | CBF-SDP Development | 01/06/26... | 12/02/27... |
| 28 | **CBF-SDP Deployment and Integration** | **22/02/27...** | **07/12/27...** |
| 29 | SDP+LAB Integration and Test (CPT) | 22/02/27... | 11/06/27... |
| 30 | SDP+LAB Integration and Site Acceptance T | 14/06/27... | 28/09/27... |
| 31 | CBF+LAB Integration and Test (CPT) | 22/02/27... | 11/06/27... |
| 32 | CBF+Integration and Site Acceptance Test ( | 14/06/27... | 28/09/27... |
| 33 | CBF-SDP Integration | 29/09/27... | 07/12/27... |
| 34 | CBF-SDP Acceptance | 08/12/27... | 30/12/27... |
| 35 | CBF-SDP Accepted | 31/12/27... | 31/12/27... |
| 36 | Limited 4Ant. B5B CBF & SDP Capability | 30/10/26... | 30/10/26... |
| 37 | **B5B FrontEnd Integration** | **02/04/26...** | **29/05/26...** |
| 38 | Subsystems Lab Integration and Test (CPT) | 02/04/26... | 27/04/26... |
| 39 | Receptor OPS/LAB Integration and Test (Losb | 01/05/26... | 29/05/26... |
| 40 | **B5B Front-End Site Integration & SAT (Losb** | **01/06/26...** | **31/12/27...** |
| 41 | Receptors 1 & 2 Site Integration & SAT (Losbe | 01/06/26... | 15/07/26... |
| 42 | Receptors 3 & 4 Site Integration & SAT (Losbe | 16/07/26... | 27/10/26... |
| 43 | Connecting 4 Receptors to CBF-SDP | 30/10/26... | 31/12/26... |
| 44 | Outstanding Receptors Site Integration & SAT | 04/01/27... | 01/07/27... |
| 45 | Connecting 64 Receptors to CBF-SDP | 01/07/27... | 30/12/27... |
| 46 | 64 Receptors connected to CBF-SDP (TBC) | 31/12/27... | 31/12/27... |




# Band 5B Schedule – work in progress



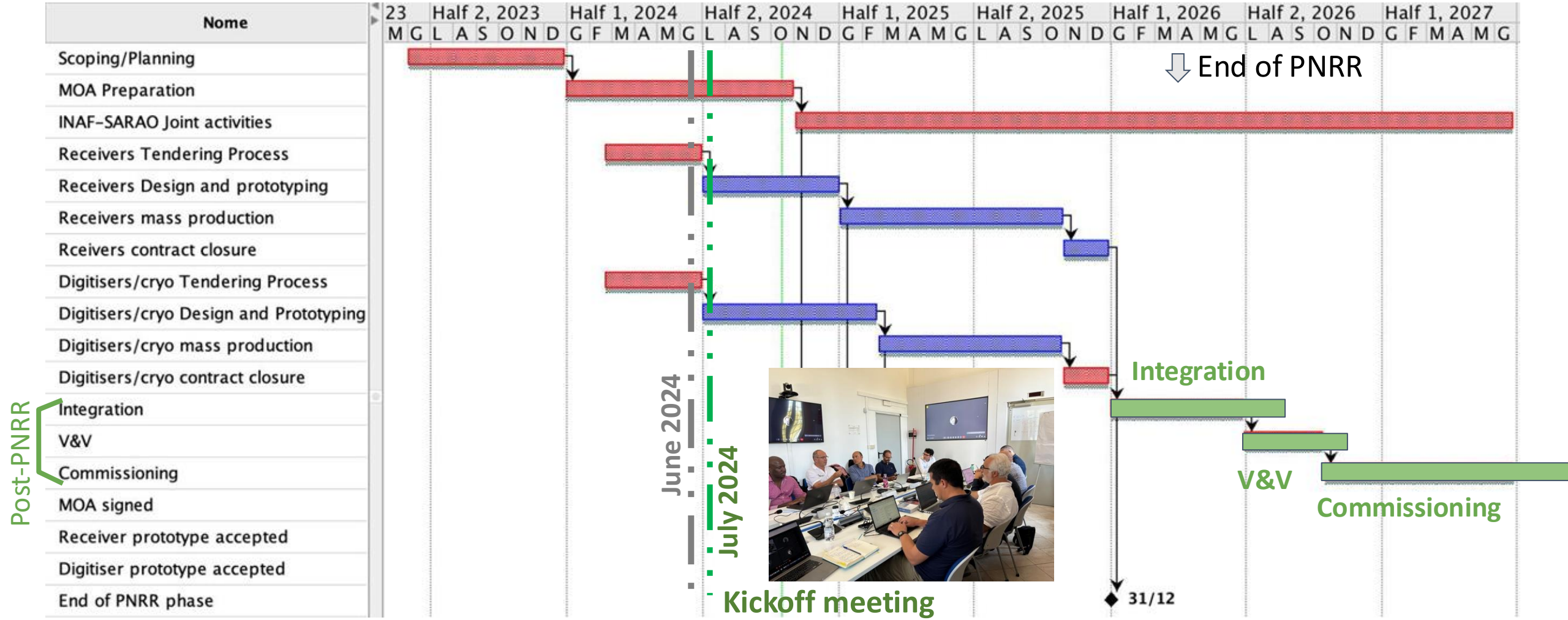

Contract awarded to MPIfR

U. Di Giammatteo

# Mid-term planning

| Nome |
|---|
| Scoping/Planning |
| MOA Preparation |
| INAF–SARAO Joint activities |
| Receivers Tendering Process |
| Receivers Design and prototyping |
| Receivers mass production |
| Rceivers contract closure |
| Digitisers/cryo Tendering Process |
| Digitisers/cryo Design and Prototyping |
| Digitisers/cryo mass production |
| Digitisers/cryo contract closure |
| Integration |
| V&V |
| Commissioning |
| MOA signed |
| Receiver prototype accepted |
| Digitiser prototype accepted |
| End of PNRR phase |

Post-PNRR

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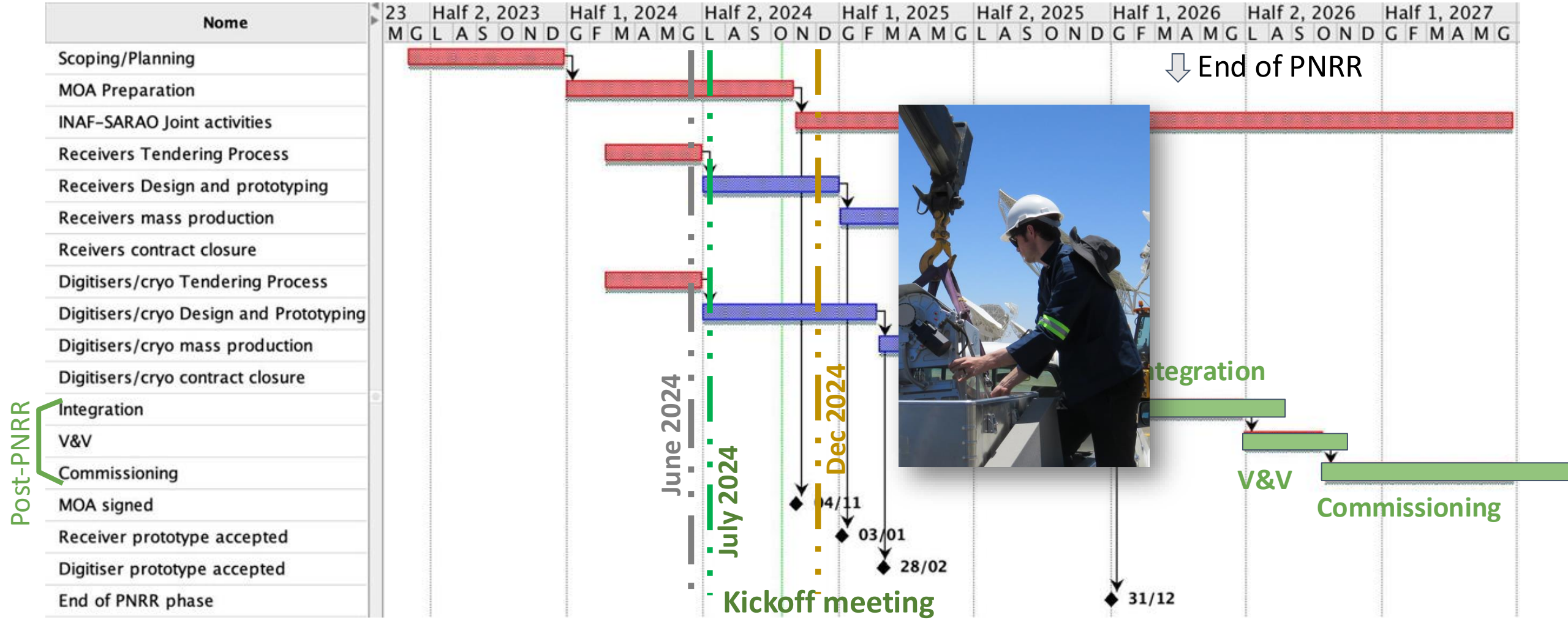
Post-PNRR




# Mid-term planning

# Mid-term planning

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|---|
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| MOA Preparation |
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| Receivers Tendering Process |
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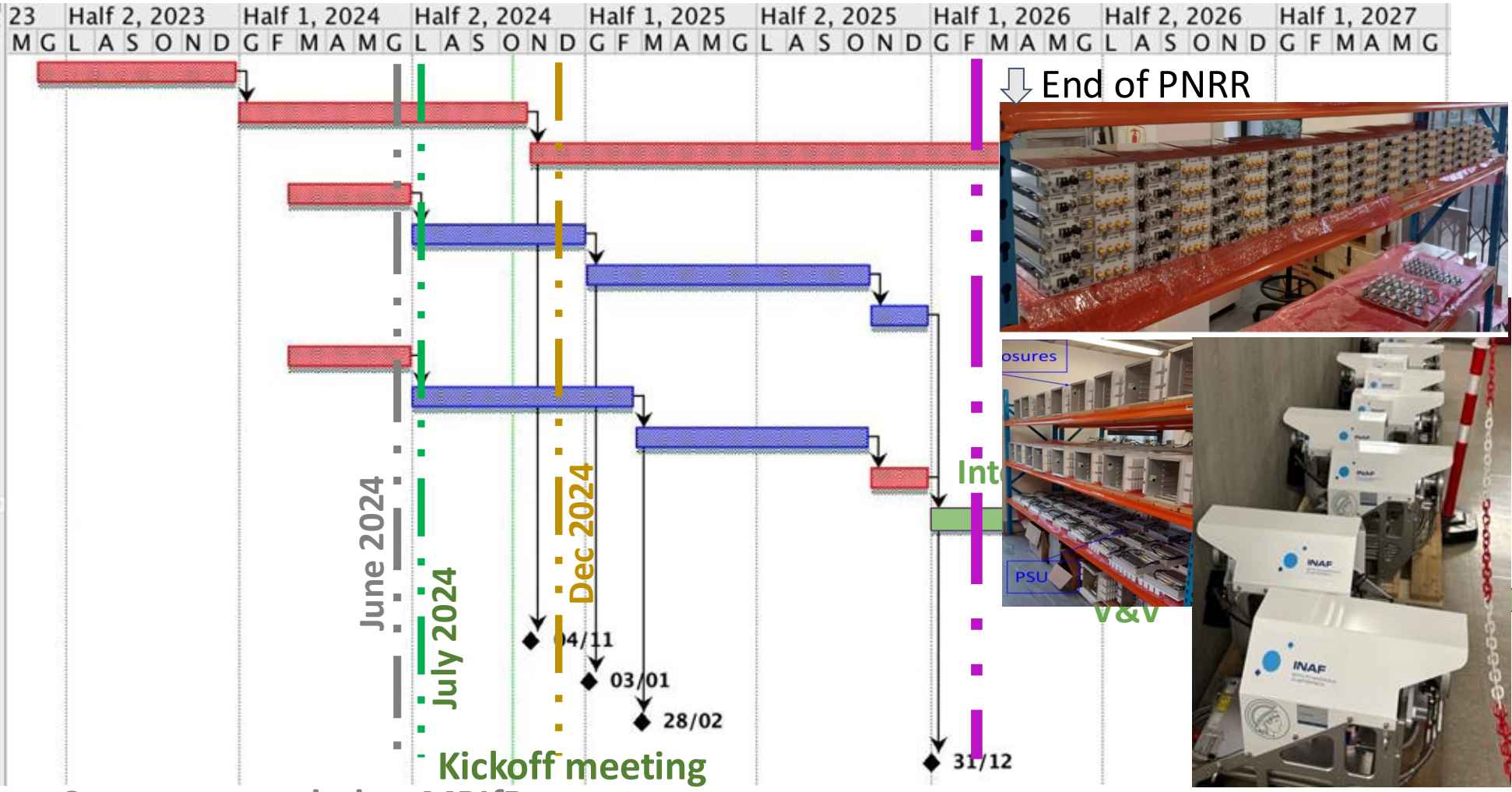
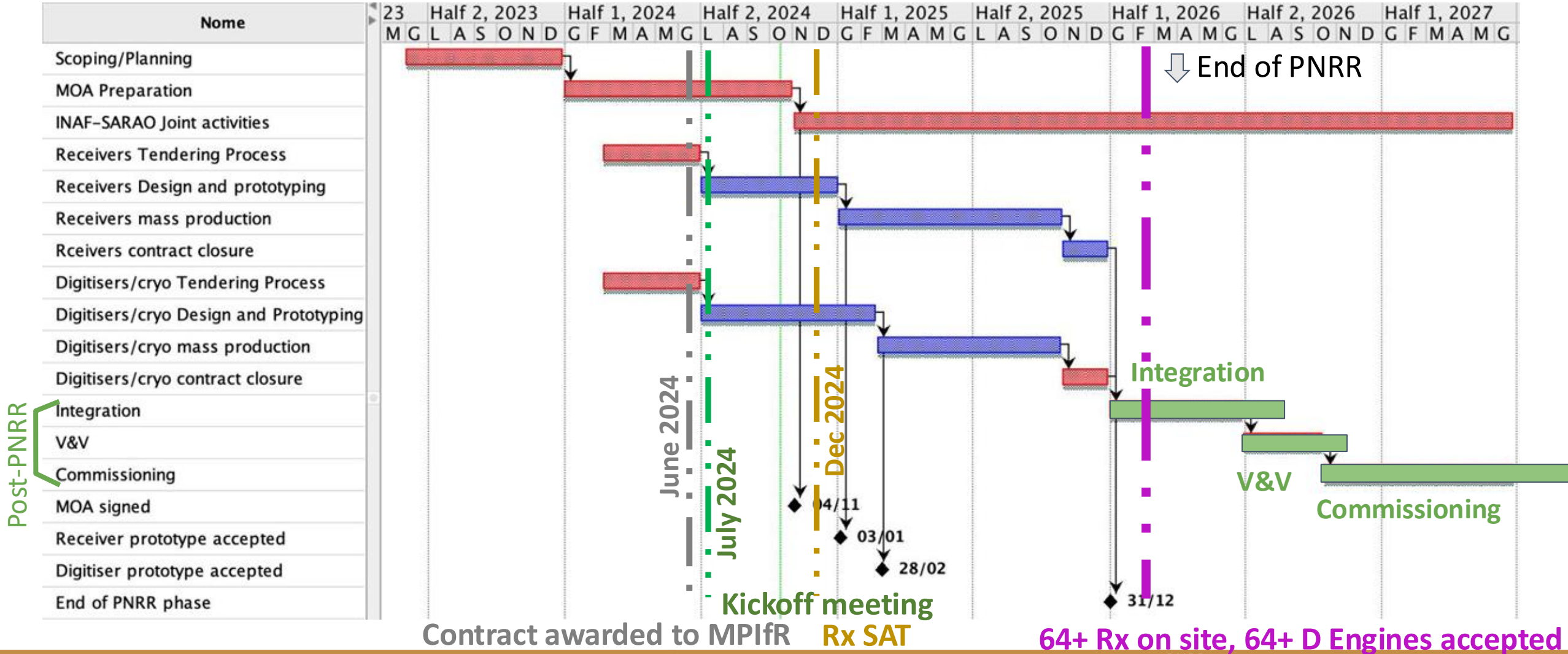
Post-PNRR

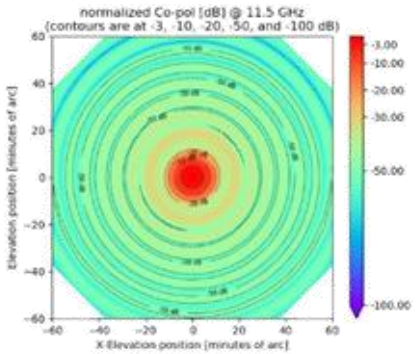


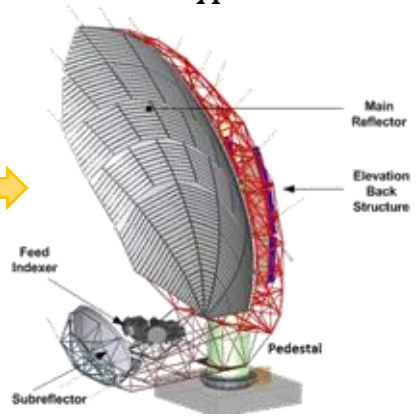



# Mid-term planning

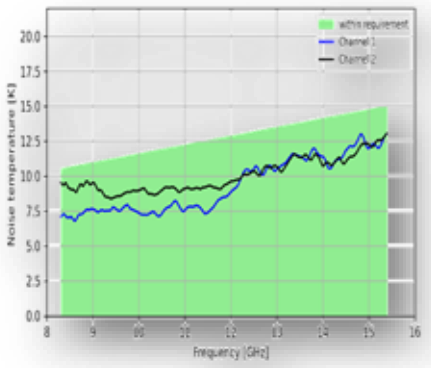
By combining (multiplying) the Feed pattern with the Dish pattern

⟹ Beam of the dish $\Omega_A$




**B5B Receiver Feed pattern**




**B5B Receiver Noise Temperature (K)**

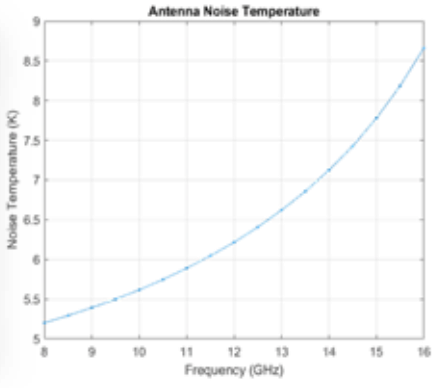



Figure 4 - Antenna Noise temperature - Zenith angle 0°.

**Antenna temperature**

From the relation $A_{\text{eff}} = \dfrac{\lambda^2}{\Omega_A}$

Tsys = Tant + Trec

⇓

**System Equivalent Flux Density (SEFD) for a single receptor**

$$\text{SEFD} = \frac{2\text{k/Jy}}{\text{Sensitivity}}$$

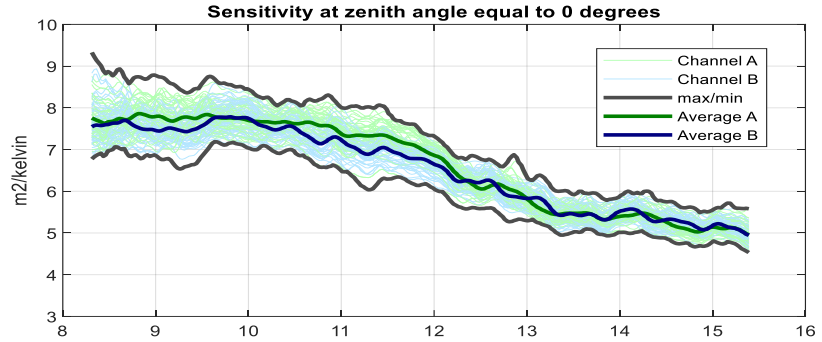
⇓

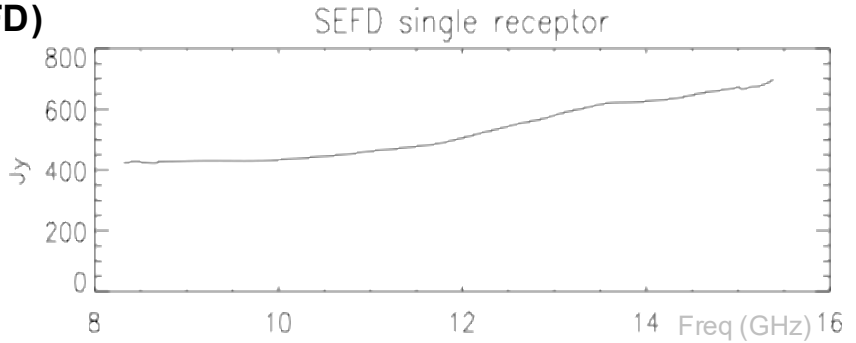
**Full Array of 64 Receptors**

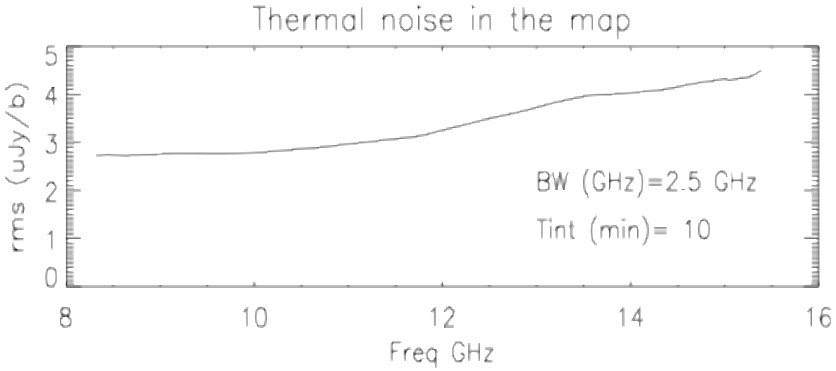
$$\text{rms} = \frac{\text{SEFD}}{\sqrt{2\text{N}(\text{N}-1)\text{T}_{\text{int}}\Delta\nu\ \text{n}_{\text{pol}}}}\ (\text{Jy})$$

$N = 64$ $T_{int}$ = 10 min

$\Delta n$ = 2.5 GHz $n_{pol}$=2




C. Trigilio, P.Bolli, M. Johnston

# The Band5B Project: System-level Simulations

Finanziato dall'Unione europea
NextGenerationEU

Ministero dell'Università e della Ricerca

Italiadomani
PIANO NAZIONALE DI RIPRESA E RESILIENZA

INAF
ISTITUTO NAZIONALE DI ASTROFISICA

# Thank you

**Maria Grazia Labate** <maria.labate@inaf.it>
and the **Band 5 team**



PNRR
Missione 4 • Componente 2
Investimento 3.1

STILES – IR0000034
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