



science  
& technology  
Department:  
Science and Technology  
REPUBLIC OF SOUTH AFRICA



SARAO  
South African Radio  
Astronomy Observatory



# MeerKAT Extension (MK+)

## Project Overview

Gundolf Wieching on behalf of the project





# Project Overview

- Scope and contributions
- Additional science capabilities
- Organisational structure
- Array configuration & dish “transfer”
- Timescales
  - Project Kick-off Aug. 14<sup>th</sup> 2019
- Value for SKA project



# Project Motivation

- Maintain momentum & capabilities
- Provide AA 0.5 to SAKO
- Schedule relief on SKA DSH & Infra
  - bring forward the industrialisation
  - provide SKA an array for early testing
- Exploring observing modes
  - combining different telescope beams
  - commensal observing
- New scientific capability on MeerKAT
- Future integration into SKA





# Scope of the Project



- Extend MeerKAT with 20 SKA compliant dishes
  - longer baselines (up to 18km)
  - 40%-50% better sensitivity (at L- and S-Band)
    - Additional 200sqm/K sensitivity (in L-band)
  - better UV coverage and potential improvement in snapshot capability
- Dishes equipped with SKA Band 2 and S-Band systems
- Increase MeerKAT Backend capabilities
  - upgrade MeerKAT correlator
  - upgrade MPIfR beamformer





# Joint Science Proposal

- First SA/MPG meeting in Cape Town, June 3<sup>rd</sup> & 4<sup>th</sup>
  - Preparation for one joint MK+ Legacy Project/Survey
  - Provision of key datasets for a diverse range of astrophysical topics for a wider community
  - Avoiding competitions with existing MeerKAT LSPs/other SKA pathfinder surveys

Three potential science projects being discussed

- HI intensity mapping experiment (proposed by Mario Santos et al)
  - Novel cosmological constraints, primordial non-Gaussianity etc.
- Medium-shallow HI survey (proposed by Gyula Józsa et al)
  - Statistical HI sample for: galaxy evolution, accretion, dark matter etc.
- Wide Area S-band Southern Sky survey (proposed by Sui Ann Mao et al)
  - Broadband polarization and total intensity science drivers
  - Potentially simultaneous S- and L-band survey with matched resolution

# MK+ S-Band Legacy Survey



**MeerKAT+ is uniquely positioned in this critical frequency domain at S band**

- **S-band (1.75-3.5 GHz) – lasting legacy in SKA era**
- Opens up new parameter space for discoveries in frequency, resolution, depth and polarization:
  - New classes of polarized radio sources in extremely turbulent environments
  - Probe extremely high density and magnetic field environments
  - Probe environments with mixed thermal and synchrotron emitting gas & entrainment
  - Significantly improve constraints on intrinsic source polarization properties
  - Spatially resolved spectral shape, curvature enabling easy identification of GPS, CSS sources..
  - And many more!!
- White paper on MK+ Science in final preparation
  - ready in the next month (coordinated by Roger Deane & Sui Ann Mao)

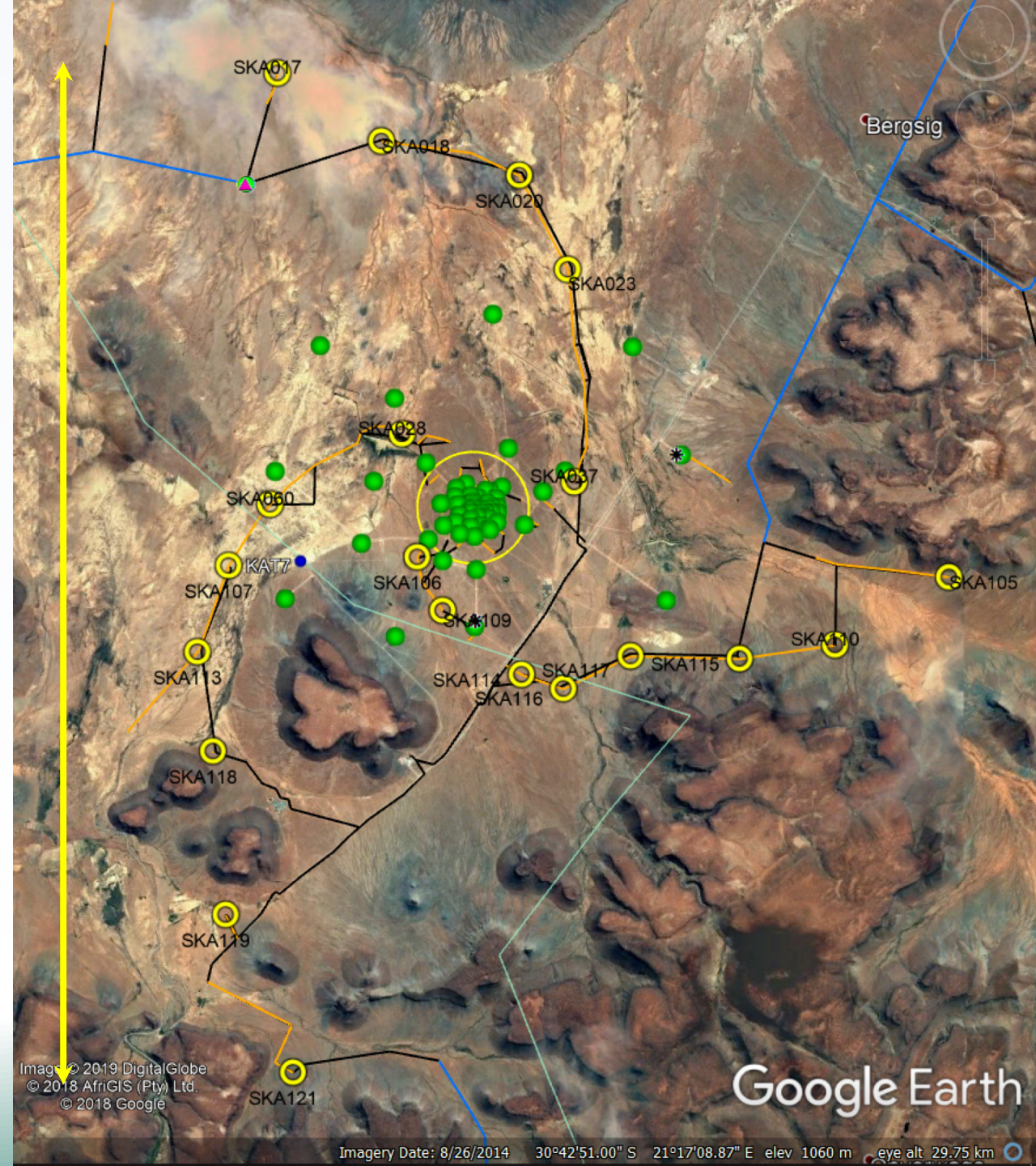
# Array Configuration

## Requisites:

- make use of SKA positions
- max baseline 18km
- 20 out of 31 possible locations
- Study to optimize for different parameters e.g.
  - low sidelobe levels
  - max angular resolution,
  - snapshot filling factor vs full track filling factor,
  - ...
- deadline end Nov 2019

## Reference array shown

- vary minor to down selection







# Receiver systems

- SKA Band 2 Rx and MPIfR S-Band have been tested on MeerKAT and will be soon be tested on SKA-MPG Dish
- MeerKAT L-Band, SKA Band 2 and MeerKAT digitizer:
  - frequency range 0.95 – 1.67 GHz:
    - L-Band (0.90 – 1.67 GHz) vs Band 2 (0.95 – 1.76GHz)
  - cryogenic cooled: LNA: 20K, OMT: 70K
- MPIfR S-Band
  - frequency range 1.75 – 3.50 GHz:
    - digital reduced to 0.875 GHz bandwidth to cater for correlator
  - cryogenic cooled: LNA and OMT <20K
  - analogue RF and integrated digitizer temperature controlled to 20mK
  - Filterbank, packetizer and controller integrated in one unit
- Systems availability for MK+:
  - SKA Band 2 tendering in progress
  - S-Band Rx in production





# Backend Extension

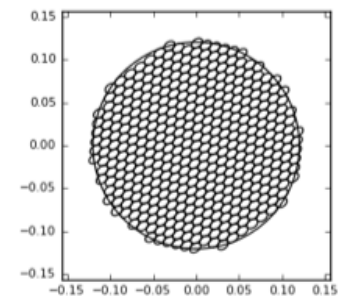
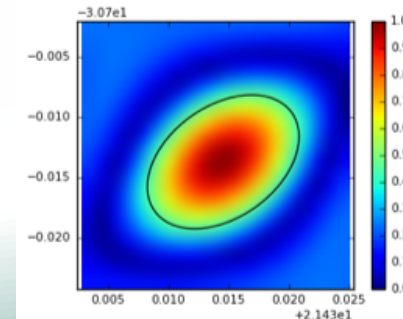
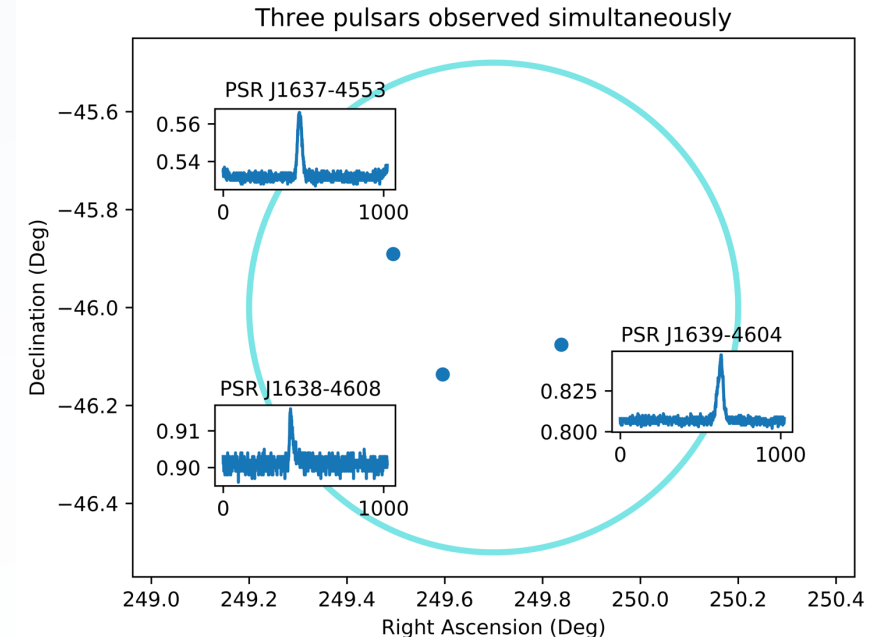
- Extension of MeerKAT correlator is under investigation
  - suppose to process 84 antenna inputs
- MPIfR Backend scalable due to generic hardware and software containerisation
  - current installation
    - 102 x Huawei FusionServer 2288H V5
    - 190 x Nvidia GTX 1080Ti
    - 20 TB RAM
    - 4 PB of storage distributed across the cluster with a writing speed >40GB/s
    - Combined 61 PetaOp/s compute (using DP4A instructions)



# MPIfR Beamformer FPFUSE

## Subset of the cluster

- Filterbanking beamformer:
  - 32 x Huawei FusionServer 2288H V5
    - 2 x Nvidia GTX 1080Ti
    - 384 GB RAM (50 second voltage buffer for whole array)
- Combined 1 PetaOp/s compute (using DP4A instructions)
- Outputs high-time-resolution Stokes I for pulsar and transient searching
- Theoretically can produce 2000+ beams
- Regularly observes with 864 beams for science observations with MeerTRAP
- All beams independently steerable, typically elliptical packing used to cover FoV







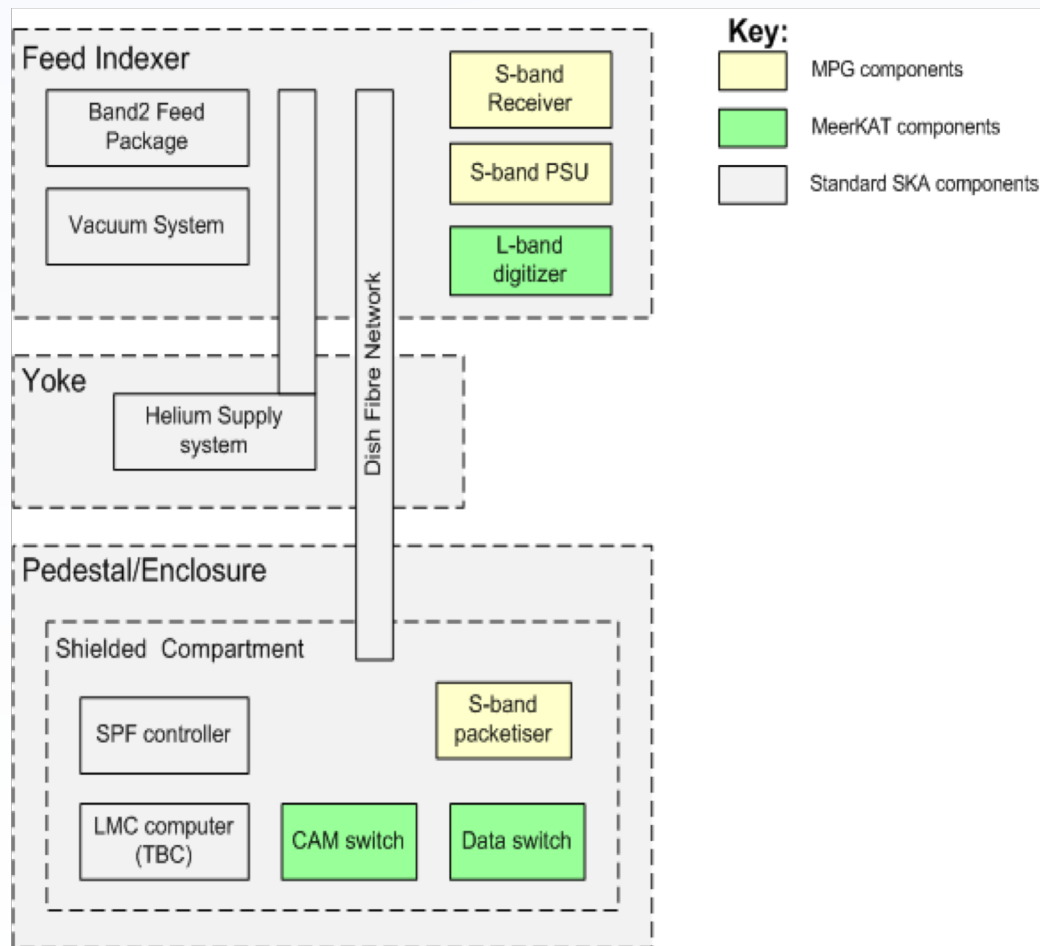
# Contributions

	Product	# of units	SARAO	MPG	China	SKA product
Dishes	Dish Structure	Industrialisation (4)				y
		Production (16)				
	SPF services (He, Vac, Cntrl)	Industrialisation (4)				y
		Production (16)				
	SPF Band 2	Industrialisation (4)				y
		Production (16)				
	L-band Digitiser	20				
	S-band Receiver	20				
Infra	Roads	for 20 dishes				y
	Foundations					
	Power reticulation					
	Fibre reticulation					
Back-end	Correlator (64 - later 84 Dishes)	64 (goal 84)				
	Science processor L-band (84 Dishes)	84				
	Beamformer & science processor S-band (Dishes)	84				

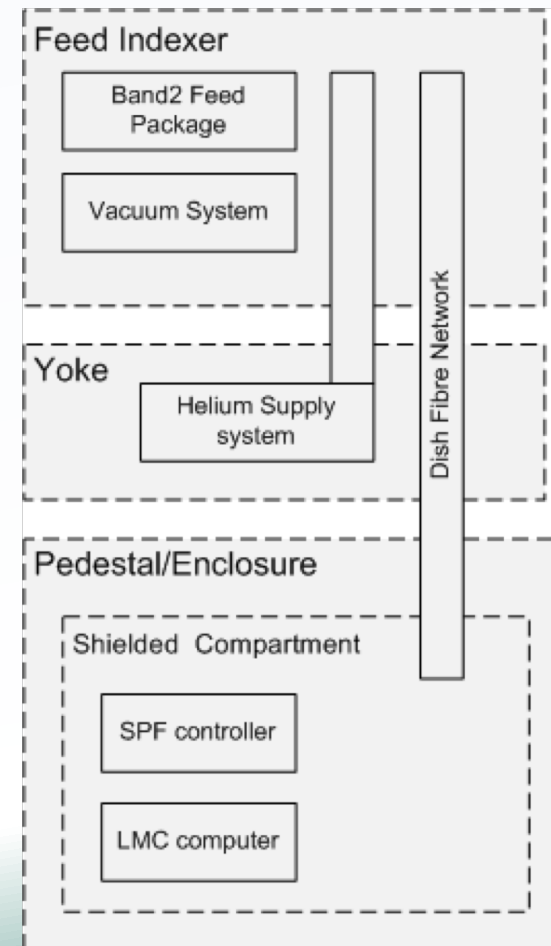


# DISH Configuration (SKA vs MK+)

MeerKAT Extension Dish



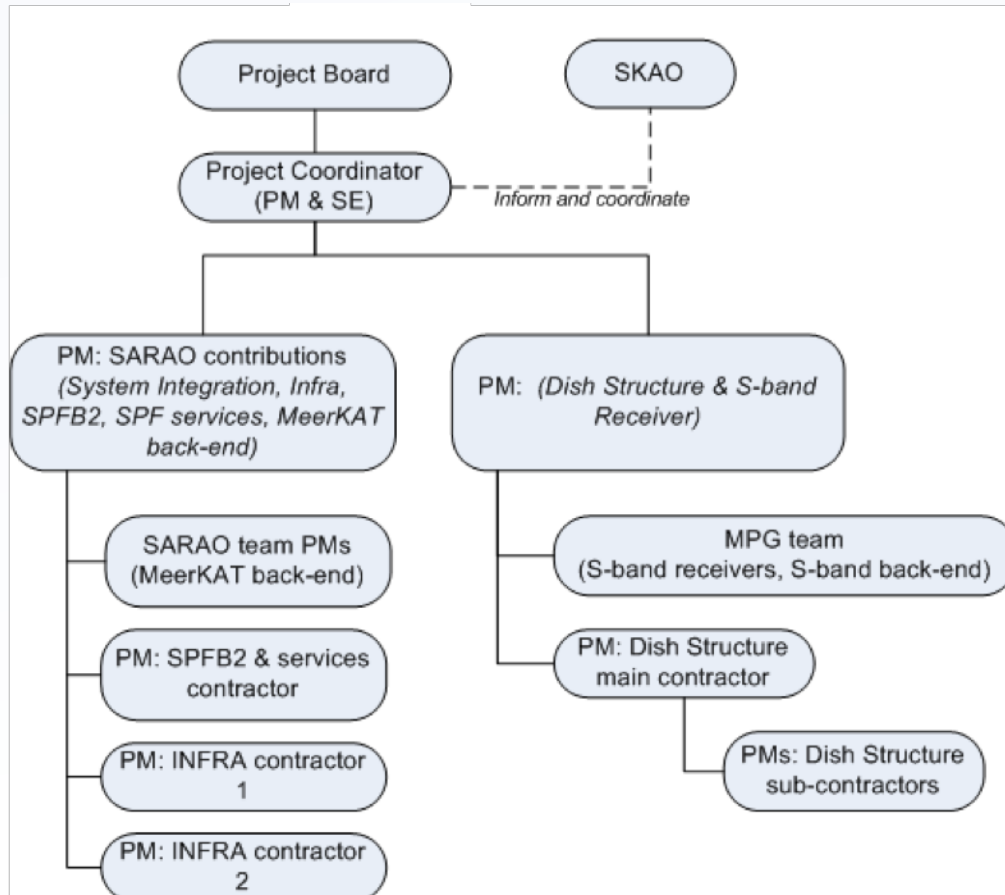
“SKA Compliant” Dish



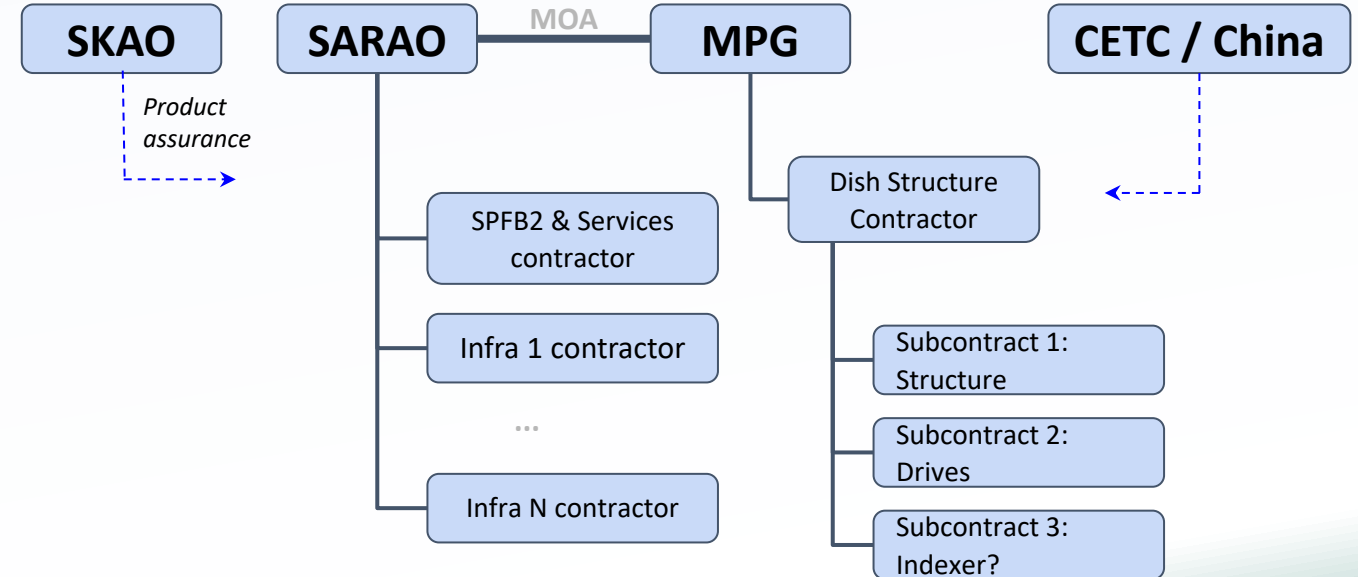


# MK+ Structure

## Project Management



## Organisational Structure







# Product Assurance

- Focus on SKA products
- Product acceptance by SKA
- Reduce retro-fits, hence cost & schedule
- Risk management
- Exercising the PA process for full-scale SKA production
  - Building up the capabilities
- Technical focus rather than purely documentation
- Focus on known vulnerabilities
- Embedding the MeerKAT and SKA-MPG lessons learned into MK+
  - RFI components & workmanship
  - Mechanical joints
  - Actuators
  - Structural components critical to alignment
  - ..

*SKAO agreed to be actively involved*

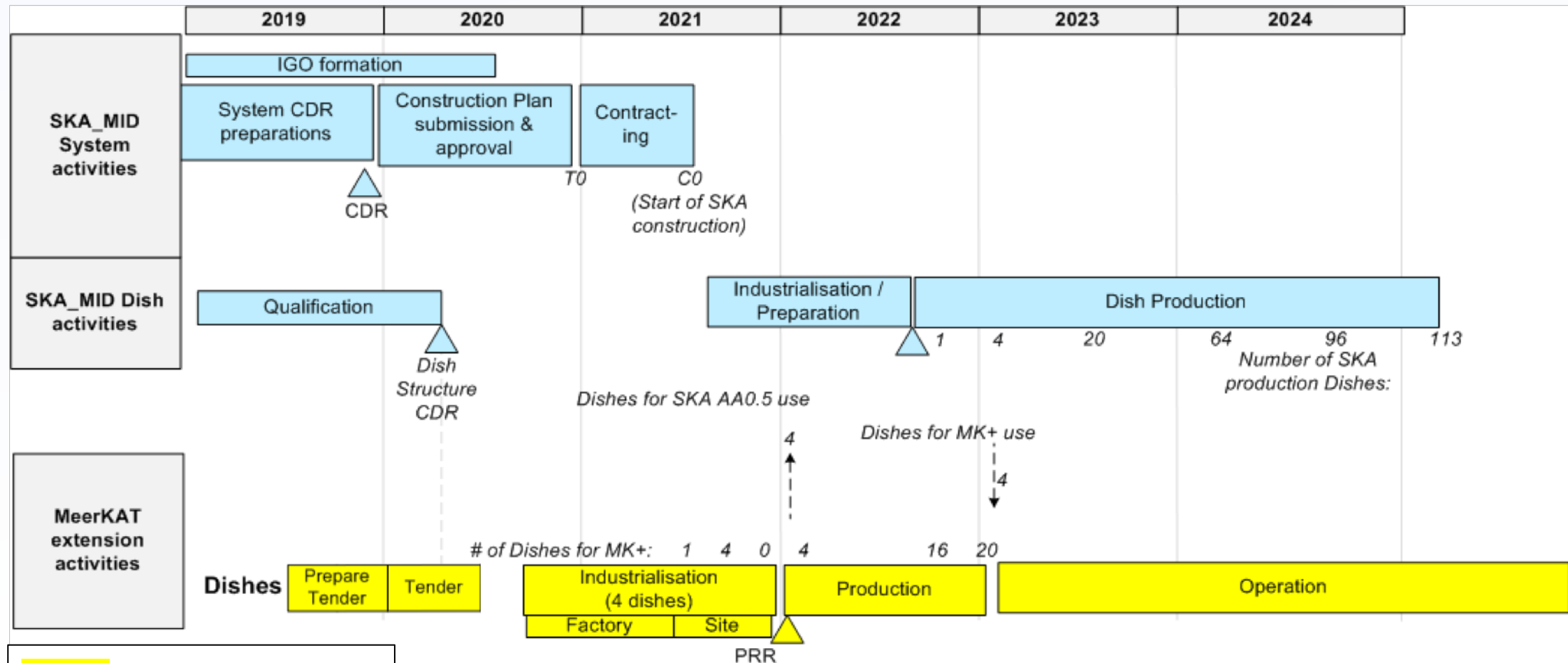


# Timeline

- MK+ requires an ambitious timeline to deliver unique science
- Synchronisation with SKA construction
  - Especially to provide AA 0.5 in due time
- Synchronisation with SKA-DSH structure design consortia
  - SKA-DSH structure CDR, delays will have a direct impact on MK+
- Timelines for
  - Dishes
  - Infrastructure
  - Combined



# Timeline: Dishes

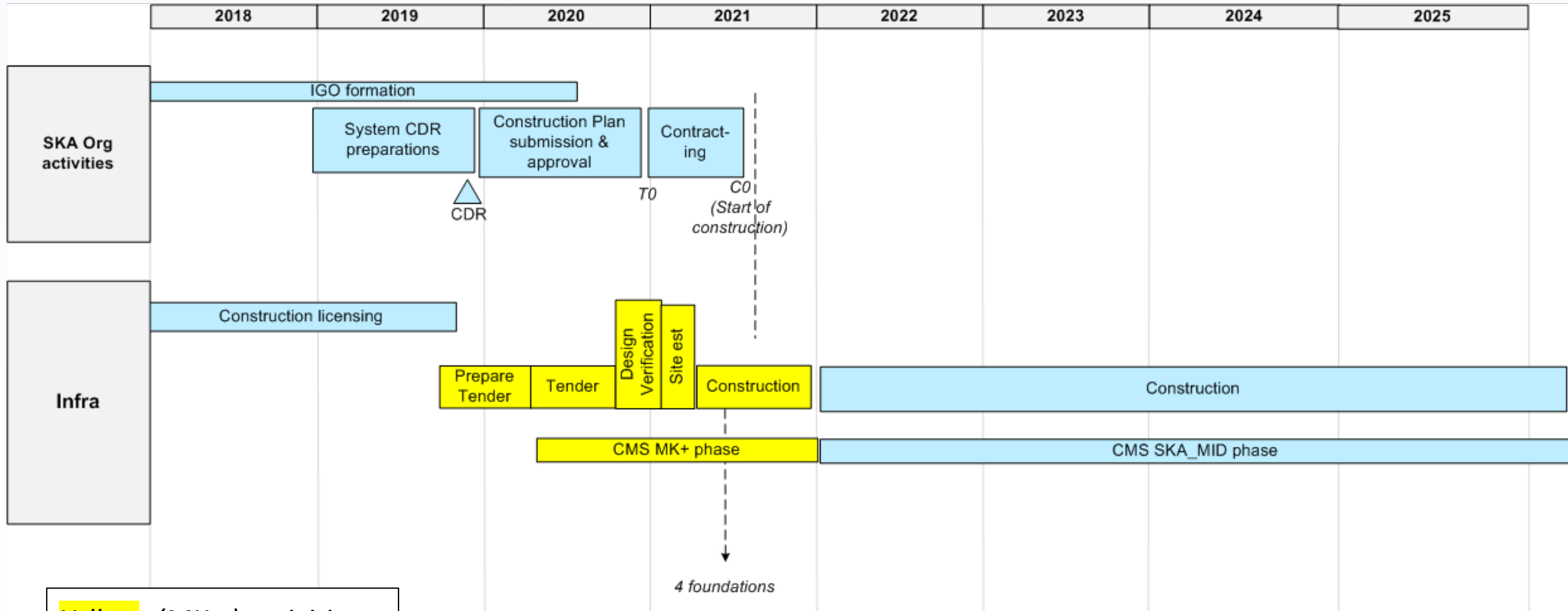


Yellow: (MK+ ) activities

Blue: SKA activities



# Timeline: Infrastructure

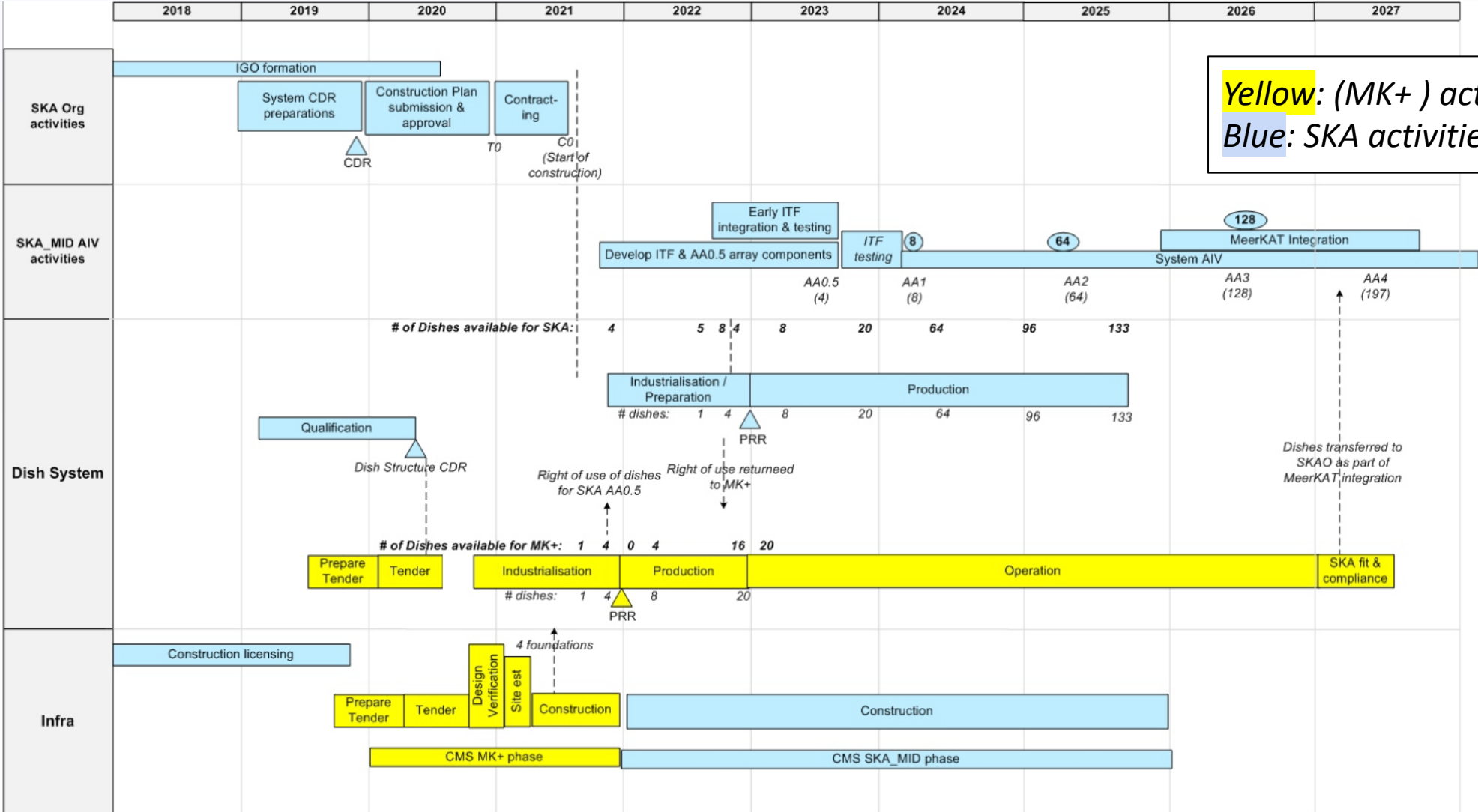


**Yellow:** (MK+ ) activities  
**Blue:** SKA activities





# Timeline: Overview



**Many thanks to the whole MK+ team!**

