The SKA DISH
Local Monitor & Control

Corrado Trigilio
on behalf of LMC team

DISH

SKA1 Mid – Science

DISH

Science Drivers for telescope requirements

- 21-cm HI-line: evolution of galaxies, (local, z ~ 0 to Hi z)
- All southern sky survey to detect all pulsars at 1400 MHz out to a distance of 10 kpc.
- Follow-up observations of detected pulsars at high resolution (<20 mas resolution).
- Carrying out a decade long timing campaign to time most detected pulsars and others.

Other Science objectives:

- Cosmic magnetism
- Star formation history
- Cradle of life
- Exoplanets
- SETI
- Transients (GRB, FRB, SN…)
- GW with pulsars
- AGN, radio jets
- Our Galaxy
- …other unknown?...

SKA1 Mid – After Re-baseline:

After Re-baseline:

- SKA Survey in Australia deferred
- PAF deferred
- Inclusion of high frequency band in the first phase (from both Gal and extraGal science needs)

SKA1 Mid – Configuration

SKA1 Mid

Location: Karoo in SA

Array Configuration:

3 logarithmic spiral arms,

Dense inner-core (~2 km diam., 50%)

→ Brightness Sensitivity

→ Pulsar Sensitivity

Max Baseline: 150 km

197 dishes

133 SKA 15 m

64 Meerkat 13.5 m

SKA1 Mid – Operations

Central building

Array management: TM

control of dishes

monitoring of dishes

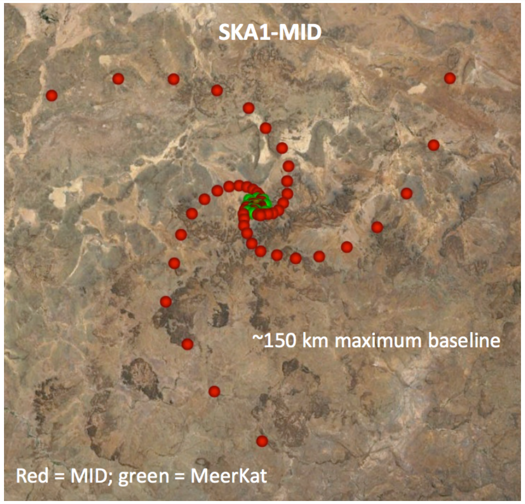
Central processor CSP

Visibility data

Each Dish of array

C&M (LMC)

Digitalized signal (Rx)



SKA1 Mid – Frequency bands

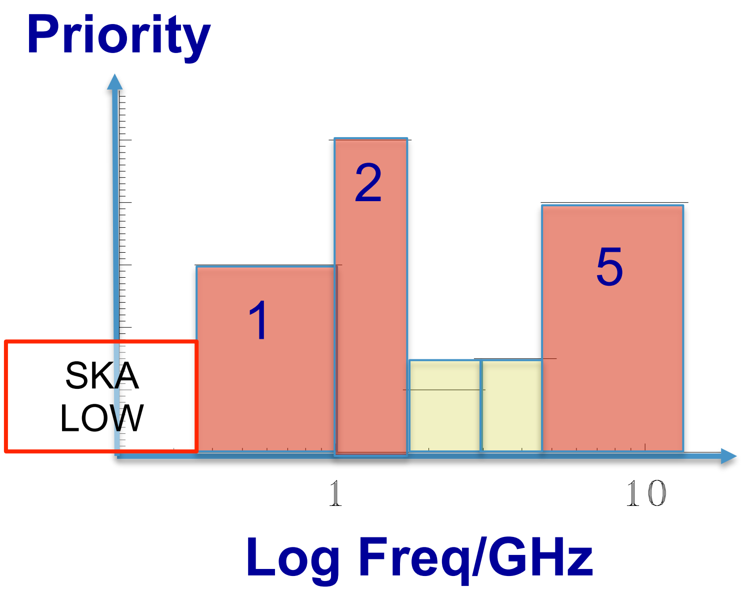
SKA SQUARE KILOMETRE ARRAY DISH

High priority bands for SKA-1 construction

SPF Bands

- **1: 0.35 – 1.05 GHz**
- **2: 0.95 – 1.76 GHz**
- 3: 1.65 – 3.05 GHz
- 4: 2.80 – 5.18 GHz
- **5a: 4.60 – 8.50 GHz**
- **5b: 8.30 – 15.4 GHz**

Populated
whole array band 1, 2
67 dishes band 5



0.22” @ 1.7 GHz; 34 mas @ 15 GHz

Band 5 considered as high priority after scientific meeting in Naxos, (galactic and extragalactic science) and re-baseline

The Dish Consortium - SKADC

The international DISH Consortium is responsible for the **design**, **verification and prototyping** of:

- antenna structure
- optics
- feeds (front end)
- receivers (back end)
- control system

and all the supporting systems and infrastructures ahead of the production of the **133 SKA-mid dishes** in Phase 1 of construction of the SKA.

Since 2017 the consortium is led by Wang Feng (JLRAT)/China (previous lead CSIRO in Australia, withdrawn after rebaseline)

The DISH Consortium:
four main work packages – Sub-Elements

- **DS** (Dish Structure): CETC54 (China) + MTM (Germany) + South Africa (SKASA) + SAM (Italy)
- **SPF** (Single Pixel Feeds): Onsala Space Observatory (Sweden), EMSS (SA), Oxford University/STFC (UK)
- **SPFRx** (Receivers): NRC (Canada) + Bordeaux University (France)
- **LMC** (Local Monitoring and Control): INAF (OACT + OATS), SAM, EIE (Italy)

The Dish Consortium - Timeline

SKA SQUARE KILOMETRE ARRAY DISH

The DISH Consortium: Roadmap

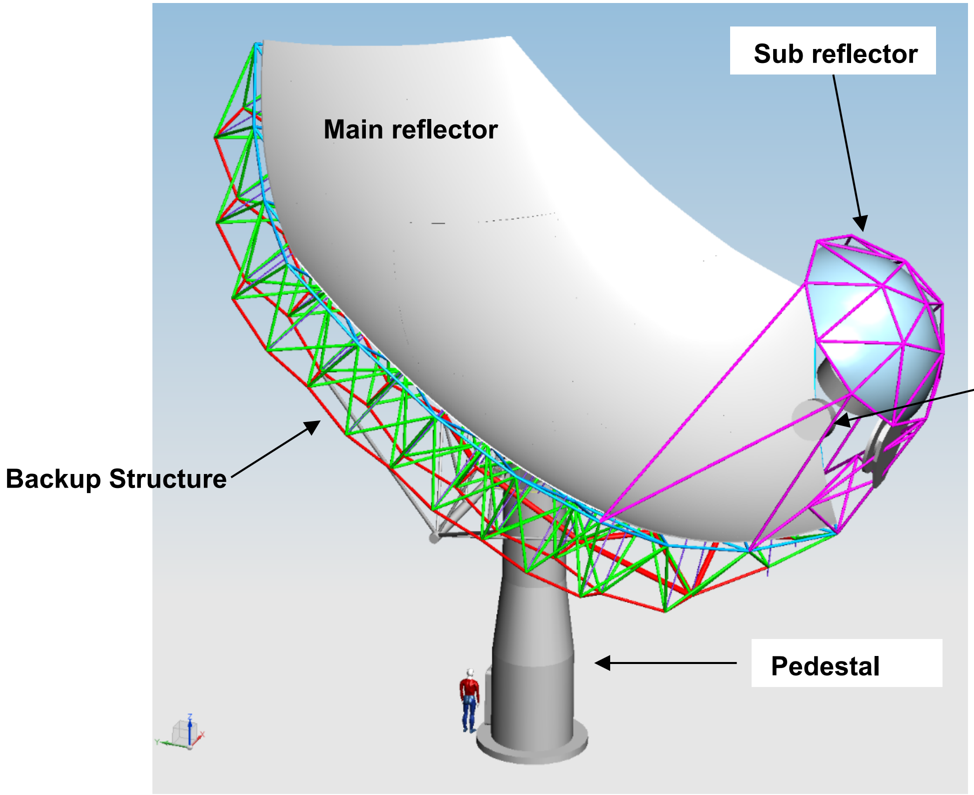
- **Oct 2013:** Kickoff meeting
- **May 2014:** Concept Design Review (**CoDR**)
- **Feb 2015-Dec 2015:** Preliminary Design Review (**PDR**) → end Stage 1
- **May-Dec 2016:** Detailed Design Review (**DDR**)
- **Feb 2018:** First SKA dish prototype assembled in China (**SKA-P**)
- **Mar-June 2018:** Second SKA dish prototype assembled in South Africa (**SKA-MPI**)
- **Early 2019:** Dish Qualification & Integration on SKA-MPI
- **Mid 2019 2019:** Critical Design Review (**CDR**) → end Stage 2
- **2019-2020:** Construction bridging + Early Production Array (**EPA**) (TBD)

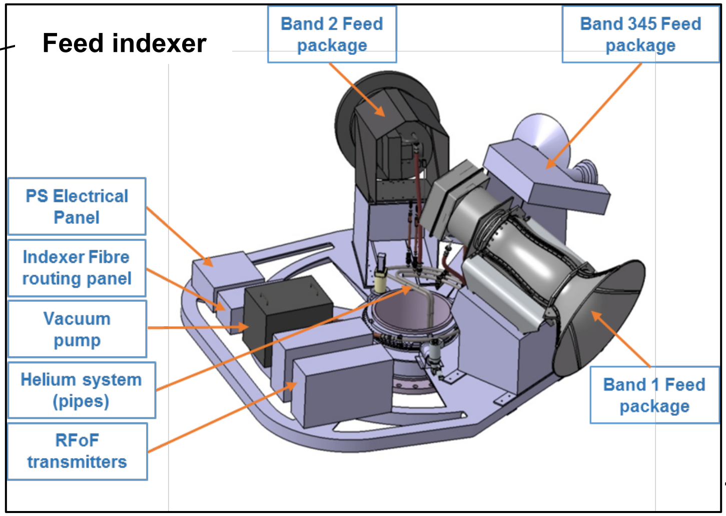
Dish Structure – Refractor

Design: Gregorian reflector, offset, unblocked aperture;
Main reflector projected diam : 15m
Feed-arm down;
Feeds at secondary focus
Sub-reflector diameter 5m

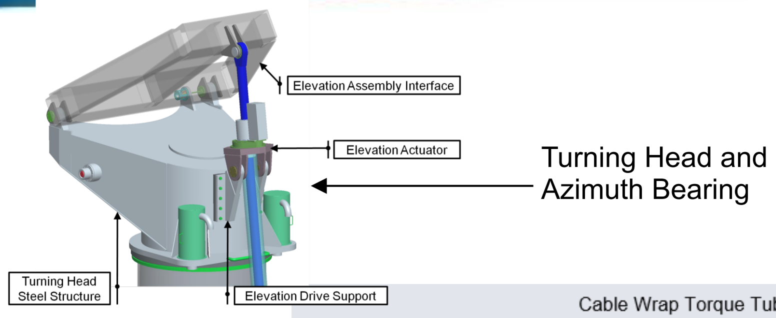
Structural members consist of mild steel.
Main Dish panels: aluminum
Sub-reflector: metalized composite panels

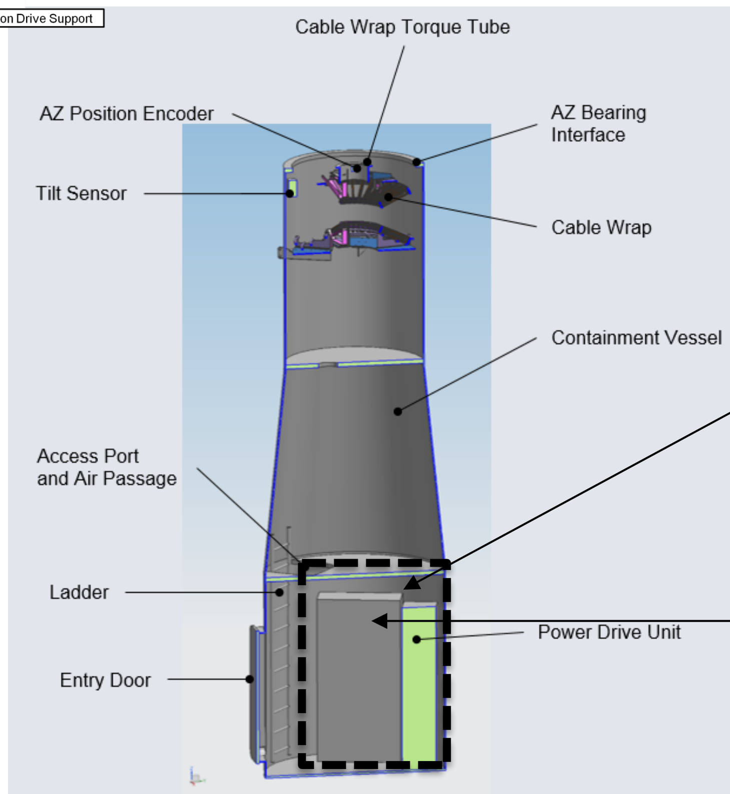
CFRP: Carbon Fiber-Reinforced Polymer





Dish Structure – Pedestal





Shielded compartment (80dB)

Double shielding enclosure inside another enclosure

This reduces the risk of self-induced RFI for the Dish and SaDT equipment located at the Dish.

Power distribution to all the sub-elements

Lighting protection, earthing

No active cooling: outside ambient air ventilation

no air conditioning (save $)

Fans for each controller

Operating Conditions

a) Climatic Conditions
- Air Temperature
  - Minimum Air Temperature: 0degC
  - Maximum Air Temperature: 45degC (50dC under extreme conditions)

Rack with:

- DS Control System
- SPF Controller
- SPFRx Receiver Pedestal Unit
- **LMC Hardware**
- DI PSC Fibre Routing Panel
- SaDT equipment

Dish Structure – Indexer (SAM)

SAM-Società Aerospaziale Mediterranea is part of the SKA «Dish Consortium», dedicated to the development of medium and high frequency radio antennas. SAM is responsible for the design and development of the electro mechanic component “Feed Indexer” which *is the only element of the structure that is not realized in China*. The first prototype of the Dish antenna has been presented in February 2018 in Shijiazhuang, China. Such prototype is producing the first scientific test data.

Dish Structure Team: China, Germany, SouthAfrica, Italy
SKA1 total Value: around 700 M€
«DISH» SKA1 Value: around 160 M€
Relevant Dates
Kick Off – September 2013
PDR – March 2016
DDR – December 2016
TRR Feed Indexer – December 2017
CDR – Planned for 24 November 2018

Investments Made by SAM: around 2,5 M€
Economic Return: from the first industrial (SKA1, first 133 antennas): 8-10 M€, from the phase 2 around 150 M€

«SKA-P prototype, feed indexer and antenna structure (Shijiazhuang, China)

Dish Structure – SKA-P

SKA Dish Prototype 06/02/2018
Shijiazhuang (China)

The selected design for the SKA dish is Chinese (CETC54), German (MT Mechatronics), Italian (SAM) collaboration

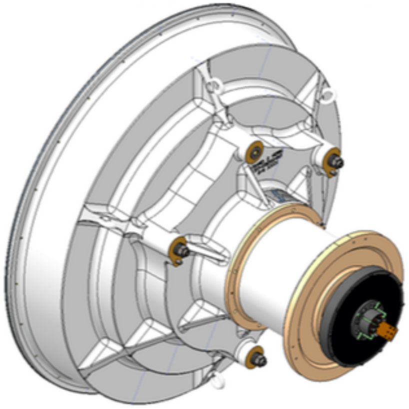
Single Pixel Feeds

SKA SQUARE KILOMETRE ARRAY DISH

Band 1
0.35 – 1.05 GHz

Quad Ridge flared feed
Uncooled Feed and LNA
3:1 frequency range

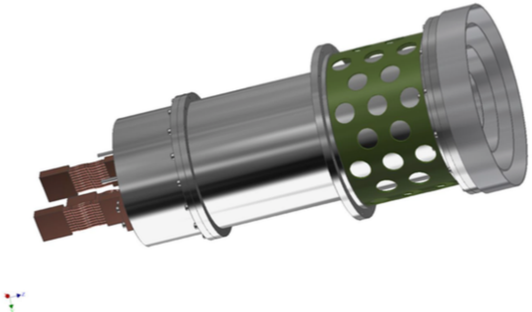
Band 2
0.95 – 1.76 GHz



Corrugated conical feed
Cryo system
LNA 1° and 2° stages @ 20 K
noise diode for calibration.

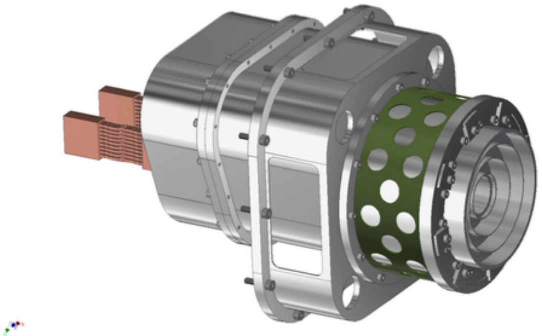
SPF Controller:
in pedestal

Band 3,4, 5a, 5b



Band 5a mechanical design

Populated only **Band 5a,5b** for 65 Dishes
feeds and front-end are cooled.
Provision is also made for future upgradeability to Band 5c.



Band 5b mechanical design

Receivers (Rx: digitalisers)

From SPF to Rx:

- **Pedestal** with RF over co-axial cable links from feeds

Master Clock timer :

- time and frequency reference (SaDT)
- control of the calibration noise source

Digitisers:

- RF conditioning (filtering and level control).
- All bands **direct digitalised**
- Bands 1-3 (1 and 2 in the 1st and Band 3 in 2nd Nyquist zone)
- Bands 4, 5a & 5b are band selected and **down converted**
- Band 5a & 5b, two individually tuneable sub-bands of 2.5GHz bandwidth
- Data packetized and transmitted to CSP

65,536 channels maximum

	RF frequency range (GHz)	RF Bandwidth (GHz)	ADC sampling rate (GSps)	Transport sampling rate (GSps)	Transport bit depth
Band 1	0.35 – 1.05	0.70	4	4	8
Band 2	0.95 – 1.76	0.81	4	4	8
Band 3	1.65 – 3.05	1.40	3.2	3.2	8
Band 4	2.80 – 5.18	2.38	16	6	8
Band 5a	4.60 – 8.50	3.9	9	2x6	4
Band 5b	8.30 – 15.30	7.0	16	2x6	4

Rx Controller:

in pedestal

Local Monitor and Control

LMC consists of a software system for C&M of the DISH equipment to TM and a hardware computer hosting it.

LMC is the beating Heart of the dish

It monitors the health of the dish and controls the whole structure and its movements

The LMC PC is in the pedestal, in a 19” shielded rack inside a shielded compartment

DSH LMC team - Italy

INAF

Catania, Trieste, Noto

Managemet, SE, Software developers

C. Trigilio , A. Ingallinera, A. Marassi,
S. Riggi, F. Schillirò

Collaborators

V. Baldini, U. Becciani, S. Buttaccio, I. Coretti,
A. Costa, G. Nicotra, C. Nocita

From Sep 2017 also

EIE

Hardware procurement and HW QTP

R. Cimmino, E. Marcuzzi, A. Cesaro

SAM

Software automated QTP

R. Aurigemma, R. Russo, E. Schiano,
F.P. Bonetti, R. Scognamiglio, A. Trotta

The SKA Control System

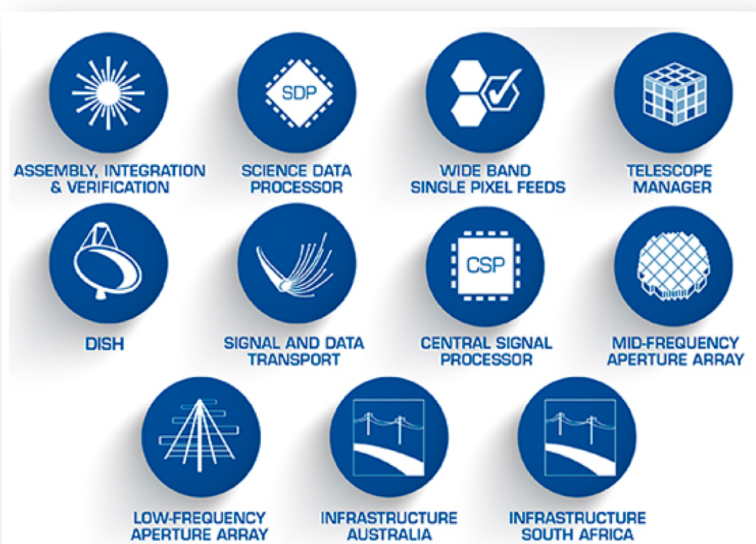
SKA Control System: a technological and organizational challenge

- large & heterogeneous system (>10^6 monit points), scalability, maintainability **> 50 years**
- group geographical dispersion & previous background

Harmonization process main outcomes (see SKA Control Guidelines)
Tango selected over other frameworks (EPICS, ACS, Meerkat CAM) (Mar 2015)

Standardization:
- architectural components (Element master, logging, alarm handler, archiver)
- *SKAControlModel*(SCM)(operatingstates/modes,...)
- control & configuration patterns
- programming languages & tools

Some areas still to be covered (e.g. deployment, configuration, testing strategies, etc)



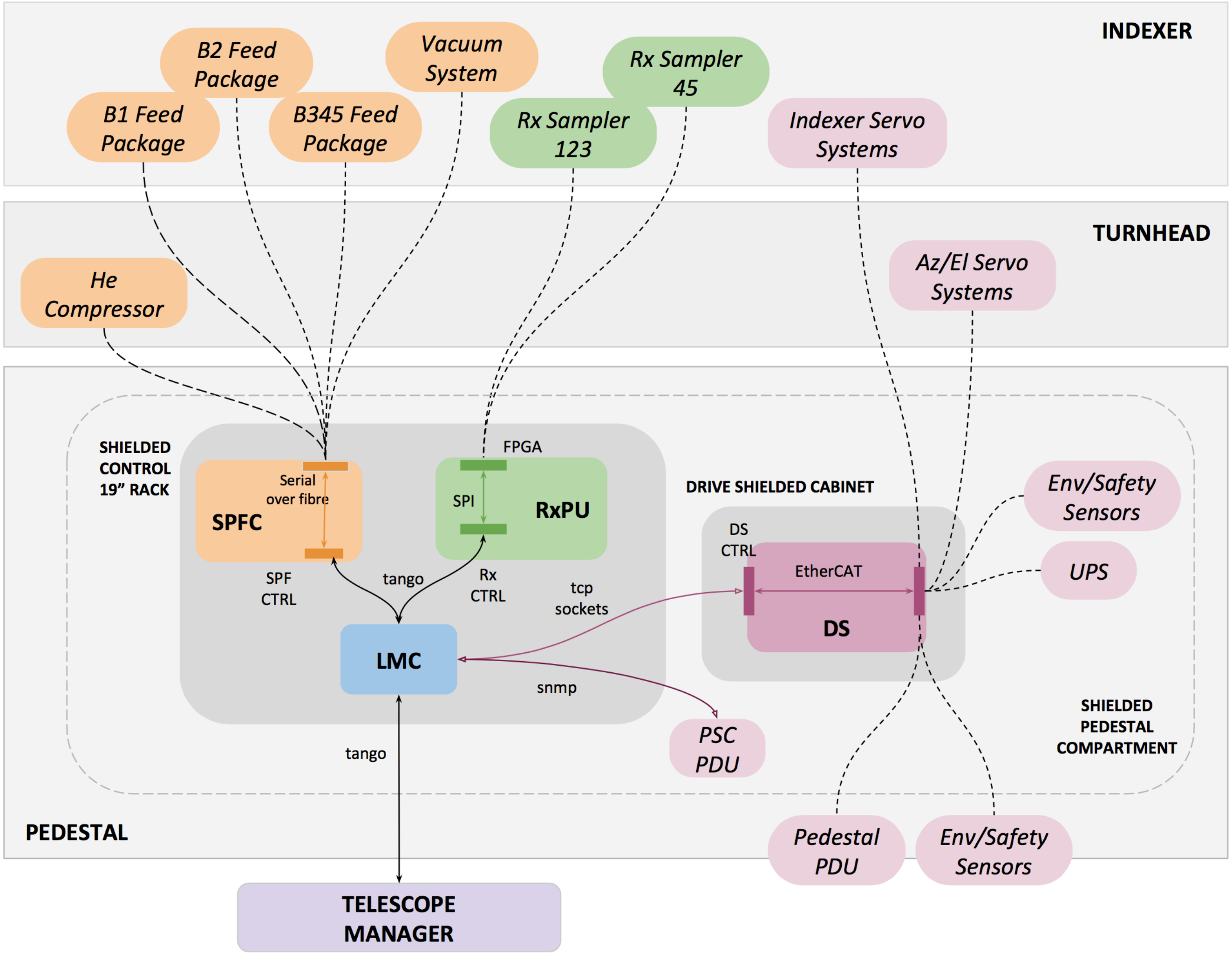
SKA CS organized in hierarchical Element facilities (=Tango domains)

- Each SKA Element has an LMC sub-element
- LMCs providing dish master control and rolled-up monitoring to Telescope Manager (TM)

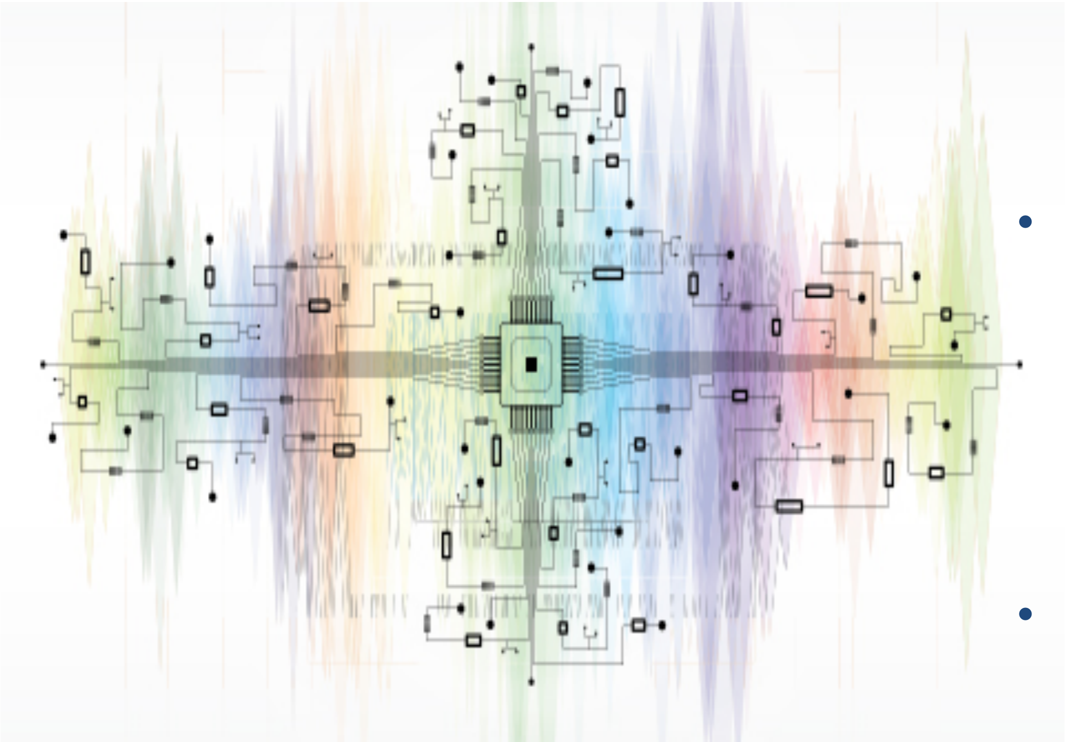
The DISH Control System

Relatively small system from the M&C view

- **Moni points: <1000**
- M&C **data rate** flowing centrally:~**200 kbps**
- **Fastest M&C rate:100ms** (ACU loop is faster)
- Moderate number of Tango Devices:<20

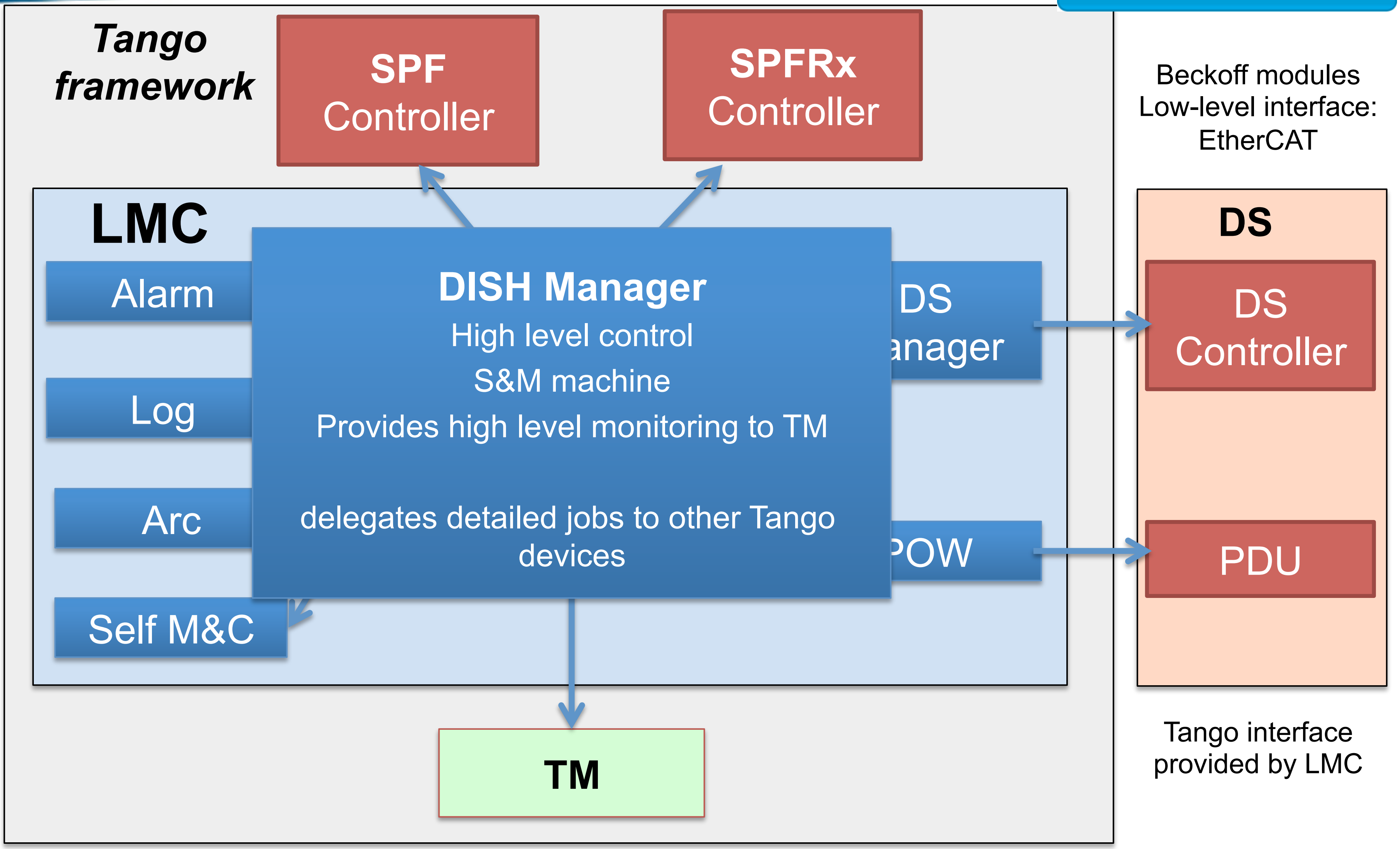


General DISH Architectural and SE



- Simple architecture, without cross connections helps readability of design and system integration.
- Early and very detailed development of modules with high connection density and high information content, allow the system to be on schedule and on budget.
- To design using architectural patterns increases system reliability and mass reproducibility.

DSH LMC - Software design



Integration with other Sub-Elements

Connections with other software developers is extremely important

In July 2017, first communication and operation test carried out by South African (SPF) and Italian (LMC) engineers

The LMC and the SPF systems successfully communicated!!!

In the picture: A. Marassi (INAF), A.Ingallinera (INAF), J. Kotze (EMSS), C. Trigilio (INAF), T. Stein (EMSS) and S. Riggi (INAF)

LMC CDR

SKA SQUARE KILOMETRE ARRAY

DISH

Sep. 2018- LMC CDR…DONE!

Final review successfully passed with LMC team, Dish Consortium Engineers, Reviewers and SKAO Representatives gathered in Catania

Photo group. From left: A. Marassi, (INAF) R. Aurigemma (SAM), S. Vrcic (NRC, CA), S. Riggi (INAF), L. Pivetta (SKAO), F. Schillirò (INAF), A. Cremonini (SKAO) D. Terret (STFC, UK) , R. Cimmino (EIE) , C. Trigilio (INAF) , M. Harmann (SKAO) , A. Ingallinera (INAF) , G. Chiozzi (ESO) , T. Kusel, G. Smit, and G. Van der Merwe (SARAO, SA) , A. Cesaro (EIE) , M. Bowen(SKAO). In the background Mt. Etna covered by clouds.

Status of Dish Sub-Elements

Dish Structure (DS):

SKA-P prototype (in China); holographic tests in progress;
SKA-MPI (in South Africa): still waiting for the drive system; RFI and performance tests planned for January 2019.
TRR to be completed, then CDR.

Single Pixel Feeds (SPF):

Band 1 and Band 2 CDR completed; some delays for vacuum, He and compressor systems.
Band 5 still in the phase of closing the Delta PDR. Consider that the design started after the SKA re-baseline.

Single Pixel Feeds Receivers (SPFRx):

Still in the phase of delta DDR, planned for February 2019.

Local Monitor and Control (LMC)

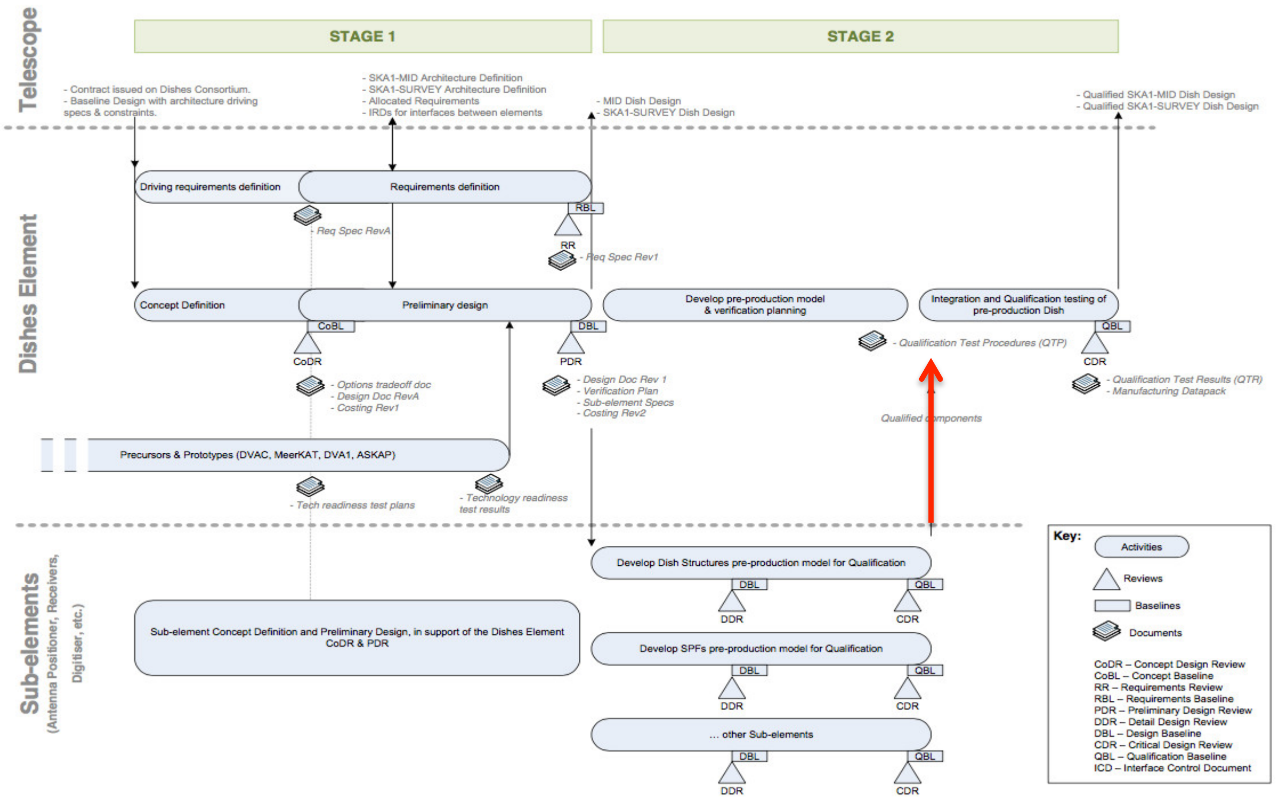
Finalising the documents and the last tests to be performed for the formal closure of the CDR.

What next?

SKA SQUARE KILOMETRE ARRAY DISH

Integration in Karoo, in South Africa, with SKA-MPI planned Jan-Feb 2019

→ SKA1_MID DSH Qualification Model (SDQM) will be delivered



DISH CDR in mid 2019 (TBC)

What next?

MeerKAT Integration in SKA1-Mid

The LMC Software is based on the Tango framework, while MeerKAT on KATCP.

In order to integrate SKA1_MID and MeerKAT, a **KATCP/Tango translator between the Meerkat RTS and the SDQM LMC** is required.

Planned in the first months of 2019

Bridging Period

Period between the end of the pre-construction and the construction.

Some effort is required to the Consortia during the Bridging. Additional work at the **Integration Test Facility in Karoo** for DSH LMC is required.

SAFe methodology for the SKA software before construction

A "**second step of harmonisation**". Collaboration with the SKA software engineering with other Control Software Groups. Constitution of a **SAFe** group for managing the control software development across SKA.

Thanks