DISH LMC

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LMC Harmonisation Workshop

Madrid 11-13 April 2016

Outline

- DSH LMC Team
- Dish Overview – SKA-Mid
- DSH LMC High level Software architecture
  - PBS
  - DSH LMC SFW specifications derivation from requirements
  - Example for Pointing functions

DSH LMC team

INAF – Italy **Catania, Trieste, Noto**

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SKA1 Mid

Science Drivers

- 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
- …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)

After Re-baseline:

SKA1 Mid

Location: Karoo in SA

Figure 27 SKA1-Mid. Key sites in South Africa. SKA1-Mid is located at the Karoo Radio Astronomy Reserve (KRAR).

After Re-baseline:

SKA1 Mid

Location: Karoo in SA

Array Configuration:
3 spiral arms,
high density at center
Max Baseline: 150 km

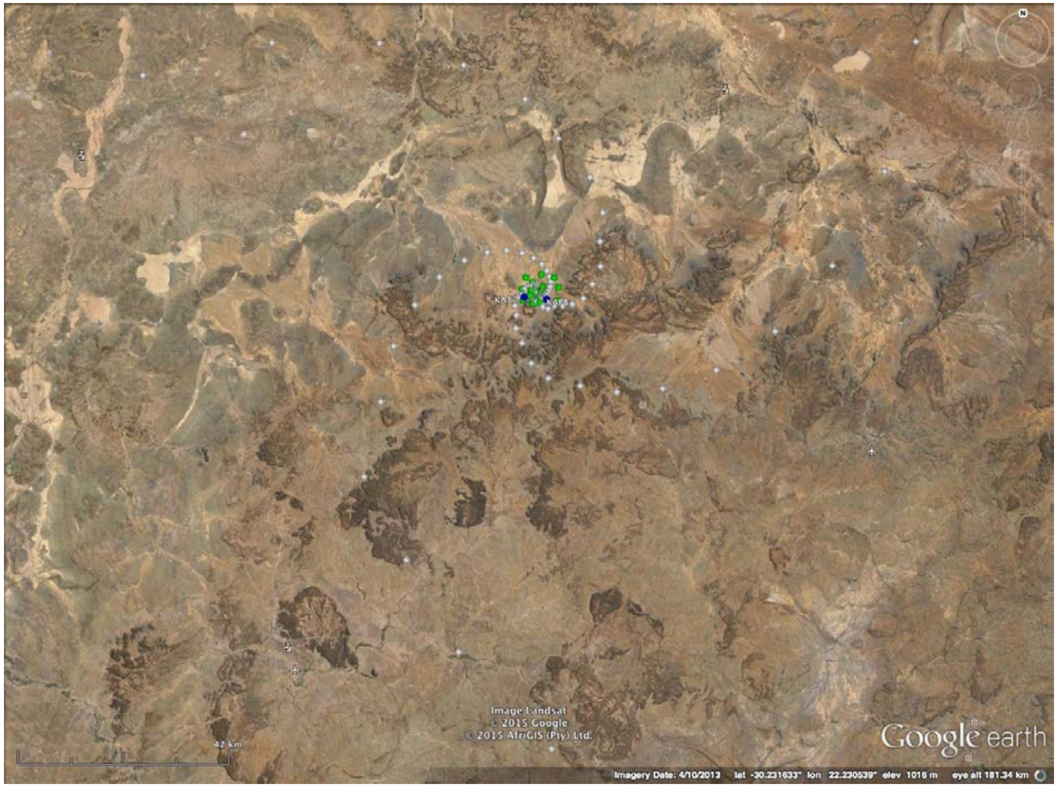


Figure 28 SKA1-Mid on the Karoo Radio Astronomy Reserve, along with MeerKAT (in green) and various facilities (dark blue).

After Re-baseline:

SKA1 Mid

Location: Karoo in SA

Array Configuration:
3 spiral arms,
high density at center
Max Baseline: 150 km

Aperture: 32 664 m^2
(3% of $1 km^2$)

197 dishes
133 SKA 15 m
64 Meerkat 13.5 m

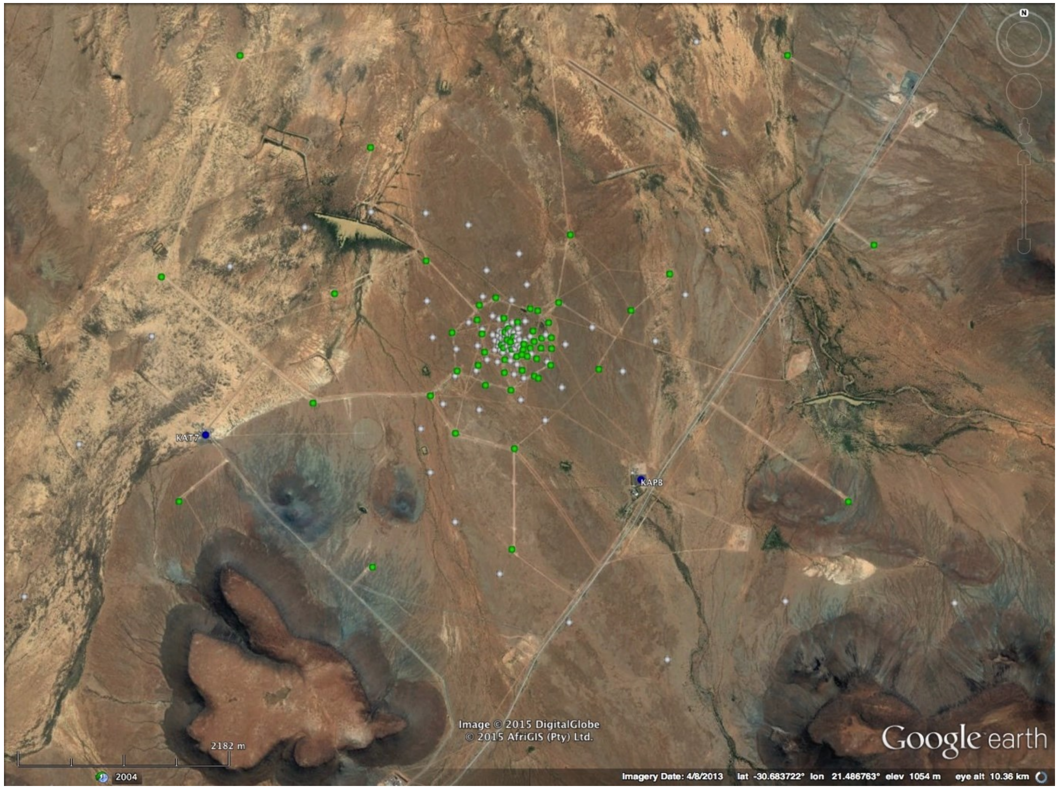
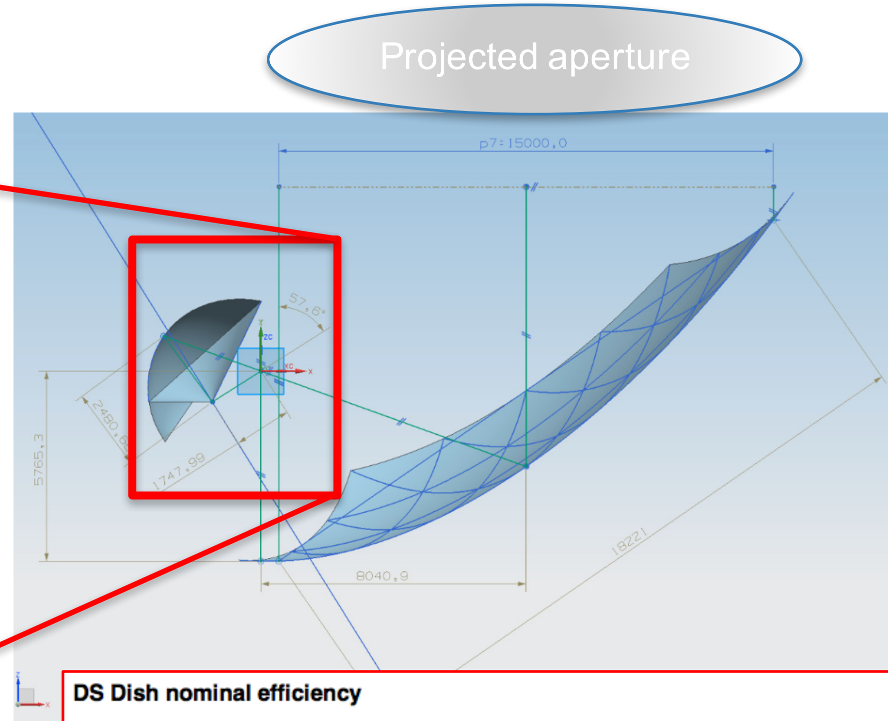


Figure 29 Zoom of SKA1-Mid (white) on the Karoo Radio Astronomy Reserve, along with MeerKAT (in green) and various facilities (dark blue).

Dish Structure – Antenna

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



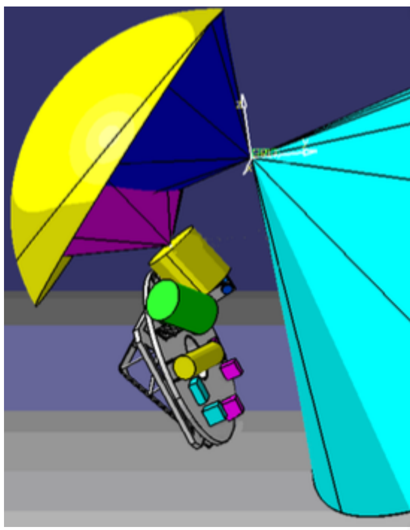


Table 8: Overall Surface Accuracy of the Telescope

Subreflector	146
Panels	239
BUS	109
RSS [µm]	301

DS Dish nominal efficiency

Over the full accessible elevation range, under ***Precision*** and ***Standard Operating Conditions***, ***Dish efficiency*** shall be at least:

98% at any frequency from 350 MHz to 5000 MHz

94% at any frequency from 5 to 8 GHz

84% at any frequency from 8 to 15 GHz

77% at any frequency from 15 to 20 GHz

Requirement

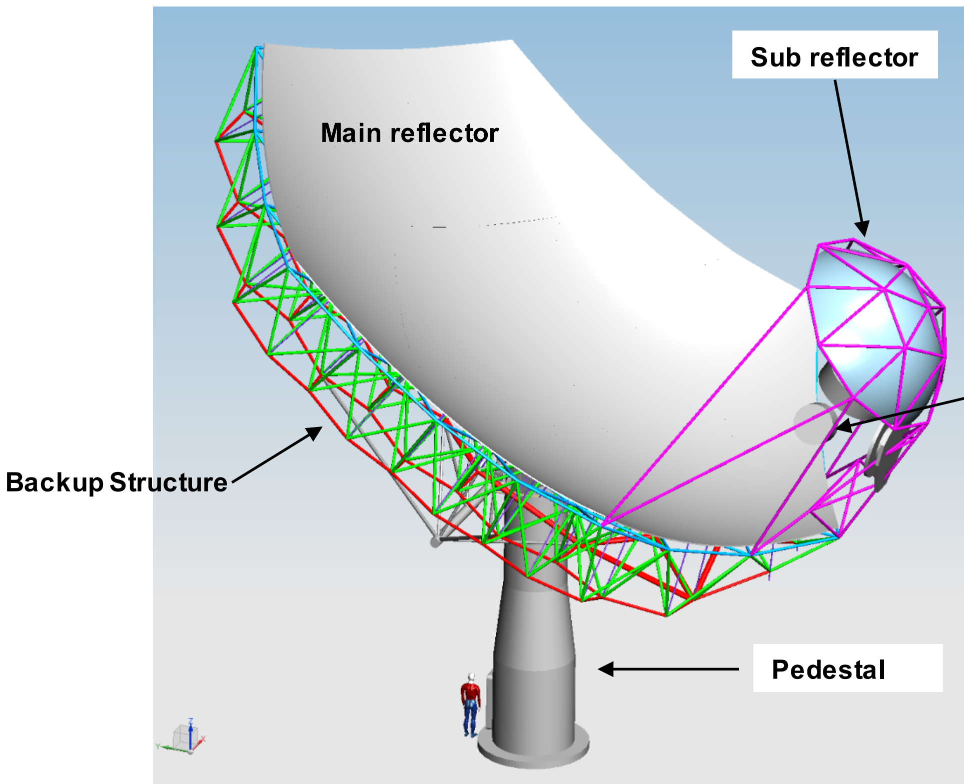
Dish Structure – Antenna

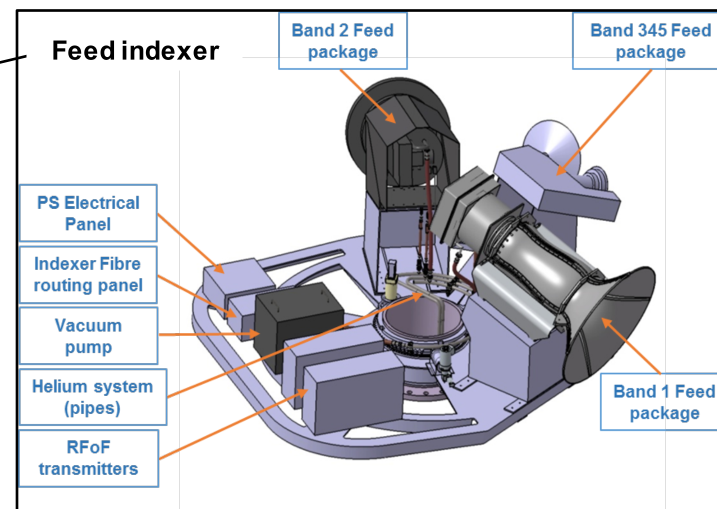
Design:

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

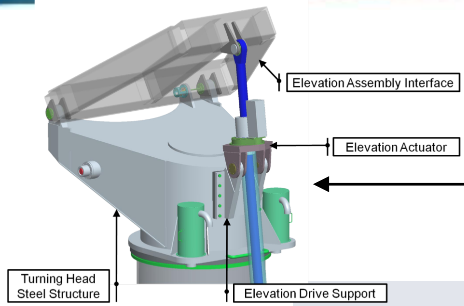
Structural members either consist of mild steel or CFRP.
The panels consist of aluminum.

CFRP: Carbon Fiber-Reinforced Polymer

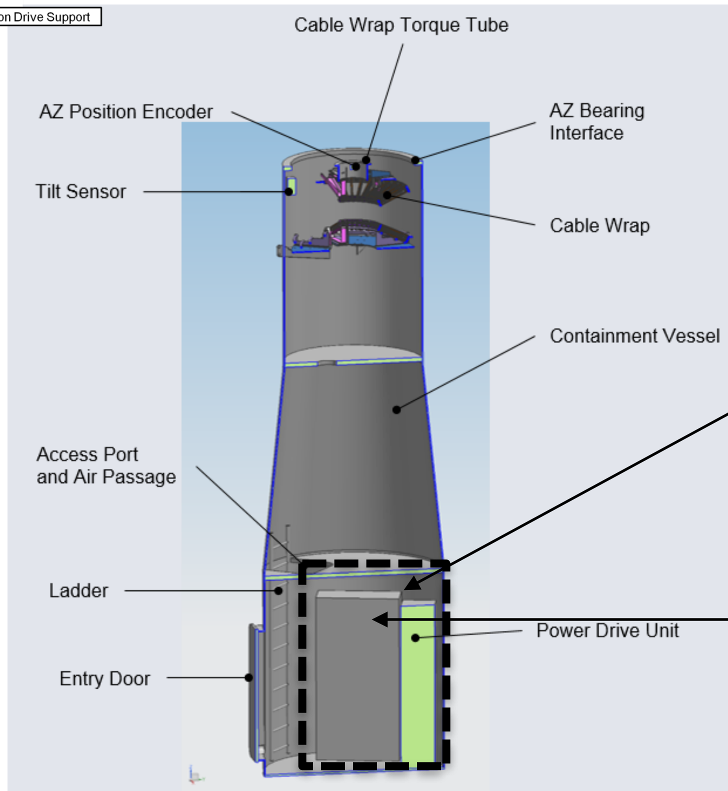




Dish Structure – Pedestal



Turning Head and Azimuth Bearing



DS Controller will use TANGO?

Shielded compartment (80dB)

Double shielding enclosure inside another enclosure (high risk posed by the high speed digital electronics in the pedestal, and the proximity to the antenna focus).

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

Cooling: outside ambient air ventilation

-no air conditioning (save $) - TBC

Fans for each controller

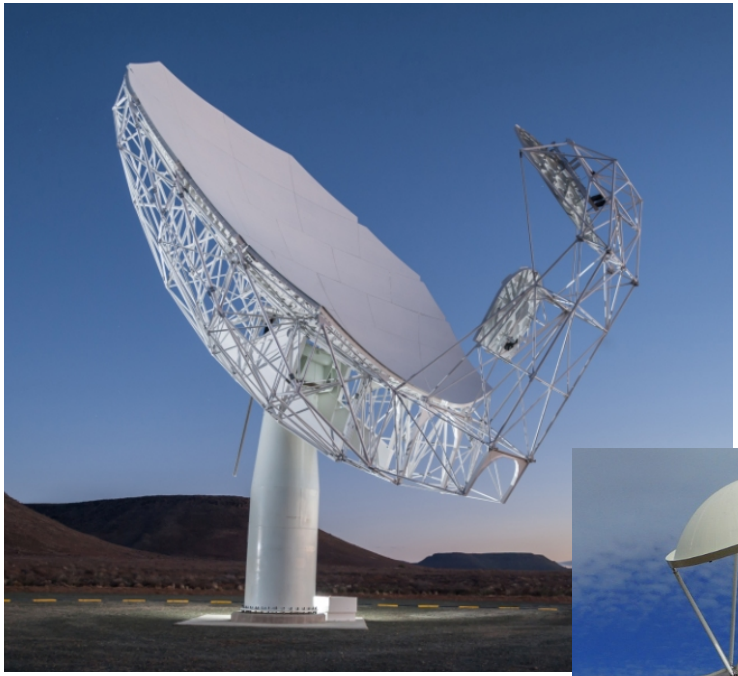
a) Climatic Conditions
- Air Temperature
  - Minimum Air Temperature: 0degC
  - Maximum Air Temperature: 45degC (50dC under extreme conditions)

Operating Conditions

Rack with:

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

Previous Dish Prototypes



MKT-1:
South Africa
March 2014

DVA-1:
NRC Canada
July 2014

DVA-C:
JLRAT China
August 2014

SKA-Mid: SPFs - Bands

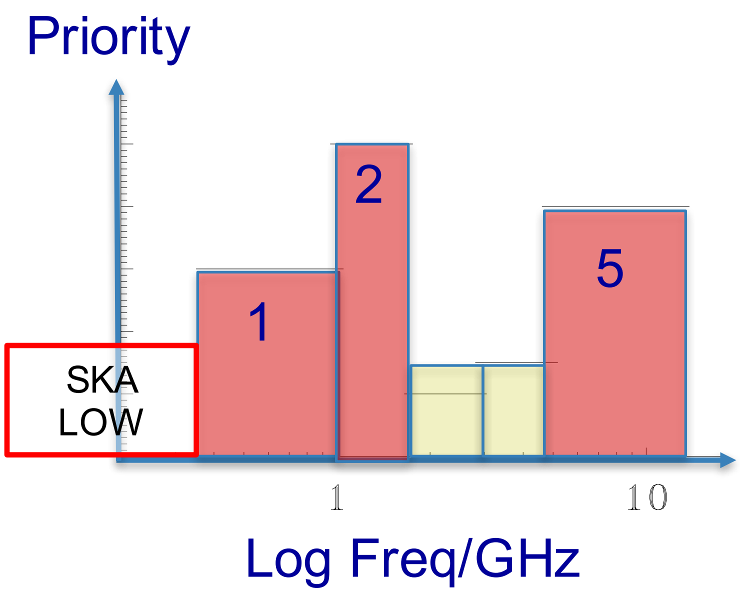
High priority bands for SKA-1 construction

SPF Bands

- 2: 950-1760 MHz
- 5: 4.6-13.8 GHz
- 1: 350-1050 MHz

- 3: 1.65-3.05 GHz
- 4: 2.8-5.2 GHz

Frequency Coverage for SKA1

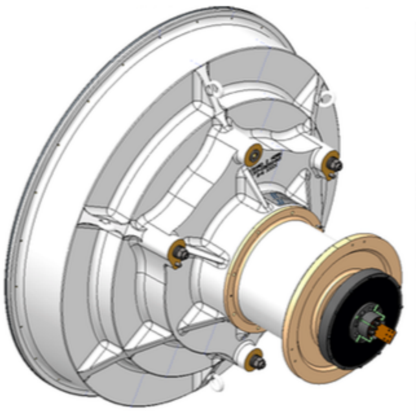


Band 5 considered as high priority after scientific meeting in Naxos,

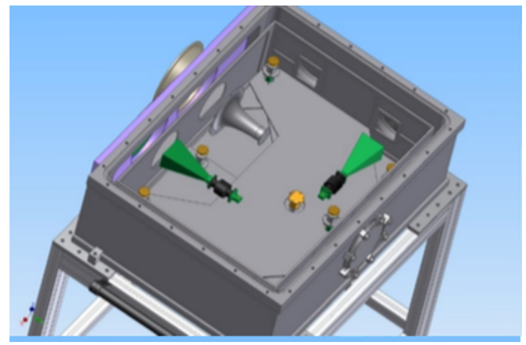
(galactic and extragalactic science)

and re-baseline

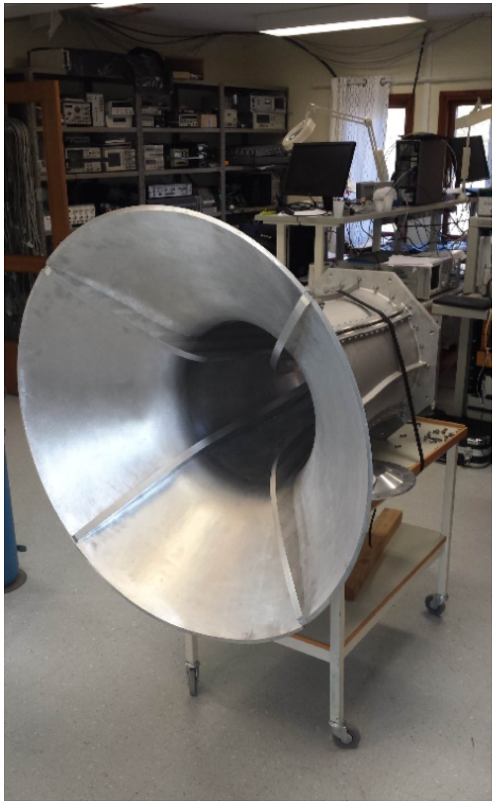
SKA-Mid: SPFs - Bands



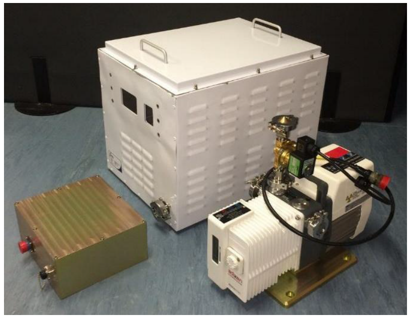
Band 2 feed horn design
Cryo system



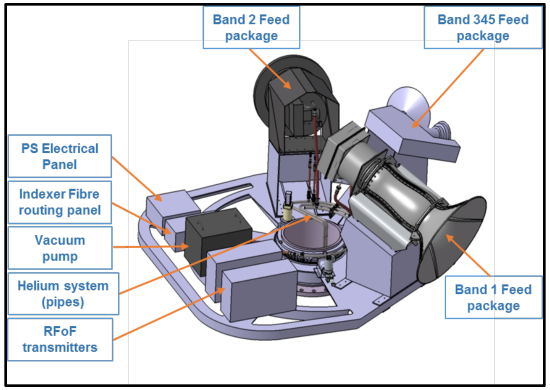
Band 3,4,5 Common cryostat
→ Band 5 only for SKA1



Band 1 feed horn prototype
Uncooled Feed and LNA

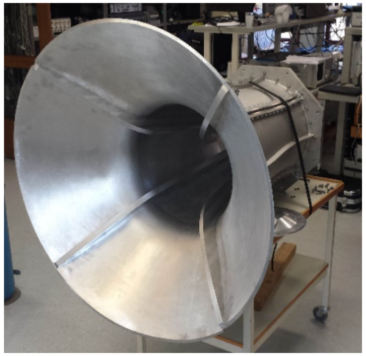


MeerKAT
vacuum assemblies

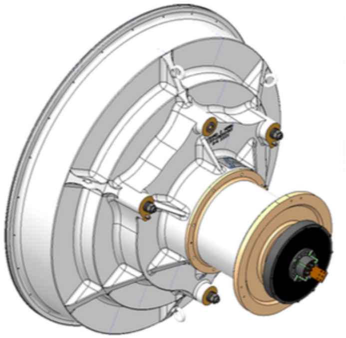


SKA-Mid: SPFs - Bands

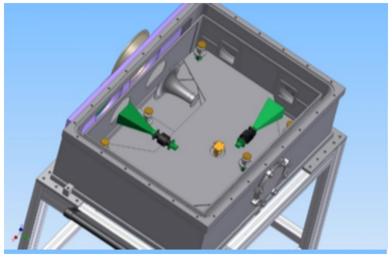
- Band 1 and LNA at room temperature. Two amplification stages, calibration noise.
- Band 2 cryostat and LNAs to ~20K. Two amplification stages, calibration noise.
- Bands 3, 4 and 5 in one cryostat. For Band 5 the entire system will be cooled.
- He System: Common He system; single He compressor and supply at yoke.
- Vacuum System: Rotary vane vacuum in indexer; vacuum lines to all SPF.
- Controller: in pedestal to C&M all three SPFs, He and vacuum systems, interfaces with the Dish LMC for external control and monitoring, uses **Tango**



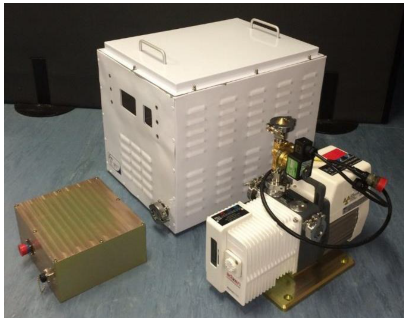
SPF Band 1



SPF Band 2



SPF Band 3,4,5



MeerKAT vacuum assemblies

SKA-Mid: Receivers

From SPF to RX (location):

- Pedestal with RFoF links from feeds

Master Clock timer :

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

Digitisers:

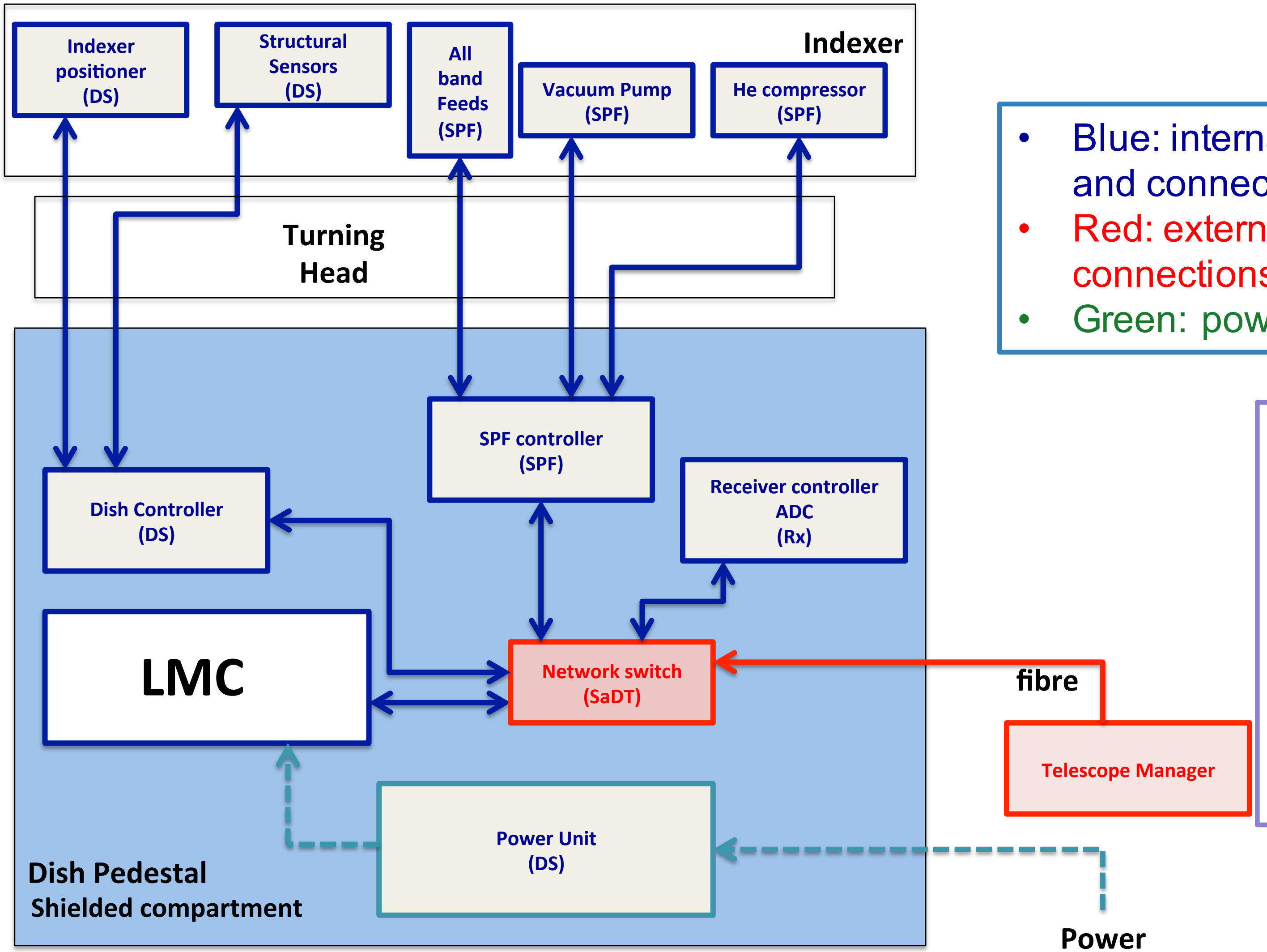
- RF conditioning (filtering and level control).
- Bands 1-3 **direct digitised** (1 and 2 in the 1° and Band 3 in 2nd Nyquist zone)
- Bands 4 & 5 are band selected and **direct digitised**
- Band 5, two individually tuneable sub-bands of 2.5GHz bandwidth, **direct digitised**
- Data packetised and transmitted to CSP

Controller:

- in pedestal
- Uses **Tango**

	Frequency range (GHz)	Instantaneous bandwidth (GHz)	Sampling rate (GSps)	Total digitized bandwidth (GHz)	Sampling bit depth	Transmit bit depth	Raw data transmit rate (Gbps)
Band 1	0.35 – 1.05	0.700	4	2	8	8	64
Band 2	0.95 – 1.76	0.808	4	2	8	8	64
Band 3	1.65 – 3.05	1.403	3.17	1.585	8(1)	8	50.72
Band 4	2.80 – 5.18	2.38	12	6	4	4	96
Band 5	4.60 – 13.8	2 x 2.5(2)	32	5	3	4(3)	80

LMC physical overview



- Blue: internal sub-elements and connections
- Red: external elements and connections
- Green: power links

Functional

External: TM

Internal:

SPF

Rx

DS

Data rate for SKA_Mid

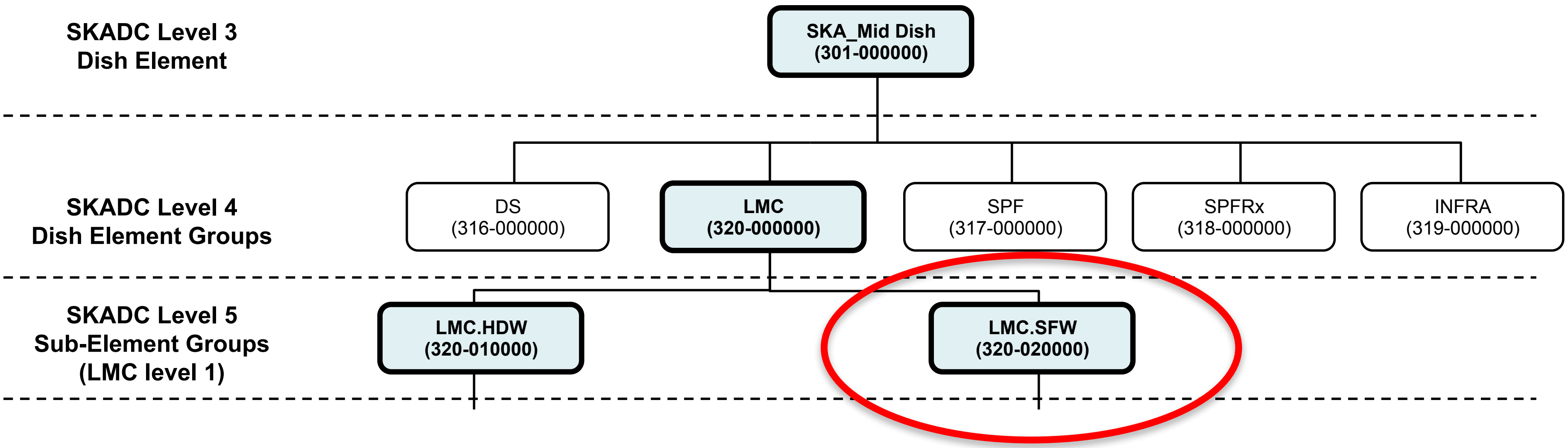
TM_DSH data rate calculation: SKA_MID Dish

		Number of sensors	update period	Bytes per sample	Throughput (kbps)	Comments
Dish Structure	Monitor slow	150	1	10	12	
	Monitor fast	5	0,1	10	4	
	Pointing measured	2	0,1	10	1,6	time stamped pointing estimates (az/el + tilt) once every 10
	Control	5	0,1	10	4	time stamped pointing control polinomial once every 100m
SPFs (Band 1-5)	Monitor slow	500	1	10	40	
	Monitor fast	5	0,1	10	4	
Receiver	montior slow	200	1	10	16	
	monitor fast	5	0,1	10	4	

			Proposed specs
Total	**Monitor**	**81,6** kbps	**200** kpbs
	Control	**4** kbps	**10** kpbs

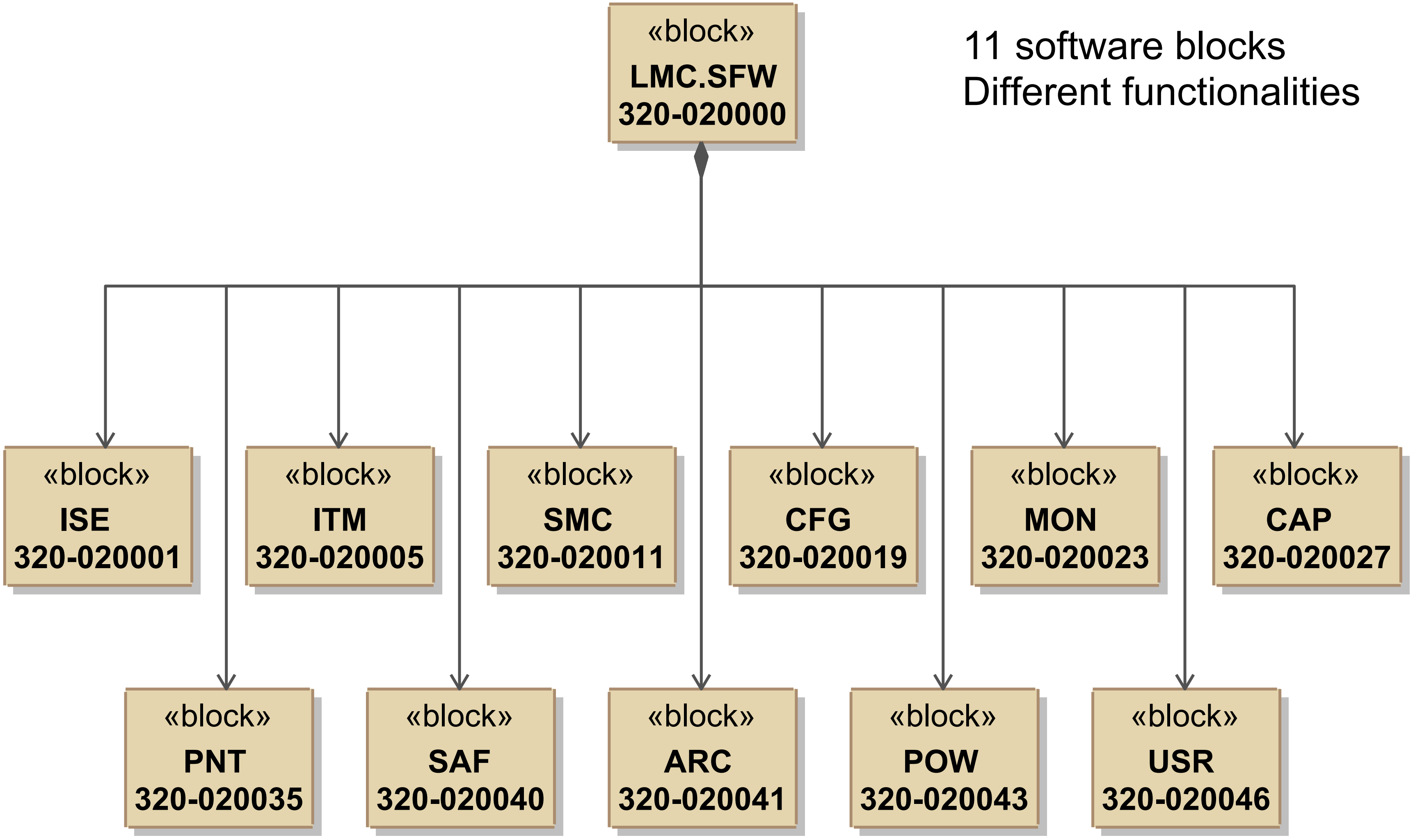
		Monitor (kbps)	Control (kbps)
SKA_Mid (DS, SPF, Rx)	Pedestal	200	10
~~**SKA_Survey (DS, PAF)**~~	~~Pedestal~~	~~100~~	~~10~~
~~**SKA_Survey (DS, PAFRx)**~~	~~Bunker~~	~~700.000~~	~~300.000~~

DSH Product Breakdown Structure



LMC.SFW Product Breakdown Structure

11 software blocks
Different functionalities

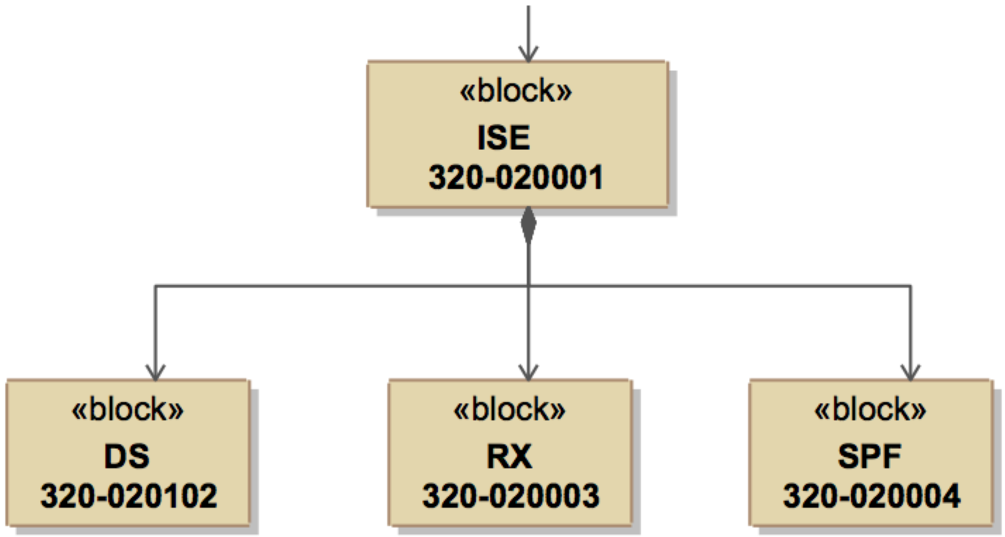


PBS: ISE

Sub-element Monitor & Control Interface Manager

- implementing communication with the controllers of SE according to the internal ICD
- providing commands to control SE systems
- receive monitoring data, event and alarms from SE systems
- providing a stream of monitoring data/event/alarms towards other LMC packages higher in the functional hierarchy

If all SE use TANGO, the ISE block will be almost transparent



Interface with Dish Structure controller (Antenna ACU, Indexer, sensors…)

Tango??? Hope!

Interface with SPF Receiver (digitaliser, time and freq, noise cal) controller)

Uses TANGO

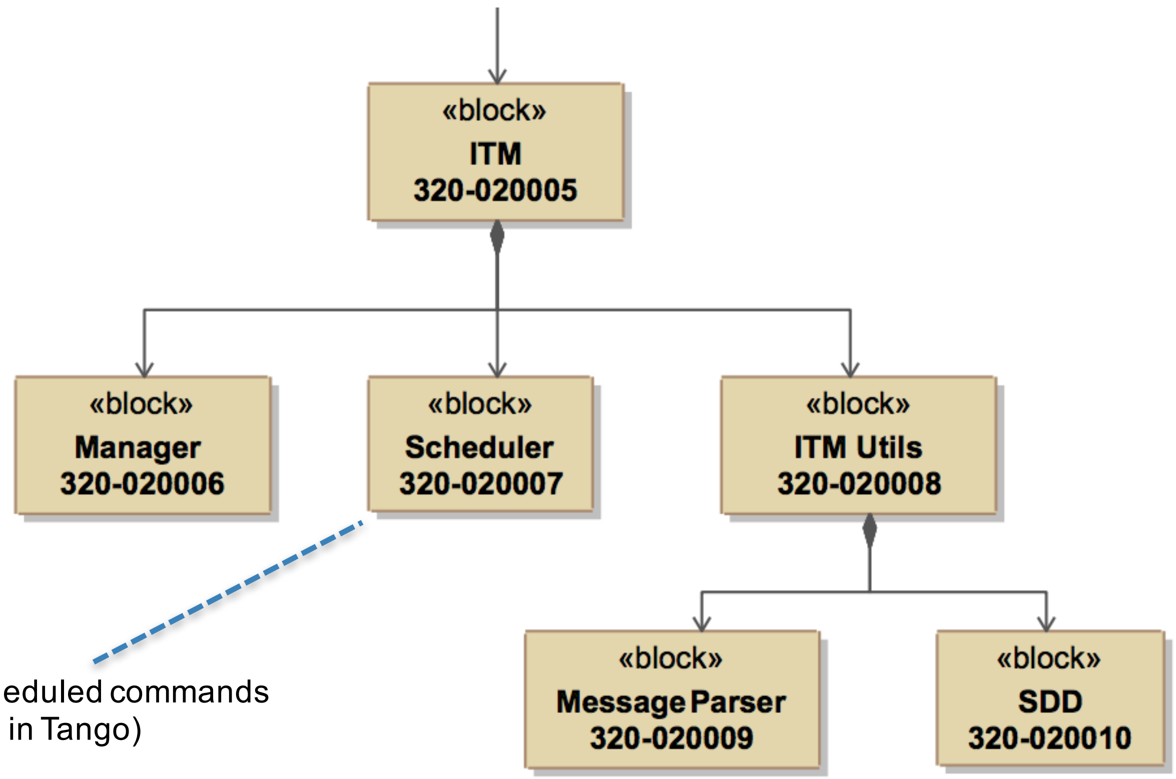
Interface with Single Pixel Feed controller (Pump, cryo system, LNA…)

Uses TANGO

PBS: ITM

TM Monitor & Control Interface Manager

Implement external interface with TM.TELMGT according to the TM-LMC ICD (**non well defined**). It contains components handling and dispatching TM.TELMGT commands to internal LMC components, reporting data, metadata, software and firmware versions from LMC components to TM.TELMGT; services interfacing with Telescope Model.



Manages commands from/to/ TM and sends to LMC components

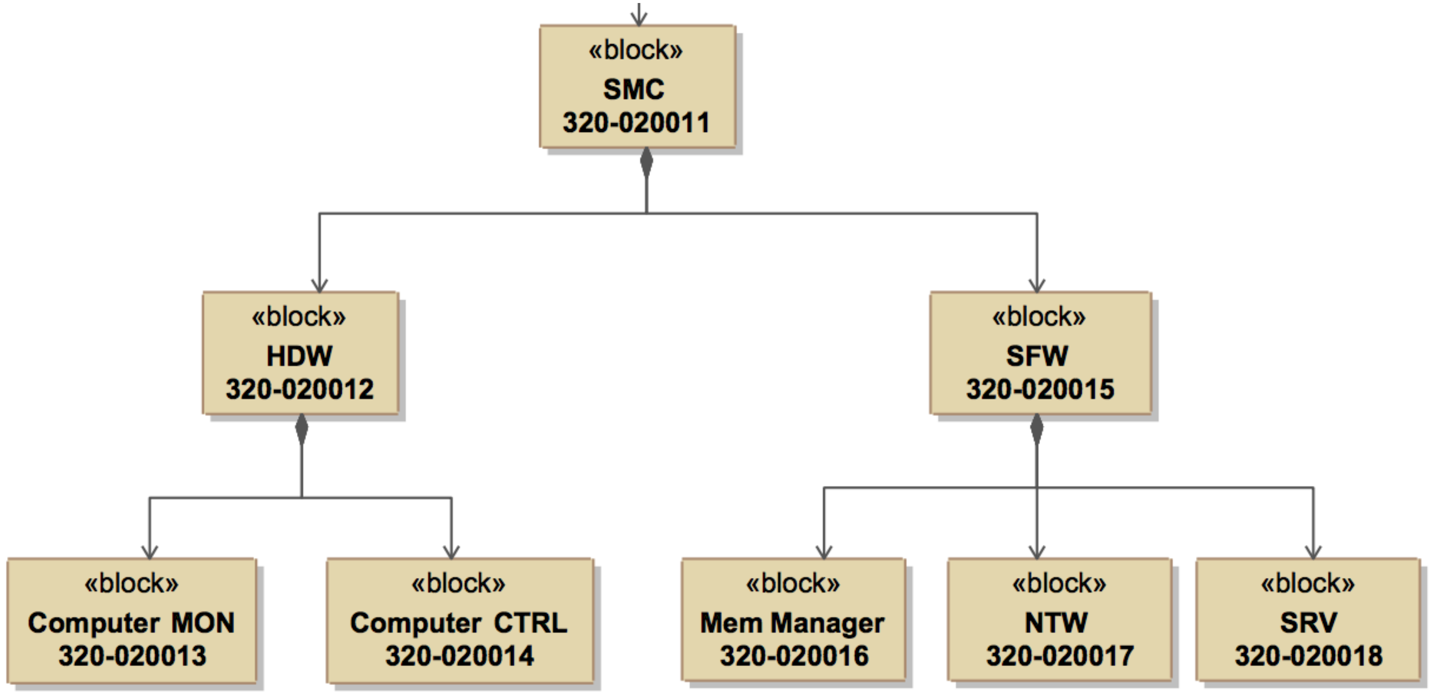
Manages time scheduled commands (non implemented in Tango)

Utilities as message parser and Self Description Data (SDD)

PBS: SMC

LMC
Self Monitor and Control

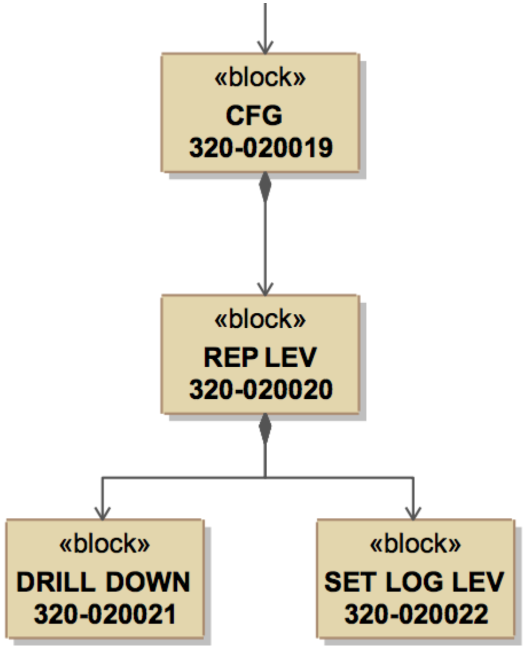
- Monitor and control of the LMC hardware (i.e. disk status, CPU temperatures, ...) and OS system services (i.e. networking, DBs, daemons, ...), start-up/shutdown of the components
- Monitor and control of all LMC software components according to predefined hierarchy levels reporting monitoring information and faults to Monitoring



PBS: CFG

Configuration Manager

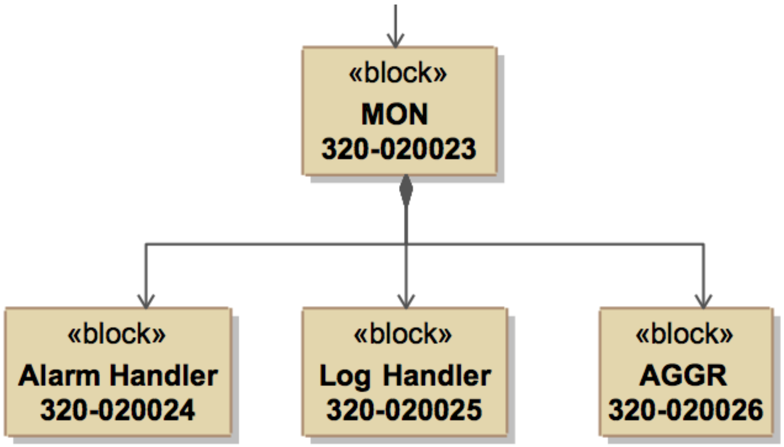
Responsible to set monitoring information reporting (level, drill-down...) requested by TM



PBS: MON

Monitoring Manager

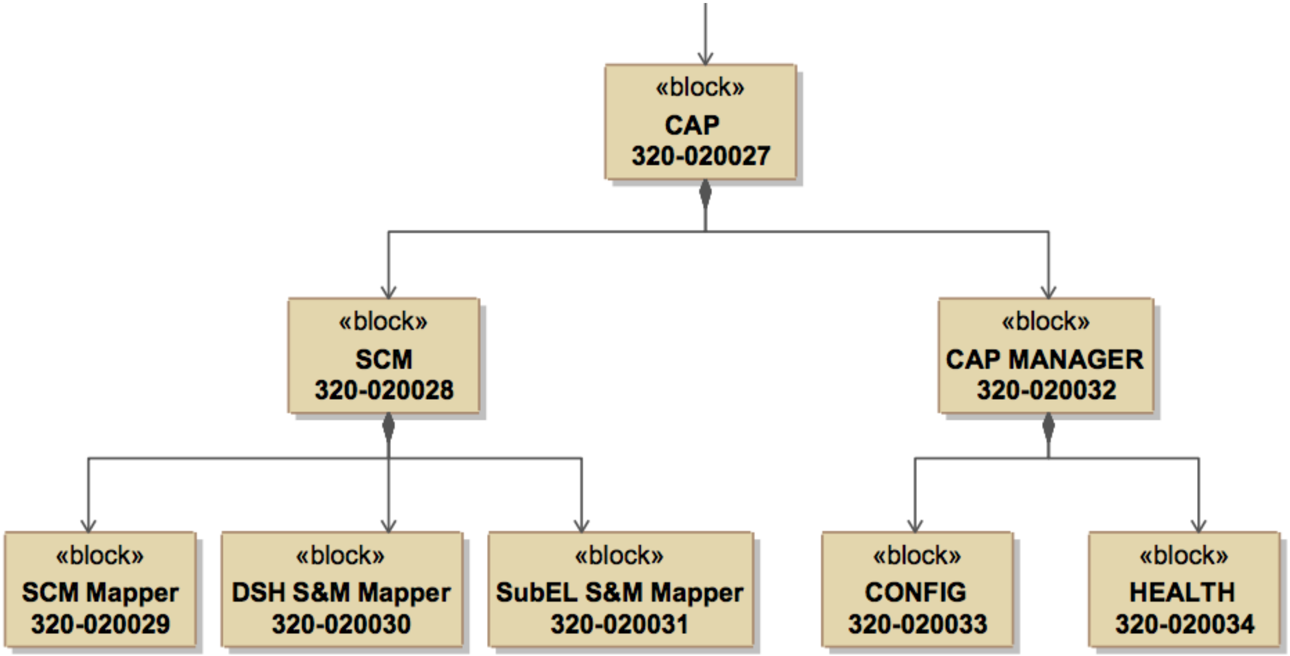
Collecting and aggregating monitoring data (including self-monitoring data), capabilities from dish sub-elements to be reported to TM.TELMGT processing alarms, logs and events detected in sub-elements and LMC (filtering according to the Log Level in CFG, corrective actions, ...) before sending them to TM.TELMGT.



PBS: CAP

Capabilty Manager

To identify capabilities and availability of capabilities, to detect missing components in dish sub-elements, to perform mapping of sub-element operating states and modes from internal (to DSH) to external state model (SCM), to derive global states from sub-system states, configure the capabilities.



SKA Control Model (SCM):

- SCM Mapper (external S&M notation)
- DSH S&M Mapper (internal S&M notation)
- Sub-elements S&M Mapper (internal notation)

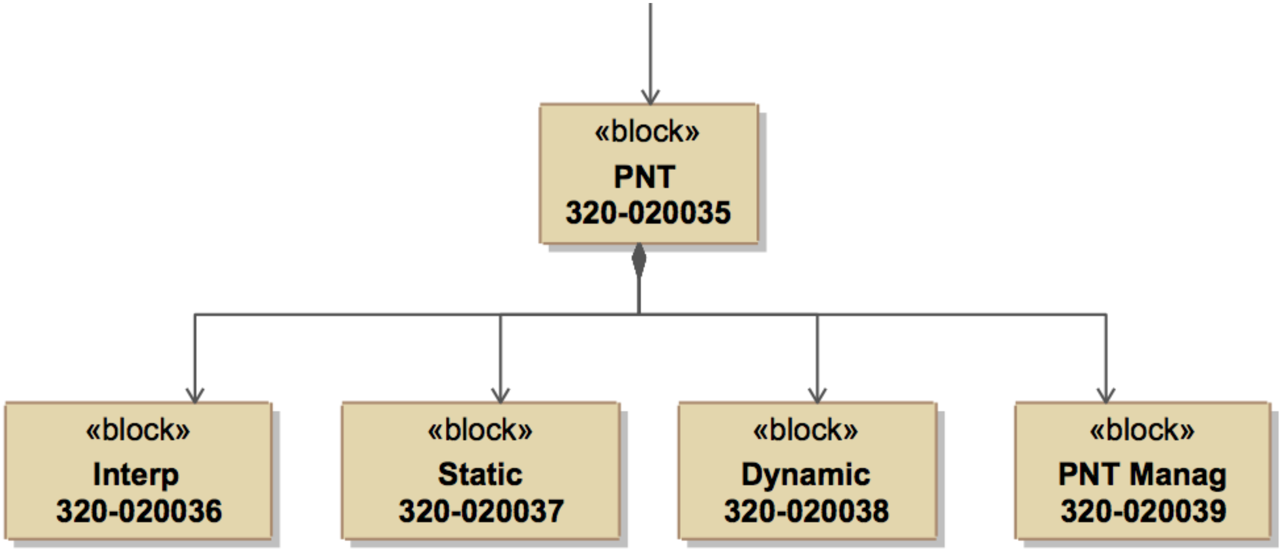
Capability Manager:

- Configurator
- Health manager

PBS: PNT

Pointing Manager

Responsible for executing pointing of the dish. This includes the acquisition of the telescope model and parameters for static and dynamic pointing corrections, acquisition of the sensor values for dynamical pointing corrections, time stamp Az/El interpolation, computation of static and dynamic corrections, sending pointing coordinates to DS, TM and archive.

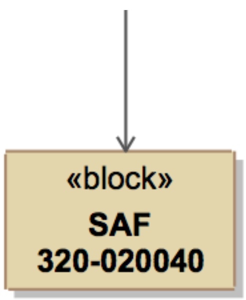


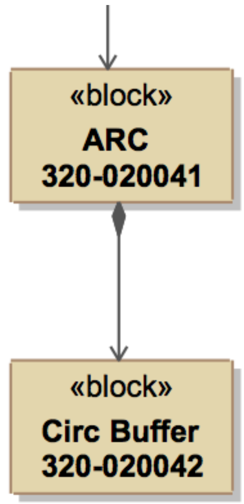
PBS: SAF, ARC ,

Safety, Archive, Power Managers

Responsible to take safety actions in presence of critical or **emergency** scenarios for **people or instrumentation**, such as power failure or TM communication cuts, strong wind at the station…

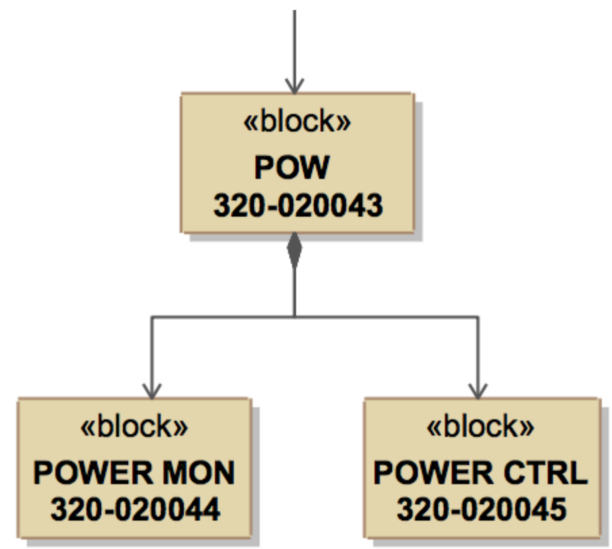
STOW manager





To store and retrieve data from/to the circular monitoring archive.

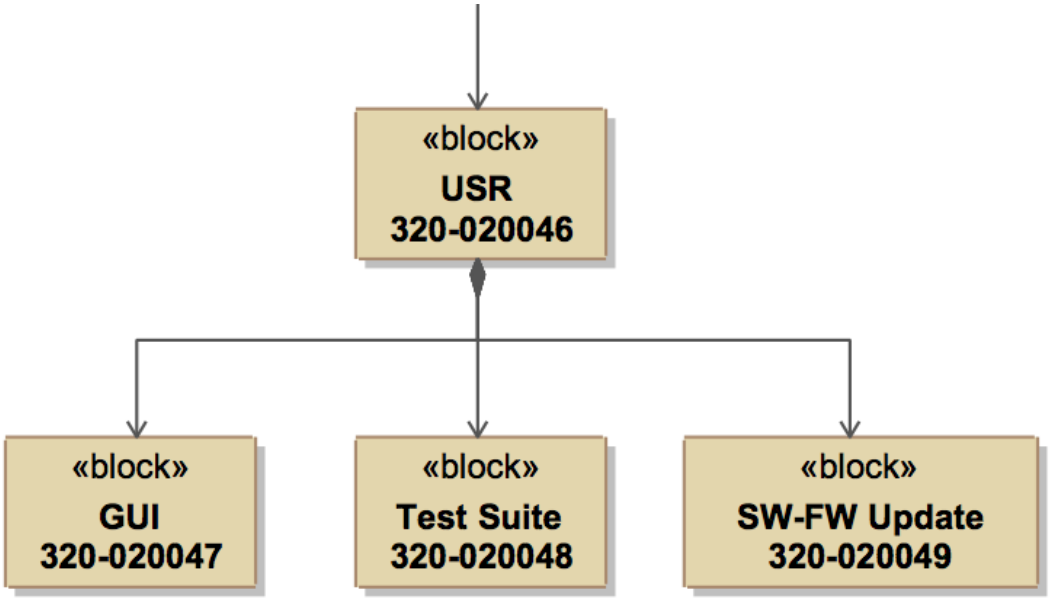
Monitor power distribution within the dish and capabilities of emergency power supply (UPS status...), allowing power cycling operations on hardware components.



PBS: USR User interface, Tests, Integration, Remote Support

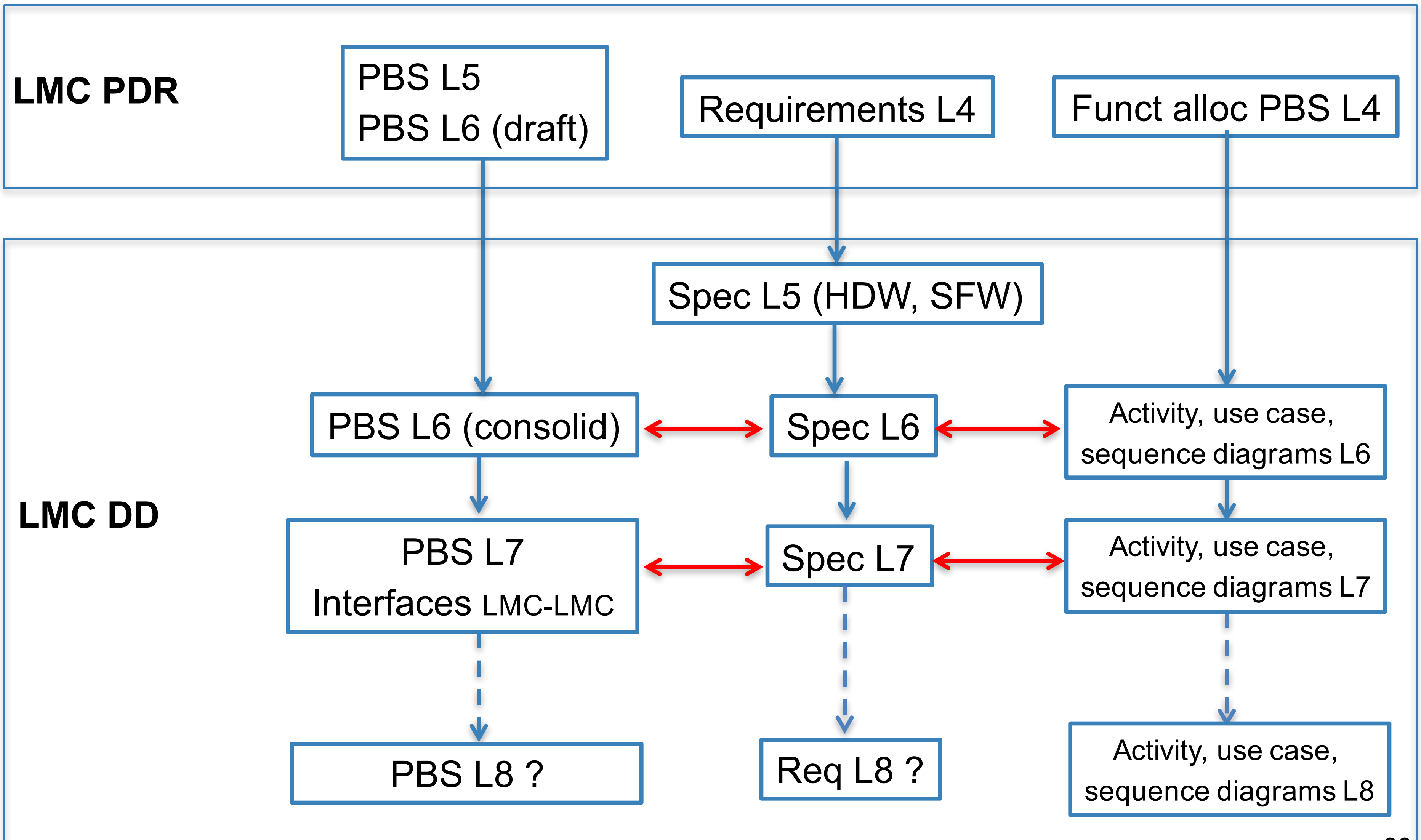
Utilities to build, test, integrate and maintain the LMC software system.

- supplying a build and verification suite for the entire LMC software, to be used during development and pre-integration stage
- providing detailed emulators of each sub-element controller, including exposed commands, monitored data, alarms and faults to test the sub-element interface package
- providing tools to generate emergency or severe failure scenarios to test system response under such circumstances.
- providing the LMC GUI tools to view monitoring data in real-time, browse historical data, send commands to sub-element components supporting remote service operations, such software/firmware update, download of circular monitoring buffer and tunnelling capabilities to access engineering sub-element GUIs.



PBS → Requirements → Functions

Iterative procedure



Specifications derivation: L4→L5

From Level 4 Requirements (LMC) to Level 5,6,7 Specifications

Level 5: split specifications for and software…

L4 Req. ID	Requirement Description	L5 Req. ID/ Interface Def
R.LMC.CC.1 LMC apply pointing corrections	LMC shall apply corrections to the received pointing commands, to compensate for local pointing errors, using a pointing model provided by TM, including the following: - Structural deformations due to gravity (from pointing model and pointing command) - Corrections based on tilt sensor (if applicable)	**R.LMC.CC.SFW.1** LMC apply pointing corrections
R.LMC.CC.2 LMC Configure DSH.	LMC shall set all internal states, modes and configuration data for DSH items, based on the external state, mode, configuration and capability commands received from TM.	**R.LMC.CC.SFW.2** LMC Configure DSH D.I.M.LMC_SRx.D004 D.I.M.LMC_SRx.D005 D.I.M.LMC_ SPF.D004 D.I.M.LMC_ SPF.D005

… and hardware

R.LMC.ED.1 LMC Condensation	Electronic equipment shall be safe and withstand, without damage or degradation or additional maintenance tasks, the presence of condensation while in the off state. Degraded functionality and performance will be allowed directly after start-up until such time that the condensation has evaporated.	**R.LMC.ED.HDW.1** **LMC Condensation**

Specifications derivation: L5→L6

From Level 5 specifications (LMC.STW) to Level 6 Specifications

Level 6: definitions for software PBS items

L5 Number	*L5 Description*	*L6 Number/L6 Name*	*L6 description*	*Refine*
R.LMC.CC.SFW.1 LMC apply pointing corrections	LMC shall apply corrections to the received pointing commands, to compensate for local pointing errors, using a pointing model provided by TM, including the following: - Structural deformations due to gravity (from pointing model and pointing command) - Corrections based on tilt sensor (if applicable)	**R.LMC.CC.SFW.PNT.1** Configure static Dish Model Parameters	LMC shall use the static Dish Model Parameters provided by TM and store them in a file as default parameters. This model shall include structural deformations due to gravity.	R.LMC.FMD.SFW.1 (correct pointing commands)
		R.LMC.CC.SFW.PNT.2 Configure dynamic Dish Model Parameters (if applicable)	LMC shall use a model provided by TM to compute pointing corrections based on sensors (tilt, Temp). (Formula to derive dAz dEl)	R.LMC.FMD.SFW.1

R.LMC.CC.SFW.2 LMC Configure DSH	LMC shall set all internal states, modes and configuration data for DSH items, based on the external state, mode, configuration and capability commands received from TM.	**R.LMC.CC.SFW.ITM.1** S&M, Configuration and capability command from TM.	LMC shall receive external state, mode ,configuration and capability commands from TM for itself and all sub-systems.	
		R.LMC.CC.SFW.CAP.1 Internal ST&M setting	LMC shall set all internal states, modes and configuration data for **DS, SPF, Rx and LMC itself** based on the external state, mode, configuration and capability commands received from TM.	
		R.LMC.CC.SFW.CAP.2 ST&M mapping	LMC shall map each state and mode of the subs-systems into an overall state for DSH	

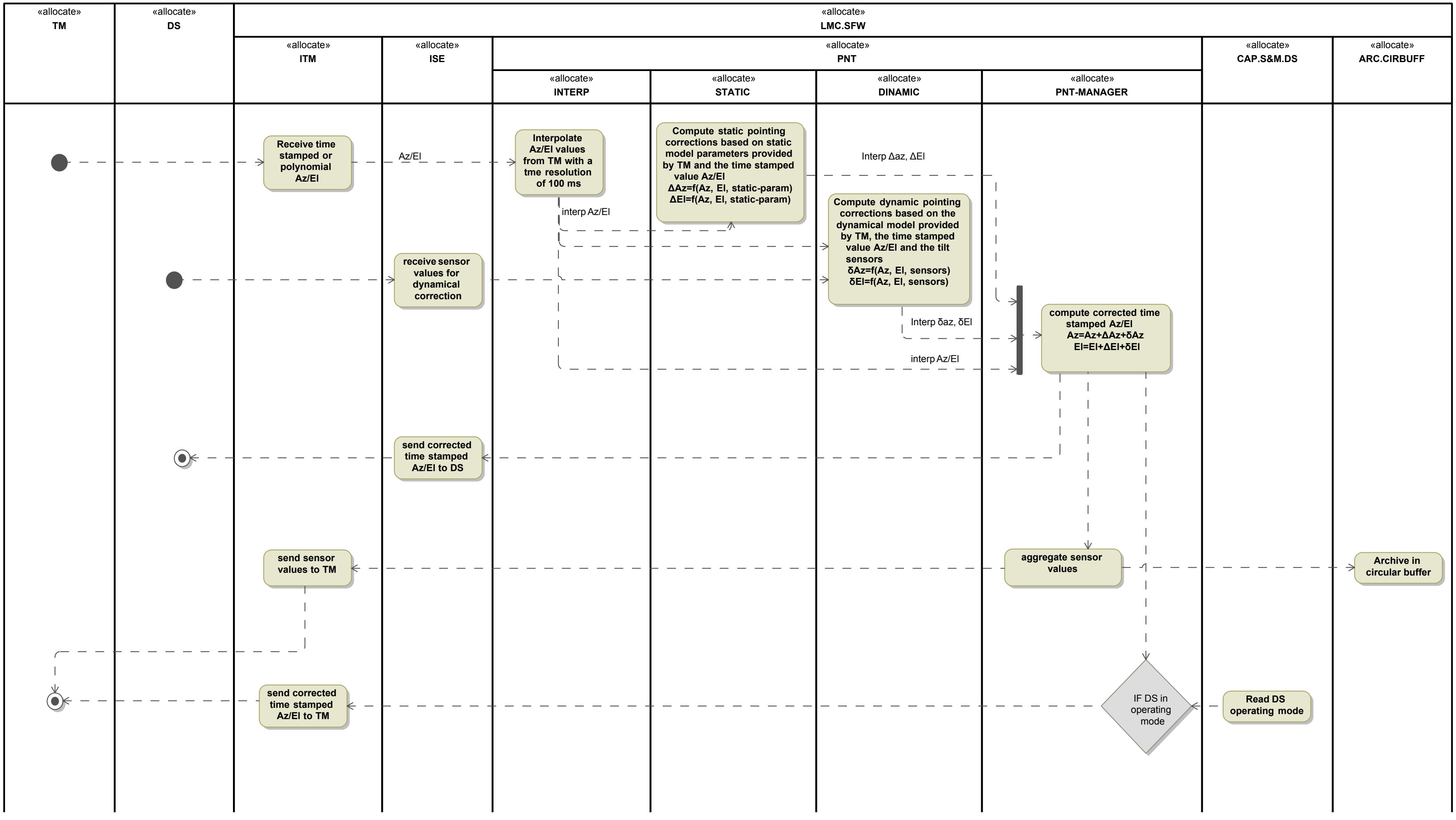
Specifications derivation: L6→L7

From Level 6 specifications (LMC.STW.item) to Level 7 Specifications

Level 7: definitions for components of PBS items (leaf level)

L6 Number/Name	*L6 Description*	*L7 Number/L7 Name*	*L7 Description*	*Refine*
R.LMC.CC.SFW.PNT.1 Configure static Dish Model Parameters	LMC shall use the static Dish Model Parameters provided by TM and store them in a file as default parameters. This model shall include structural deformations due to gravity.	**R.LMC.CC.SFW.PNT.STATIC.1** Read default parameters at startup	PNT.STATIC shall read the default static parameters at startup	
		R.LMC.CC.SFW.PNT.STATIC.2 Configure static Dish Model Parameters	PNT.STATIC shall receive static Dish Model Parameters from TM.	
		R.LMC.CC.SFW.PNT.STATIC.3 Defaults for static Dish Model Parameters	PNT.STATIC shall store the static dish model parameters as default configuration.	
R.LMC.CC.SFW.PNT.2 Configure dynamic Dish Model Parameters (if applicable)	LMC shall use a model provided by TM to compute pointing corrections based on sensors (tilt, Temp). (Formula to derive dAz dEl)	**R.LMC.CC.SFW.PNT. DYNAMIC.1** Read default dynamical parameters at startup	PNT. DYNAMIC shall read the default dynamical parameters at startup	
		R.LMC.CC.SFW.PNT.DYNAMIC. 2 Configure dynamical Dish Model Parameters	PNT. DYNAMIC shall receive dynamical Dish Model Parameters from TM.	
		R.LMC.CC.SFW.PNT. DYNAMIC.3 Defaults for dynamical Dish Model Parameters	PNT. DYNAMIC shall store the dynamical dish model parameters as default configuration.	

Activity Diagram (example for PNT)



Thanks