SKA CSP Local Monitor and Control Sub-element Detailed Design Description

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Prepared By	Name	Sonja Vrcic	Signature	Sonja Vrcic (Mar 16, 2016)
	Organisation	NRC		
Reviewed By	Name	Swaminathan Natarajan	Signature	Swaminathan Natarajan (Mar 17, 2016)
	Organisation	TCS		
	Name	Elisabetta Giani	Signature	Elisabetta Giani (Mar 18, 2016)
	Organisation	INAF		
	Name	Carlo Baffa	Signature	Carlo Baffa (Mar 18, 2016)
	Organisation	INAF		
Approved By	Name	David Loop	Signature	David Loop (Mar 18, 2016)
	Organisation	NRC		
Issued By	Name	Donna Morgan	Signature	
	Organisation	NRC		

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Designation	Name	Organisation
Primary Author and Responsible Organisation1	Sonja Vrcic Sonja.Vrcic@nrc-cnrc.gc.c.a	National Research Council of Canada

[1] The "Responsible Organisation" is responsible for ensuring that the IP Declaration in Appendix A is accurate and completed in accordance with the SKA IP Policy.

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LIST OF ACRONYMS AND ABBREVIATIONS

ADD	Architecture Design Document
AIV	Assembly, Integration and Verification
AOR	Annual Operating Requirement
ARC	Architecture Work Package
ASIC	Application Specific Integrated Circuit
ASTRON	Netherlands Institute for Radio Astronomy
ATC	Astronomy Technology Centre
CA	Consortium Agreement
CAD	Computer Aided Design
CDR	Critical Design Review
CDRL	Contract Data Requirements List
CIDL	Configuration Item Data List
CM	Configuration Management
COMP	Commissioning, Operation and Maintenance Plan
ConOps	Concept of Operations
COTS	Commercial Off-The-Shelf
CP	Construction Plan
CSCI	Computer Software Configuration Item
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSP	Central Signal Processor
CUR	Curtin University
DDD	Detailed Design Document
DOC	Development and Operational Cost
DRD	Document Requirements Descriptions
DSH	Dish Element or Consortium
DSP	Digital Signal Processing
ECP	Engineering Change Proposal
EICD	External Interface Control Document
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interface
FAD	Feasibility Analysis Documentation
FFT	Fast Fourier Transformation

FMECA	Failure Modes, Effects and Criticality Analysis
FPGA	Field Programmable Gate Array
FTA	Fault Tree Analysis
GPU	General Processing Unit
HDL	High Level Design Language
HSP	Health and Safety Plan
ICD	Interface Control Document
IICD	Internal Interface Control Document
ILS	Integrated Logistic Support
ILSP	Integrated Logic Support Plan
INAF	National Institute for Astrophysics
INFRA	Infrastructure Element or Consortium
I/O	Input/Output
IP	Intellectual Property
IR	SKA South Africa and Australia Infrastructure Requirements
KLAASA	Key Lab of Aperture Array and Space Application
LFAA	Low Frequency Aperture Array Element or Consortium
LSA	Logistical Support Analysis
MATLAB	MATLAB simulation language and application
M&C	Monitor and Control
MGR	Telescope Manager Element or Consortium
MOD	Modelling Work Package
MOU	Memorandum of Understanding
MTTR	Mean Time To Repair
NCRA	National Centre for Radio Astrophysics
NRC	National Research Council (Canada)
NZA	New Zealand Alliance
QA	Quality Assurance
OPS	Operations Work Package
OX	Oxford University
PA	Product Assurance
PDF	Portable Document Format
PDR	Preliminary Design Review
PHS&T	Packaging, Handling, Storage and Transportation
PIP	Physical Implementation Proposal
PMX	PowerMX

PPIA	Precursor and Pathfinder Interaction and Analysis (Work Package)
PTP	Prototyping Plan
QA	Quality Assurance
QAP	Quality Assurance Plan
QC	Quality Control
QP	Quality Plan
RAM	Reliability, Availability and Maintainability
RAMS	Reliability, Availability, Maintainability and Safety
RFI	Radio Frequency Interference
RMP	Risk Management Plan
RR	Risk Register
RRS	Reutech Radar Systems
RS	Requirement Specification
SAD	System Baseline Design
SADT	Signal and Data Transport Element or Consortium
SDE	Software Development Environment (Work Package)
SDP	Science Data Processing
SEMP	System Engineering Management Plan
SKA	Square Kilometre Array
SKAO	SKA Organisation (or office)
SKA-SA	SKA South Africa
SMART	Software Methods, Approaches, Research, and Technologies
SOW	Statement of Work
SPA	Software Product Assurance
SRR	System Requirements Review
STFC	Science and Technology Facilities Council
SW	Swinburne University of Technology
SW	Software
SYSML	System Engineering Simulation Language and application
TBC	To be confirmed
TBD	To be decided
TCS	TATA Consultancy Services
TDT	Time Domain Team
UMAN	University of Manchester
UML	Unified Modelling Language
UTC	Universal Time Coordinated

VPL	Verification Planning Work Package
WBS	Work Breakdown Structure
WP	Work Package
WPEP	Work Package Execution Plan

LIST OF TERMS

Alarm The term Alarm (with capital A) refers to the CSP-generated message used to report errors and faults. This document describes only those Alarms generated by the CSP; Alarms generated by the TM are sent elsewhere (beyond the scope of the CSP/TM interface).

Active Alarm An Alarm which has an alarm state that has been raised, but not cleared.

Alarm Detection Point The entity that detected the alarm.

Component The term *Component* (with a capital C) is used to refer to a CSP hardware or software Component that can be identified, controlled and monitored via TM and LMC.

Capability The term Capability refers to a representation of a CSP functionality that can be identified, controlled and monitored via TM and LMC. The CSP sub-elements provide a layer of abstraction to allow LMC to set, control and monitor signal processing without being aware of the sub-element implementation.

Event The term *Event* (with capital E) refers to a message used to report an event. An event is something that happens which may be of interest. Examples: a fault, a change of status, crossing a threshold, or an external input to the system.

Error A deviation of a system from normal operation.

Fault Non-transient error or warning condition.

Log A record generated and logged into a file in order to store (more-or-less permanently) information that can be of interest during testing and troubleshooting.

Perceived Severity The severity of the Alarm as determined by the Alarm Detection Point using the information it has available. Severity is also assigned to Events (TBC).

Scan A scan is an atomic unit of observation during which CSP produces a set of output data products. Certain parameters can change only at scan boundaries, most notably the observing band and the composition of a Sub-Array. Note that, while the scan is a common concept used in most current interferometers and output data formats, it is still TBD whether “scan” will be so used by the SKA.

Sub-array A collection of telescope resources devoted to a particular observing task. It is possible that multiple such tasks may be in progress concurrently. CSP sub-array is an exclusive set of Capabilities. Exclusive in this context means that a Capability cannot belong to more than one sub-array at any given time.

1 INTRODUCTION

1.1 Purpose of Document

The purpose of this document is to describe design for the SKA1 Central Signal Processor Local Monitor and Control (CSP.LMC) sub-element to a level sufficient for the Critical Design Review and the beginning of the construction phase, as called out in the "CSP Statement of Work" [AD1].

1.2 Scope of Document

This document describes how the CSP.LMC design meets the requirements specified in the "SKA CSP Local Monitor and Control Sub-element Requirement Specifications" [AD2] and in the Interface Control Documents [AD4 to AD8] which describe the CSP.LMC external interfaces identified in the "CSP Architecture Design Document" [AD3].

The current version of this document is sufficient to support the creation of a Preliminary Design baseline. In compliance with the "CSP Statement of Work" [AD1], this is the 50% version of the document, and many sections of this document are not complete. The focus of this release is the functional decomposition and feasibility of the design to meet requirements and compliance to external interfaces. This document contains the infrastructure and decomposition to support the further design of lower level components.

The complete version (100%) of this document will be created to support the Critical Design Review for the CSP.LMC sub-element and the CSP Element. At that point the CSP.LMC design will be defined to a level sufficient to prove that the proposed design is complaint with the requirements and that CSP.LMC can be constructed with low risk. This Detailed Design Document (DDD), with references to supporting information and data, will provide the key design artefact to support the Construction Phase activities.

This document describes an implementation of the CSP LMC Sub-element that meets the "SKA CSP LMC Requirements Specification" [AD1], identifies the functions of the system, decomposes the system into simpler logical design components, describes those components and how they cooperate in order to satisfy requirements and use cases. This Detailed Design Description also identifies the states and modes of the CSP Element and CSP.LMC sub-element itself, and describes flow of information and messages both internally and externally.

1.3 Intended Audience

CSP LMC Sub-element Detailed Design Description is a part of the CSP package for the Critical Design Review (CDR) and will be used by the review panel to evaluate the proposed design and estimate development cost and effort.

During the construction this document can be used as a basis for the development of the SKA1 CSP LMC.

1.4 Telescope Overview

The Square Kilometre Array (SKA) will be built over two sites in Australia and Africa, and it will, when both phases are complete (SKA1 and SKA2), provide over a million square metres of collecting area through many thousands of connected radio telescopes. The Square Kilometre

Array (SKA) will be constructed in two phases: SKA1 is being designed now; SKA2 is planned to follow.

SKA Phase 1 Baseline Design [RD9] specifies that the SKA telescopes will be built in two sites, one in Western Australia at the Murchison Radio Observatory centred near Boolardy Station and one in Southern Africa, centred in the Karoo Central Astronomy Advantage Area, but extending eventually to neighbouring countries in Southern Africa for SKA2.

The telescope facilities for SKA1 have been defined as:

- SKA1_Low, a low-frequency aperture array to be built in Australia; and
- SKA1_Mid, a mid-frequency array of parabolic reflectors (dishes) to be built in South Africa.

1.4.1 SKA1_LOW Telescope – Overview

Figure 1-1 is a schematic representation of the SKA1_Low telescope extracted from the SKA Phase 1 Baseline Design [RD9]. Figure 1-1 shows the major SKA1-LOW functional blocks and signal flow among them. The red boxes in the diagram show how the components and functionality have been grouped in the Elements. The green dashed lines show bi-directional flow of the monitor and control data, while orange dashed lines show the distribution of synchronisation and timing signals.

The SKA1-Low telescope consists of 512 stations, each station consist of 256 dual polarisation log-periodic antennas. The stations are distributed over an area with approximately 40-km radius located within Boolardy Station in Western Australia. Stations are organised into spiral arms with a high degree of randomisation, with the greatest density in the central core. Signal from the antenna elements that belong to the same station is combined, so that each stations acts like single large antenna, capable of forming one or more ‘beams’ on the sky (with field-of-view of ~20 deg^{2}). Signals from the station beamformers are transported to the Central Signal Processing building located at Boolardy Station, for further processing.

The SKA1_ Low Telescope can be split into up to 16 sub-arrays and each sub-array can be operated as a separate conceptual telescope in terms of beam pointing and setting of configurable imaging and non-imaging parameters. Sub-arrays are fully independent, the exception being that they all operate on the same real-time timing reference.

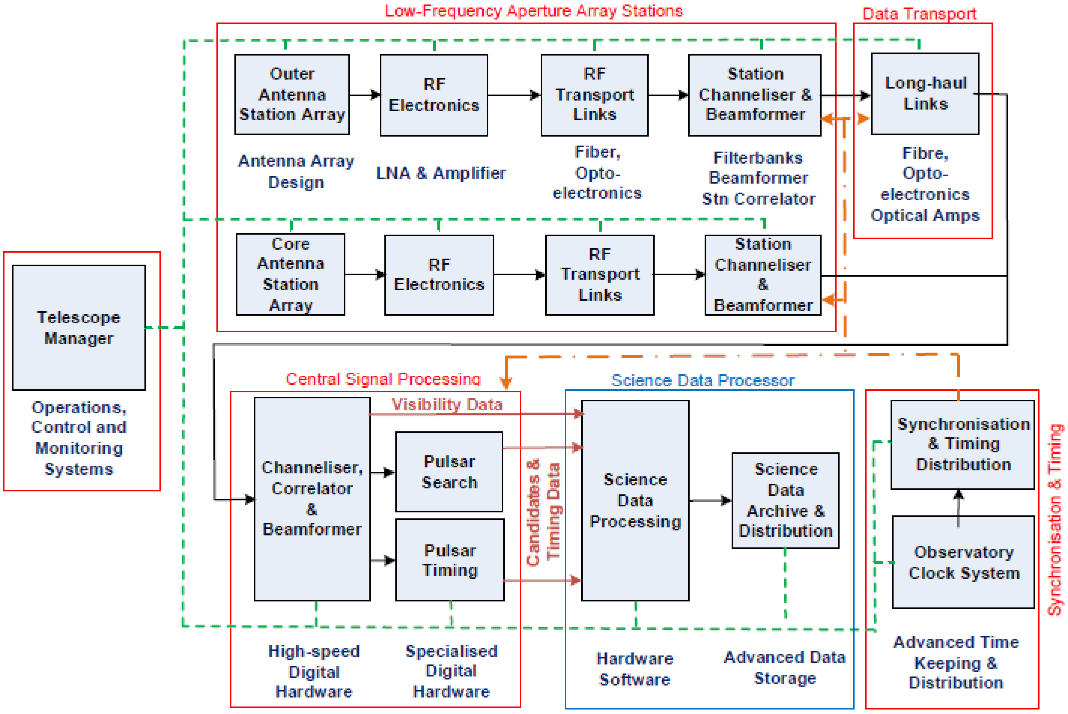


Figure 1-1 SKA1-low Functional Diagram, from BDv2 [RD9]

SKA1-Low is able to concurrently operate in imaging and non-imaging mode in each sub-array.

CSP_Low "Imaging mode" divides input beam data from each station (300 MHz bandwidth) into more than 64,000 frequency channels; for each channel CSP_Low cross-correlates each pair of stations that belong to the same sub-array (including each station with itself), and transmits those correlation products (often referred to as visibilities) to the Science Data Processing Centre in Perth where the visibilities are processed by the Science Data Processor (SDP) to produce high-quality continuum and/or spectral-line images.

In the "non-imaging mode" SKA1_Low forms a number of tied-array beams and processes data for each beam independently:

1) In Pulsar Search mode CSP_Low forms up to 500 *Pulsar Search* beams, for user selectable bandwidth of up to 128 MHz per beam, based on the sum of the selected stations within an aperture of 20 km of the sub-array centre, and searches for pulsars in each beam. Pulsar Search beams may be distributed among up to 16 sub-arrays, and pulsar search performed independently and concurrently in each sub-array.
2) In Pulsar Timing mode CSP_Low forms up to 16 pulsar timing beams (300 MHz of bandwidth per beam) based on the sum of selected stations within aperture of 20 km from the subarray centre, and in each beam independently times a pulsar with a known ephemeris to high (+/-100 nsec) accuracy and precision. Pulsar Timing beams may be distributed among up to 16 sub-arrays and pulsar search performed independently and concurrently in each sub-array.

In the same manner as visibilities, output data from Pulsar Search and Pulsar Timing is transported to the Science Data Processing Centre in Perth.

1.4.2 SKA1_MID Telescope - Overview

Figure 1-2 is a schematic representation of the SKA1_Mid Telescope extracted from the SKA Phase 1 Baseline Design [RD9].

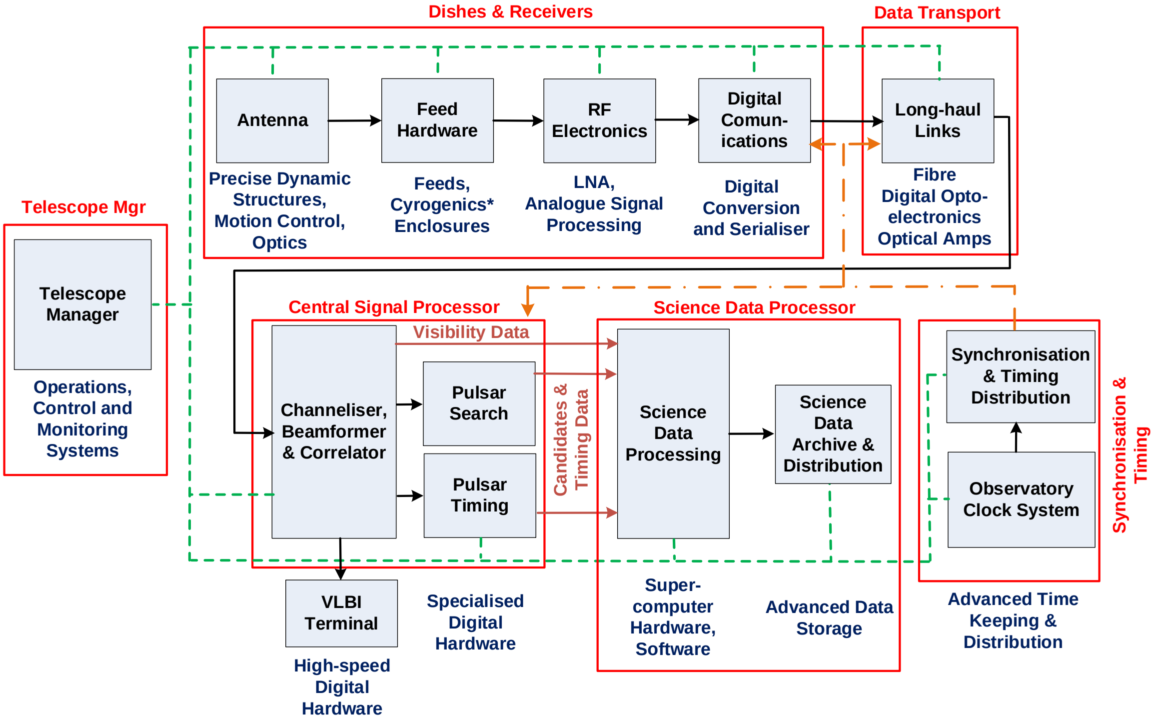


Figure 1-2 SKA1_Mid Functional Diagram, from BDv2 [RD9]

The SKA Phase 1 MID Telescope (SKA1_Mid) is a mixed array of 133 15-m SKA1 dishes and 64 13.5-m diameter dishes from the MeerKAT telescope. The antennas will be arranged in a moderately compact core with a diameter of ~1 km, a further 2-dimensional array of randomly placed dishes out to ~3 km radius, thinning at the edges. Three spiral arms will extend to a radius of ~80 km from the centre. The SKA1 dishes will be capable of operations up to at least 20 GHz, although initially equipped to observe only up to 13.8 GHz for SKA1.

The SKA1_ Mid Telescope can be split into up to 16 sub-arrays so that each sub-array can be operated as a separate conceptual telescope in terms of antenna pointing, band selection, and setting of configurable imaging and non-imaging parameters. Sub-arrays are fully independent, the exception being that they all operate on the same real-time timing reference.

For the sub-array in the “imaging mode” each pair of antennas in a sub-array is cross-correlated to produce full-polarisation visibility spectra across the required bandwidth and number of channels. The visibilities are then processed by the Science Data Processor (SDP) to produce high-quality continuum and/or spectral-line images.

In the “non-imaging mode” SKA1_Mid forms a number of tied-array beams and processes data for each beam independently:

1) Up to 1500 *Pulsar Search* beams (spread over up to 16 sub-arrays), each covering 300 MHz, based on the sum of selected antennas within +/-10 km of the sub-array center, are used to search for pulsars and fast transient sources. These data may also be used for relatively crude pulsar timing.

2) Up to 16 *Pulsar Timing* beams (spread over up to 16 sub-arrays), each covering up to 2.5 GHz, based on the sum of selected antennas within +/-10 km of the sub-array center, are

used to very accurately measure deviations between observations of known pulsars and existing ephemerides.

SKA1_Mid is also able to form up to 4 VLBI beams (spread over up to 4 sub-arrays). In VLBI beamforming/imaging mode a subset of antennas that belong to a subarray (up to the full extent of the array, i.e. up to 200 km end-to-end) are added coherently to form dual-polarisation beams, and the real-time sample data — at VLBI standard sample rates — are transmitted to external VLBI equipment for inclusion in global VLBI array correlations. Note: ‘standard’ imaging and non-imaging operations cannot be performed for a sub-array in the VLBI beamforming mode, but can be concurrently performed for other sub-arrays.

SKA1 antennas have 5 different bands (700 MHz/pol bandwidth to 2x2.5 GHz/pol bandwidth) with sample word sizes ranging from 8 bits/sample to 4 bits/sample and sample rates ranging from 2.5 to 6 Gsamples/sec. The total data rate from each SKA1 antenna into the CSP is capped at 100 Gbps (CSP needs a single 100GBASE-X4 interface to each SKA1 antenna).

The MeerKAT antennas sample data at 1712 Msamples/sec, 8-bit resolution with overlap/coverage of SKA1 bands 1 and 2 (TBC). The MeerKAT to CSP interface is 2x10GBASE-SR or 40GBASE-SR4, preferably the latter. Digital sample rate conversion to SKA1 antenna sample rates must be performed in order to correlate input from MeerKAT and SKA1 antennas.

1.5 CSP Element Overview

1.5.1 CSP_Low Overview

Figure 1-3 is a simplified context diagram that shows CSP_Low and the Elements it interfaces with in the SKA1_Low telescope. Blue arrows are used to show flow of the observed astronomical data and green arrows are used to show flow of monitor and control data.

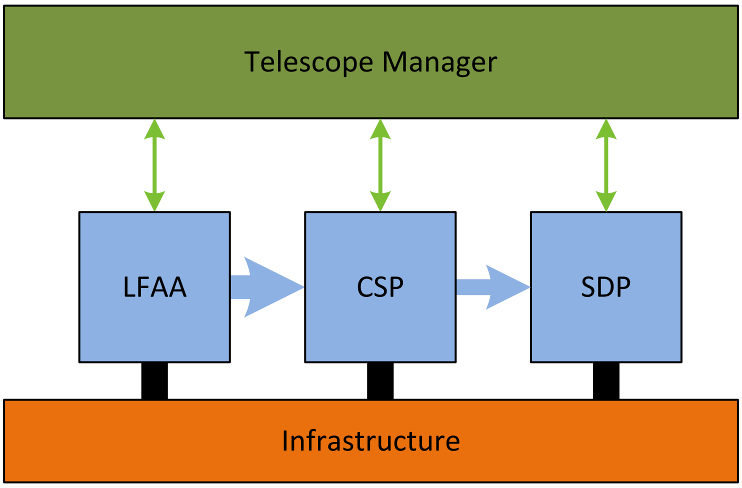


Figure 1-3 CSP_Low Context

The CSP_Low receives observed (astronomical) data from the Low Frequency Aperture Array (LFAA) and, on request, in each of up to 16 sub-arrays, independently and concurrently, performs the following:

- Generates visibility spectra and forwards the resulting data to the Science Data Processor.
- Forms up to 500 pulsar search beams, performs pulsar search and/or search for transients in all beams concurrently and forwards candidate data to the Science Data Processor.

- Forms up to 16 pulsar timing beams, concurrently and independently times a pulsar (with known ephemera provided by TM) in each beam, as requested and forwards results to the Science Data Processor.

CSP_Low accepts commands and various metadata from Telescope Manager (TM), and sends status and other information and metadata to the Telescope Manager (TM). The general intent is that all information and commands (with possible exception of the bulkiest and most time-critical) flow through TM. CSP_Low equipment is installed in the central Signal Processing facility at the site; CSP_Low relies on the Infrastructure to provide shielded building, power, etc. as defined in [AD6].

Interfaces with other SKA1_Low Elements are defined in the relevant Interface Control Documents, as follows: Telescope Manager [AD4], LFAA [RD20], SDP [RD21] and Infrastructure [AD6].

1.5.1.1 CSP_Low Sub-elements

As specified in the "SKA CSP Architecture Design Document [AD3], the CSP_Low comprises four design sub-elements (see Figure 1-4):

1) Correlator and Beamformer (CSP_Low.CBF)
2) Pulsar Search (CSP_Low.PSS)
3) Pulsar Timing (CSP_Low.PST)
4) Local Monitor and Control (CSP_Low.LMC).

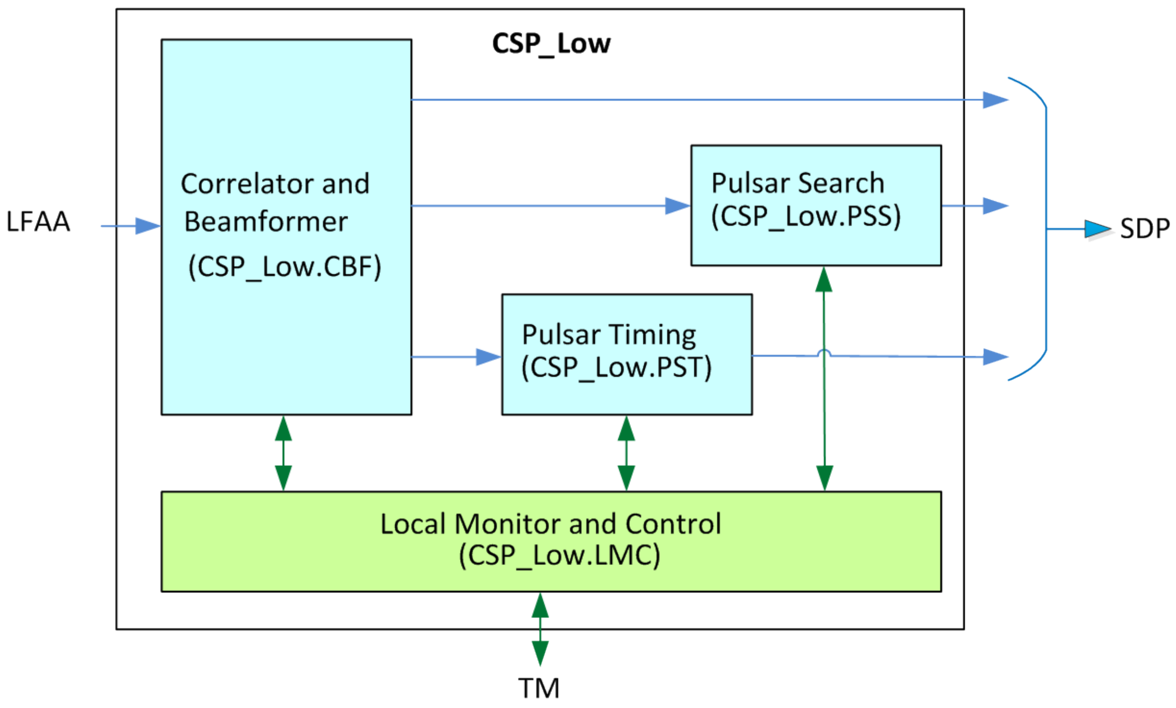


Figure 1-4 CSP_Low Sub-elements

The Correlator and Beamformer (CSP_Low.CBF) receives data from LFAA stations and generates visibilities that are sent to SDP. CSP_Low.CBF also calculates the voltage beams for pulsar timing and polarisation power beams for pulsar search.

The 300 MHz of station data received from LFAA is coarsely channelized into 384 frequency channels, each with 781 kHz bandwidth. The total output data of LFAA (CSP_Low.CBF input) is 512 stations x 300 MHz x 32/27 x 2-polarisations x 2x8-bit complex = 5.8 Tbps.

The correlator calculates cross-correlation products for each pair of stations that belongs to the same sub-array, including auto-correlations. There are approximately 64K frequency channels for the n(n+1)/2 = 1024x1025/2=524800 visibilities, where n is the number of signal paths to correlate (512 stations x 2 polarisations). Each complex product has a minimum integration time of 0.9 seconds, and therefore the maximum visibility data rate, generated when all stations belong to the same sub-array, is 524800 visibilities x 64k channels = 37 Giga-visibilities/second. At 80 bits per visibility the output data rate is 3 Tbps.

The CSP_Low.CBF beamformer adds signals from all stations in a sub-array to form coherent beams, each with combined sensitivity of the antenna stations that form a sum.

To adequately fill the primary beam, 500 Pulsar Search beams are formed using ~15 kHz wide frequency channels per beam.

Fewer pulsar timing beams are required (16), as they are used for targeted observations of known pulsars. Pulsar timing beams use full bandwidth (300 MHz) for sensitivity.

To meet the requirement that imaging, pulsar search and pulsar timing can be performed concurrently within each sub-array, separate channelizers for imaging, pulsar search and pulsar timing are required, each one designed to meet specific needs.

The Pulsar Search Engine (CSP_Low.PSS) accepts up to 500 Pulsar Search beams from CSP_Low.CBF and searches each beam individually for pulsars and transient sources over a range of dispersion measures (DM), accelerations, and periods. Each processing node operates mostly independently on two of the 500 beams (TBC). The resulting source candidates are sorted and some basic sanity checks are performed before Pulsar Search candidate data is transmitted to the SDP.

The Pulsar Timing Engine (CSP_Mid.PST) is able to independently and concurrently time up to 16 known pulsars, each in a different Pulsar Timing beam produced by CSP_Mid.CBF. Pulsar Timing beams are formed using full system bandwidth of 300 MHz. The Pulsar Timing Engine is relatively small system, consisting of 16 compute nodes, each node processes different pulsar timing beam.

The CSP_Low Local Monitor and Control (CSP_Low.LMC) provides the gateway to the Telescope Manager (TM) on behalf of all CSP_Low sub-elements [AD3]. All configuration, control, and monitor messages for CSP_Low flow through CSP_Low.LMC. The CSP_Low sub-elements consist of digital hardware and computers; all sub-elements implement a functionally rich interface that allows for setup of various parameters, operational and observation modes. The Human-Machine Interface (HMI) that allows operations personnel to control and monitor the telescope in order to achieve engineering and scientific goals is provided by Telescope Manager (TM). Interface between TM and CSP_Low.LMC is a machine-to-machine interface [AD4], as is the interface between CSP_Low.LMC and other CSP_Low sub-elements [AD8].

1.5.2 CSP_Mid Overview

Figure 1-5 is a simplified context diagram that shows CSP_Mid and the Elements it interfaces with in the SKA1_Mid telescope. In the diagram, blue arrows are used to show flow of the observed astronomical data and green arrows are used to show flow of monitor and control data.

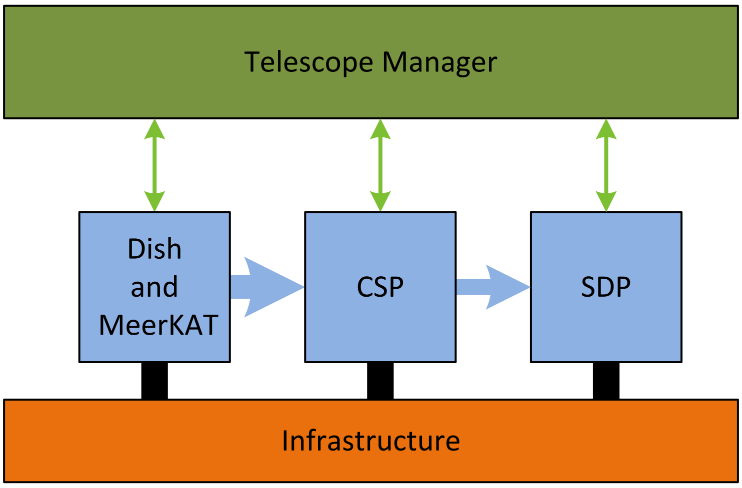


Figure 1-5 CSP_Mid Context

The CSP_Mid receives observed (astronomical) data from the SKA1 and MeerKAT dishes, and, on request, in each of up to 16 sub-arrays, independently and concurrently, performs the following:

- Generates visibility spectra and forwards the resulting data to the Science Data Processor.
- Forms up to 1500 pulsar search beams, performs pulsar search and/or search for transients in all beams concurrently and forwards candidate data to the Science Data Processor.
- Forms up to 16 pulsar timing beams, concurrently and independently times a pulsar (with known ephemera provided by TM) in each beam, as requested and forwards results to the Science Data Processor.

In addition, CSP_Mid is able to form up to 4 VLBI beams, in up to 4 sub-arrays. However, VLBI beam-forming cannot be performed concurrently *in the same sub-array* with imaging, pulsar search and/or pulsar timing. Imaging, pulsar search and pulsar timing can be performed concurrently with VLBI in other (non-VLBI) sub-arrays.

CSP_Mid accepts commands and various metadata from, and sends status and other information and metadata to the Telescope Manager (TM). The general intent is that all information and commands, except for the bulkiest and most time-critical, flow through TM. CSP_Mid equipment is installed in the Central Signal Facility; CSP_Mid relies on the Infrastructure to provide shielded building, power, etc.

Interfaces with other SKA1_Mid Elements are defined in the relevant Interface Control Documents, as follows: Telescope Manager [AD5], Dish [RD17], MeerKAT Antennas [RD18], SDP [RD19] and Infrastructure [AD7].

1.5.2.1 CSP_Mid Sub-elements

As specified in the "SKA CSP Architecture Design Document [AD3], the CSP_Mid comprises four design sub-elements (see Figure 1-6):

5) Correlator and Beamformer (CSP_Mid.CBF)
6) Pulsar Search (CSP_Mid.PSS)
7) Pulsar Timing (CSP_Mid.PST)
8) Local Monitor and Control (CSP_Mid.LMC).

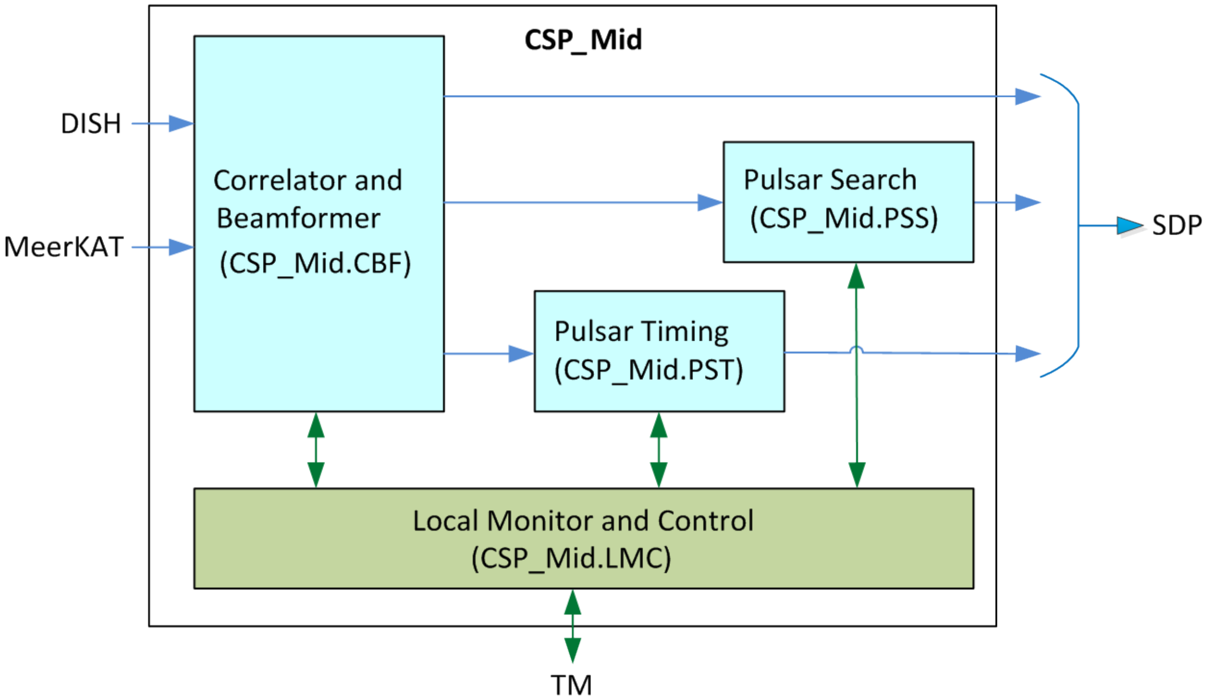


Figure 1-6 CSP_Mid Sub-elements

CSP_Mid.CBF performs two basic functions, correlation and beamforming. CSP_Mid.CBF calculates full-polarisation cross-correlation spectra with ~64,000 channels for every pair of antennas in each sub-array, including antennas against themselves. Each sub-array may be observing in a different observing band, and spectral zoom may be employed to provide finer spectral resolution over a range of narrower bandwidths. The maximum data rate to the SDP arises when all 197 antennas are used in a single sub-array. In this case, ~64,000 complex spectral channels for each of 4 polarisation products are produced on each of N(N+1)/2 = 197*198/2 = 19503 baselines. Each complex product is referred to as a "visibility" and with the minimum specified integration time of 140 msec, 19503 baselines x 4 pol prods/baseline x 64,000 channels/pol prod x 1/0.14 sec ~= 35.6 Gig visibilities/sec. At ~80 bits per visibility[2], the data rate (to the SDP) is ~2.85 Tbps.

The central beamformer, included in CSP_Mid.CBF, coherently adds signals from all antennas together to form beams, each with the combined sensitivity of the antennas that form the sum, to be used for searching and timing pulsars. In order to adequately fill the primary beam of the antenna[3], CSP_Mid is able to form up to 1500 Pulsar Search beams, with 4096 channels per beam. By contrast, only 16 Pulsar Timing beams are required, as they are used for targeted observations of known pulsars. However Pulsar Timing requires a much wider bandwidth per beam for sensitivity; for that reason CSP_Mid is able to form Pulsar Timing beams for up to full input bandwidth for Bands 1 to 4 and for up to 2.5 GHz for Band 5.

Within any sub-array the correlator and central beamformer must operate concurrently and therefore separate correlator, Pulsar Search, and Pulsar Timing channelizers are required, each one designed to meet specific needs. Each beam may be assigned to any of the (up to 16) sub-

[2] 64 bits for I+jQ data; 8 bits for the "time centroid index", and 8 bits for a "quality" value (i.e. fraction of data that was correlated).
[3] That is, each coherent beam on a 20 km aperture has a HPBW of ~λ/20 km — a sliver of the individual antenna's HPBW of ~λ/D, with D~15 m. Thus, many coherent beams must be formed and searched to cover some reasonable portion of the primary beam.

arrays, and the Pulsar Search beams in particular may be tuned to different observing frequencies within the band, with some restrictions.

In addition, CSP_Mid can form up to four coherent independently pointed VLBI beams, within up to four sub-arrays. VLBI beamforming cannot be performed in the same sub-array concurrently with SKA1 imaging, Pulsar Search and Pulsar Timing. Each of the four VLBI beams can have multiple “VLBI standard” sub-bands, with bandwidth of 512 MHz, 256 MHz, 128 MHz, …, or 1 MHz (up to the full observing bandwidth of the particular band in use). The bandwidth and sub-bands can be independently selected for each VLBI beam. Streaming real-time data for VLBI beams are transmitted to external VLBI equipment, which may be located in the SDP facility. To facilitate beamformer calibration, CSP_Mid.CBF must simultaneously produce cross-correlations within each VLBI sub-array.

The Pulsar Search Engine (CSP_Mid.PSS) accepts up to 1500 Pulsar Search beams from CSP_Mid.CBF and searches each beam individually for pulsars and transient sources over a range of dispersion measures (DM), accelerations, and periods. Each processing node operates mostly independently on two of the 1500 beams (TBC) received from CSP_Mid.PSS at 300 MHz/beam channelized into 4096 channels. The resulting source candidates are sorted and some basic sanity checks are performed before Pulsar Search candidate data is transmitted to the SDP.

The Pulsar Timing Engine (CSP_Mid.PST) is able to independently and concurrently time up to 16 known pulsars, each in a different Pulsar Timing beam produced by CSP_Mid.CBF.

The CSP_Mid Local Monitor and Control (CSP_Mid.LMC) provides the gateway to the Telescope Manager (TM) on behalf of all CSP_Mid sub-elements [AD3]. All configuration, control, and monitor messages for CSP_Mid flow through CSP_Mid.LMC. The CSP_Mid sub-elements consist of digital hardware and computers; all sub-elements implement a functionally rich interface that allows for setup of various parameters, operational and observation modes. The Human-Machine Interface (HMI) that allows operations personnel to control and monitor the telescope in order to achieve engineering and scientific goals is provided by Telescope Manager (TM). Interface between TM and CSP_Mid.LMC is a machine-to-machine interface [AD5], as is the interface between CSP_Mid.LMC and other CSP_Mid sub-elements [AD8].

As described in [AD8] each of the CSP_Mid sub-elements (CBF, PSS and PST) is responsible for internal monitor and control of its components. Overall approach to implementation of the monitor and control functionality in CSP_Mid is hierarchical.

1.6 Document Overview

This document follows a template that was agreed by the SKAO and the CSP Consortium. It covers the key contents called out in the SKA Statement of Work for Central Signal Processor [AD1].

Detailed information is provided in the appendices or is contained in the referenced documents.

1.7 Requirement Allocation Overview

The key function of the CSP.LMC in both SKA1 Telescopes is to provide a single point of contact for Telescope Manager (TM), so that TM can configure and execute observations without being aware of the internal CSP design and implementation. For example, in order to execute a Pulsar Search observation, TM assigns receptors to a sub-array, specifies the number of Pulsar Search beams to be used by a sub-array, and provides pointing and other beamforming parameters and the start time; CSP.LMC translates parameters provided by TM into CSP.CBF and CSP.PSS parameters as appropriate.

CSP.LMC co-ordinates functionality of the CSP sub-elements by forwarding information supplied by one sub-element to the other, when required.

The role of CSP.LMC is to report status on behalf of CSP, including overall CSP state and mode of operation, availability of the CSP functionality and, where applicable, status and progress of the commands issued by TM. Where necessary and applicable, CSP.LMC performs mapping between external view of the CSP and internal implementation. CSP.LMC reports on behalf of the CSP as a whole, and allows TM to monitor and control individual Capabilities, CSP sub-elements, and components, when required.

CSP.LMC makes provision for TM to set CSP engineering parameters, as well as engineering parameters for CSP sub-elements and their components, such as logging levels, alarm thresholds, etc. CSP.LMC makes provision for TM to set mode of operation and initiate state transitions, such as shut-down, start-up, etc.

CSP.LMC implements monitoring functionality such as periodical and on-demand reporting of the health, status and configuration parameters, reporting alerts and significant events.

In addition to the functional requirements, a number of non-functional requirements have been assigned to CSP.LMC, they relate to availability, reliability, safety, maintainability and testability of the system.

The scope of CSP.LMC **does not** include:

1. Calculating central beamforming calibration coefficients. These are supplied by TM as specified in [AD4] and [AD5] and forwarded by CSP.LMC to CSP.CBF. CSP.CBF is responsible for applying these models to effect real-time beam formation and calibration within the accuracy and precision required by CSP.CBF.
2. Calculating earth rotation delay polynomials or any clock correction or modification coefficients for each antenna/station. These are supplied by TM as specified in [AD4] and [AD5] and forwarded by CSP.LMC to CSP.CBF. CSP.CBF is responsible for applying these models to effect real-time delay and phase tracking within the accuracy and precision required by CSP.CBF.
3. Making any decisions as to observation start time, stop time, or configuration. CSP.LMC applies/responds to requests received from TM, and forwards those requests to other CSP sub-elements, as applicable.
4. Transmitting any engineering or science meta-data to the Science Data Processor (SDP). CSP.LMC communicates with Telescope Manager, any data that has to be exchanged between SDP and CSP flows via TM.
5. Making any decisions as to whether CSP equipment is powered on or off, or performing transitions to low-power state. Any such decisions are made by Telescope Manager. CSP.LMC makes provision for TM to request shut-down and power-up of the CSP equipment as well as transitions to/from a low-power state. In addition, power-down may be performed by the CSP equipment which implements autonomous ‘deadman’ protection as a safety measure.

1.8 Documentation Tree

The current version of this document does not reference substantial supporting information. Future releases may reference supporting information.

2 APPLICABLE AND REFERENCE DOCUMENTS

2.1 Applicable Documents

The following documents at their indicated revision form part of this document to the extent specified herein. Unless otherwise noted, the latest Revision is assumed.

Table 2-1 Applicable Documents

Ref No	Document/Drawing Number	Applicable Document Title	Issue Number
AD1	SKA-TEL-CSP-0000159	SKA Statement of Work for Central Signal Processor (PM-3a)	-
AD2	SKA-TEL-CSP-0000100	SKA CSP Local Monitor and Control Sub-element Requirements Specification (EG-1)	-
AD3	SKA-TEL-CSP-0000014	SKA CSP Architectural Design Document (SE-5)	-
AD4	100-000000-021	SKA1-LOW Interface Control Document CSP to TM (SE-6b1)	-
AD5	300-000000-021	SKA1-MID Interface Control Document CSP to TM (SE-6b2)	-
AD6	100-000000-020	SKA1-LOW Interface Control Document CSP to INFRA (SE-6b1)	-
AD7	300-000000-020	SKA1-MID Interface Control Document CSP to INFRA (SE-6b2)	-
AD8	SKA-TEL-CSP-0000019	SKA CSP Interface Control Document LMC to CSP Sub-elements (CBF, PSS, PST) (SE-7b)	-
AD9	Not available	SKA1-LOW Interface Control Document SaDT to CSP	
AD10	Not available	SKA1-MID Interface Control Document SaDT to CSP	

2.2 Reference Documents

The following documents provide useful reference information associated with this document. These documents are to be used for information only. Changes to the date and/or revision number do not make this document out of date.

Table 2-2 Reference Documents

Ref No	Document/Drawing Number	Reference Document Title	Issue Number
RD1	SKA-TEL-CSP-0000101	SKA1 CSP Local Monitor and Control Sub-element Design Description (EG-2)	-
RD2	SKA-TEL.CSP.LMC-NCRA-TSS-001	SKA1 CSP Local Monitor and Control Sub-element Test Specification (EG-3)	-
RD3	SKA-TEL.CSP.LMC-NRC-DVP-001	SKA1 CSP Local Monitor and Control Sub-element Development Plan (EG-4)	-
RD4	SKA-TEL.CSP.LMC-NRC-CST-001	SKA1 CSP Local Monitor and Control Sub-element Development and Operational Cost (EG-5)	-
RD5	SKA-TEL.CSP.SE-SSA-SRS-001	SKA1 CSP Requirements Specification	Rev.2B
RD6	SKA-TEL-CSP-000102	SKA1 CSP Element Assembly, Integration and Test Plan (SE-8)	-
RD7	SKA-TEL.CSP.SE-ATC-PLA-001	SKA1 CSP Element Commissioning, Operation and Maintenance Plan (SE-12)	-
RD8	SKA-TEL.CSP.SE-ATC-LEP-001	SKA1 CSP Element Logistic Engineering Management Plan (SE-20)	-
RD9	SKA-TEL-SKO-0000308	SKA1 System Baseline V2 Description	
RD13	SKA-TEL-TM.TELMGT-TMC-LSR-001	SKA1 LMC Scope and Responsibilities	-
RD14	TEL.TM.TELMGT-TMC-LIG-001	SKA1 LMC Interface Guidelines	-
RD15	ECSS-E-ST-40C	European Cooperation for Space Standardisation, Space Engineering - Software	6 March 2009
RD16	CSP Memo 0015	CSP States and Modes	V1.2
RD17	SKA-TEL-SKO-0000124	Interface Control Document SKA1 DISH to CSP_MID	
RD18	SKA-TEL-AIV-2310001	Interface Control Document MeerKAT to SKA1_MID CSP	
RD19	300-000000-002	Interface Control Document SKA1 MID SDP – CSP	
RD20	SKA-TEL-SKO-0000142	Interface Control Document SKA1 LFAA to CSP	
RD21	100-000000-002	Interface Control Document SKA1 LOW SDP – CSP	

3 OPERATIONAL CONCEPTS

The key functionality of the CSP.LMC is monitor and control; by its nature, CSP.LMC is interface oriented.

Interface between TM and CSP.LMC is a machine-to-machine interface [AD4] [AD5], as is the interface between CSP.LMC and other CSP sub-elements [AD8].

The main role of CSP.LMC is to provide a gateway to Telescope Manager, to make provision for TM to monitor and control CSP as a single entity, without being aware of the details of CSP implementation.

This section lists the operational concepts related to CSP monitor and control and CSP.LMC in particular. Some of the concepts listed here are derived directly from the requirements, some are result of the design decisions made at the CSP level (and documented in [AD3]) and some are assumptions and choices made by the author in the absence of the clear guidance at the project level. Changes are possible and likely.

For easier reference, each operational concept is assigned a number with the prefix ‘OpCon’.

OpCon.1. CSP.LMC reports on behalf of the CSP Element - CSP.LMC maintains overall status for the instance of CSP Element in each telescope and reports on its behalf. In other words, commands/queries addressed to the CSP Element are handled by CSP.LMC. Element level commands and queries may require setup and/or status of more than one CSP sub-element. When an Element level command/query is received, CSP.LMC forwards the command/query to the sub-elements as appropriate, collects responses from all sub-elements and based on those responses generates the response for TM. (SKA1-CSP-LMC_REQ-2121-00-02)

OpCon.2. Reporting at sub-element and component level - In the case when a command/query requires setup or status of a single sub-element, CSP.LMC forwards command/query to the sub-element, waits for the sub-element response and forwards it to TM. The same applies for commands/queries that apply for a single component (e.g. LRU or server). In some cases CSP.LMC may add additional information before forwarding a sub-element response to TM. (SKA1-CSP-LMC_REQ-2121-00-02)

OpCon.3. Command Activation Time – CSP.LMC makes provision for TM to specify the command Activation Time, which is the time when CSP should *begin* re-configuration or other action specified in the received message.

OpCon.4. A command with no Activation Time assigned to it is executed as soon as possible.

OpCon.5. Further analysis is required to decide whether CSP.LMC should accept commands received past the specified Activation Time. *Discussion: It is likely that in some cases TM may issue a command shortly before the specified Activation Time, which should not cause CSP.LMC to reject the command. CSP.LMC should report late arrival of commands as notification or warning).*

OpCon.6. In the same manner as CSP.LMC, other CSP sub-elements make provision for CSP.LMC to specify the Activation Time in the commands. A command received from TM well in advance of its Activation Time may be forwarded to sub-elements as soon as it is received, unless CSP.LMC has a reason to delay forwarding to sub-element(s).

OpCon.7. There is no limit on how soon or how distant the Activation Time specified in the message can be, i.e. how much in advance commands can be forwarded to the

CSP.LMC and other CSP sub-elements. CSP.LMC and other CSP sub-elements will provide estimates for how long does it take to propagate commands so that they can be executed as scheduled.

OpCon.8. CSP.LMC power-up - After power-up CSP.LMC performs initialisation and proceeds to ready (ok) state. During initialisation, CSP.LMC loads configuration from a local repository (file or data base). 'Local' in this context means local to CSP.LMC (not provided by TM). This initial configuration is sufficient for CSP.LMC to become operational before connection with TM is established.

OpCon.9. Establishing communication with TM and sub-elements - Immediately after initialisation CSP.LMC makes an attempt to establish communication with the other CSP sub-elements (CBF, PSS and PST). It is to be defined (TBD) whether CSP.LMC initiates communication with TM or waits for TM to initiate a connection. CSP.LMC maintains communication with TM and with CSP sub-elements at all times.

OpCon.10. Loss of communication with TM - In the case of loss of communication with TM, CSP.LMC remains operational; it collects and maintains CSP status as usual. CSP configuration without TM connection may be used for testing purposes; in which case, the CSP engineering interfaces may be used to display CSP status and/or issue commands. If the loss of communication with TM is detected during normal operations, CSP.LMC continues operations using the existing setup. It is to be determined (TBD) whether in the case of prolonged loss of communication with TM, CSP.LMC should set the CSP equipment in low power mode.

OpCon.11. Loss of communication with sub-elements - If the communication with a sub-element is lost, CSP.LMC reports the problem to TM and keeps trying to establish communication. CSP.LMC advices TM on the impact on on-going observations and on status of Capabilities (e.g. sub-arrays, beams, receptors, baselines). CSP.LMC reports CSP status as degraded. In other words, even if a CSP sub-element is fully operational, if it loses connection with CSP.LMC, the status of the sub-element in question is reported as unknown and the overall CSP status is reported as degraded. CSP.LMC remains fully operational, collects and reports status for other sub-elements and executes TM commands to the extent that the degraded CSP Element can provide (and advices TM on the Capabilities that can be provided). As soon as communication with the CSP sub-element is established, CSP.LMC collects status from the sub-element, derives status of the Capabilities and the overall CSP status, and reports to TM (e.g. by transmitting clear alarm).

OpCon.12. Capabilities – CSP.LMC implements Capabilities that represent CSP functionality, in particular receptor-input and PSS, PST and VLBI beams. This allows CSP.LMC to report overall availability and status of the input data from each receptor and related components so that TM can monitor status and configure sub-arrays without being aware of the details of the CSP implementation. In the same manner, CSP.LMC implements Pulsar Search, Pulsar Timing and VLBI beams as Capabilities, which allows TM to monitor availability and status and configure sub-arrays for Pulsar Search, Pulsar Timing and/or VLBI observations without being aware which CSP sub-element(s) and components implement the functionality.

OpCon.13. In the same manner as for the 'real' components, CSP.LMC allows TM to set and query parameters of the Capabilities.

OpCon.14. Reporting availability and use of Capabilities – CSP.LMC is able to report availability and use status of the Capabilities (i.e. how many are used and how many are available for use). Capability availability is determined based on the reports from the sub-elements.

OpCon.15. Sub-arrays are created during CSP.LMC initialization[4]. More precisely: during initialization, CSP.LMC creates the pre-defined number of sub-arrays (16 sub-arrays in each telescope). Initially, all sub-arrays are empty and IDLE (neither receptors nor beams are assigned to sub-arrays during initialization, observing mode for all sub-arrays is set to IDLE and no output products are sent to SDP).

OpCon.16. CSP.LMC does not make provision for TM to create additional sub-arrays nor to destroy existing sub-arrays.

OpCon.17. Receptors (antennas or stations) are added and removed to/from sub-arrays on TM request.

OpCon.18. Capabilities (receptor-input and beams) are created by CSP based on the available hardware and software, during initialization and when new hardware/software is added and detected. Initially, Capabilities are set to Idle Mode (details TBD). After successful initialisation, CSP.LMC is able to report availability and status of Capabilities, i.e. how many sub-arrays, receptors, beams and baselines are available for use.

OpCon.19. A receptor (antenna / station) can belong to only one sub-array at a time. A receptor must be explicitly removed from the sub-array to which it is assigned, before it can be added to another sub-array. Note: both commands (remove and add) may have the same Activation Time, but 'remove' must be received by CSP.LMC before 'add'.

OpCon.20. Receptors can be moved in and out of sub-arrays only at scan boundaries or when a sub-array is IDLE. In other words, TM cannot add/remove receptors to/from a non-IDLE sub-array.

OpCon.21. Processing of input data and generation of output products are controlled via Observing Mode parameters. CSP.LMC makes provision for TM to specify the Observing Mode for a sub-array, define Observing Mode parameters and specify the Activation Time (i.e. when to re-configure the sub-array and start signal processing).

OpCon.22. It is TBD whether duration of the scan can be specified as a part of configuration. If duration is specified, when the specified period expires the sub-array is set to Idle Mode. It is more likely that TM will use a command 'set Observing Mode=idle" to end a scan. (Both options can be supported, if needed).

OpCon.23. A command that causes an on-going observation to end is executed as specified, CSP does not wait for the on-going integration of the CSP products to end; products for the last incomplete integration are discarded, and re-configuration performed as requested.

OpCon.24. PSS, PST and VLBI beams can be assigned to a sub-array at scan boundaries or when sub-array is IDLE. Beams that are assigned to one sub-array cannot be assigned and used by another sub-array. A beam must be explicitly removed from the sub-array to which it is assigned, before it can be added to another sub-array. Note: both commands may have the same Activation Time, but 'remove' must be received by CSP.LMC before 'add'.

[4] This is contrary to the concepts presented in the CSP to TM ICDs [AD4] and [AD5]. The concept presented here is a result of a recent discussion with the TM Consortium. The conclusion was that a more practical (cleaner, easier to implement) approach is to create the maximum supported number of (empty) sub-arrays during initialisation. This allows for easier reporting, report generation, etc. The ICDs and CSP ADD [AD3] were signed and submitted for Delta-PDR before this change was discussed, the Delta-PDR version of those documents describes the old concept, i.e. provision for dynamic creation and instruction of sub-arrays.

OpCon.25. CSP.LMC makes provision for TM to revoke a previously sent command waiting to be executed. CSP.LMC makes provision for TM to obtain the list of messages waiting to be activated, to remove a specific message from the queue, and to remove all messages from the queue. (TANGO support for revoke to be confirmed).

OpCon.26. CSP.LMC makes provision for software upgrades. Implementation TBD.

OpCon.27. Where required, automatic software and firmware upgrade for all components of the same type should be provided by sub-elements.

OpCon.28. CSP.LMC implements staged power-down of CSP sub-elements and makes provision for TM to request delayed power-down (i.e. to specify the Activation Time for a power-down command).

OpCon.29. CSP.LMC implements staged power-up procedure of CSP sub-elements and makes provision for TM to specify when to begin power-up (i.e. to specify the Activation Time). Details TBD.

OpCon.30. CSP.LMC makes provision for TM to request power-down or power-up for a single sub-element (if supported by the sub-element).

OpCon.31. A TM request (command) to power-up, power-down, reset or reboot an individual component is executed by the sub-element to which the component belongs. CSP.LMC forwards such requests to sub-elements.

OpCon.32. TM provides regular updates for the delay models (polynomials) for on-going observations, as applicable (see [AD4] and [AD5]). Implementation details TBD. CSP.LMC forwards those parameters to CSP.CBF (see [AD8]).

OpCon.33. Regular updates required for delay tracking and beamforming provided by SDP, are received via TM. There is no direct communication between CSP.LMC and SDP (as defined in [AD3], [AD4] and [AD5].

OpCon.34. TM provides regular updates for the parameters used in beamforming as defined in “ICD CSP to TM” [AD4] and [AD5]). Implementation details TBD. CSP.LMC forwards those parameters to CSP.CBF (see [AD8]).

OpCon.35. For observing modes which use two CSP sub-elements, such as Pulsar Search and Pulsar Timing, one sub-element may require information from the other sub-element. There is no direct exchange of the monitor and control information among CSP sub-elements, other than communication with CSP.LMC. For instance, for a Pulsar Search observation, the CSP.PSS has to inform CSP.CBF regarding destination addresses for CSP.CBF output data. CSP.PSS sends per beam destination addresses to CSP.LMC, and CSP.LMC forwards information to CSP.CBF. This is a design decision made at CSP Element level and documented in [AD3].

OpCon.36. Errors and faults detected by CSP hardware and software components are reported to TM using Alarm messages. Individual CSP components generate and transmit Alarms to the pre-configured destination address (see OpCon.39).

OpCon.37. Events that are of interest to TM and/or operators are reported in the form of Event messages. The set of Event messages and required TM actions (if any) are agreed upon in advance. Individual CSP components generate and transmit Events to the pre-configured destination address (see OpCon.39).

OpCon.38. CSP components monitor status of the pre-defined set of the parameters at pre-configured frequency and report the status periodically and/or when a threshold is crossed. CSP makes provision for TM to change monitoring and reporting frequency, and set thresholds and triggers. Monitor point reports are sent to the pre-configured destination address (see OpCon.39).

OpCon.39. All CSP components, which have such capacity, store the destination addresses for Alarms, Events, Monitor Point reports and Auxiliary data reports in the non-volatile memory (e.g. initialisation file) so that they can be retained and restored after reset, reboot and power-down. CSP makes provision for TM to change the destination addresses for Alarms, Events, Monitor Point reports and auxiliary data reports. When requested, the change is applied as soon as possible and stored in the non-volatile memory. Configurable parameters related to the monitor points and auxiliary data may be also saved in the non-volatile memory and restored after reboot, reset and power cycle.

OpCon.40. CSP.LMC maintains the Central Log File. Alarms and Events are logged in order in which they were received (i.e. not necessarily in order in which they were generated); however each log indicates the time when the error/fault/event was reported by the entity that generated Alarm/Event. The CSP Central Log File has capacity of 10.000 logs, when the maximum capacity is reached; new log replaces the oldest log. CSP.LMC makes provision for TM to read and search the Central Log File.

OpCon.41. Some CSP components (servers) maintain own log files. In the same manner as for the CSP Central Log File, allows for TM to query (read and search) the content. Tools/access TBD.

OpCon.42. In the same manner as the destination addresses, the CSP.LMC and CSP mode of operation is stored in the non-volatile memory and restored after reset, reboot and power-down. Each component that has such capacity (i.e. access to non-volatile memory) implements this functionality. A component that reports on behalf of other component (e.g. a server that reports on behalf of a PCB) maintains Operational Mode of that component.

3.1 Operational Environment

3.1.1 CSP_Low.LMC Operational Environment

As defined in the ICD CSP to Infrastructure Australia [AD6], CSP_Low.LMC will be installed in the racks provided by CSP_Low.CBF in the Central Signal Processing facility to be built in Western Australia. This choice was made to save space; CSP_Low.LMC occupies only a small fraction of a single cabinet and can easily fit in one of the cabinets provided by CSP_Low.CBF. Power and cooling will be provided within the rack.

All CSP_Low sub-elements will be deployed in the same room. The room housing CSP_Low is an RFI shielded room with a raised computer floor. The room is ESD protected and HVAC filters prevent dust accumulation on equipment. It is assumed that no exceptional RFI radiate-emission attenuation engineering must be incorporated into CSP_Low.LMC equipment, other than standard good practises to meet data centre standards. Power and cooling will be provided by Infrastructure Australia; CSP_Low.LMC equipment will be connected to power outlets provided in the rack (rack provided by CSP_Low.CBF). Overhead trays will be provided for network cables (for connections with TM and other CSP_Low sub-elements).

3.1.2 CSP_Mid.LMC Operational Environment

As defined in the ICD CSP to Infrastructure South Africa [AD7], CSP_Mid.LMC will be installed in the racks provided by CSP_Mid.CBF in the Central Signal Processing facility KAP-B building in Karroo region in South Africa. This choice was made to save space; CSP_Mid.LMC occupies only a small fraction of a single cabinet and can easily fit in one of the cabinets provided by CSP_Mid.CBF. Power and cooling will be provided within the rack.

All CSP_Mid sub-elements will be deployed in the same room. The room housing CSP_Mid is an RFI shielded room with a raised computer floor. The room is ESD protected and HVAC filters prevent dust accumulation on equipment. The requirements demand that CSP_Mid.LMC LRUs individually meet CISPR-22 Class A radiated and conducted emission level. CSP_Mid.LMC LRUs must also meet EMC and power susceptibility standards.

Power and cooling will be provided by Infrastructure South Africa; CSP_Mid.LMC equipment will be connected to power outlets provided in the rack (provided by CSP_Mid.CBF). Overhead trays will be provided for network cables (for connections with TM and other CSP_Mid sub-elements).

3.1.3 Operations

Operational scenarios are described in Chapter 8.

3.1.4 Maintenance

The CSP.LMC hardware consists of COTS hardware (servers and network switches). CSP.LMC requires typical data centre/IT system maintenance and typical IT-support personnel.

3.1.5 Operator Role

Apart from maintenance activities, the CSP.LMC is remotely controlled via TM and ultimately by an operator within the TM environment.

During normal operations operator executes observations and monitors progress using Telescope Manager provided HMIs. The operator does not need to communicate with CSP directly; Telescope Manager translates observation scripts and other commands into CSP commands and forwards to CSP.

Operator monitors the list of active alarms and other indicators, if CSP.LMC reports an alarm or other event that requires operator attention, the operator may use TM provided HMIs to inspect CSP status and other parameters, which may result in TM generating additional commands addressed for CSP.LMC. CSP.LMC translates those commands to commands for other CSP sub-elements as applicable and forwards to other CSP sub-elements as needed.

At this time it is assumed that access to the CSP.LMC engineering HMIs is restricted to personnel responsible for maintenance. This restriction is not enforced by technical limitations; it is assumed that use of CSP.LMC engineering HMIs should be restricted to the personnel with expert knowledge of the system. CSP.LMC GUIs will be delivered as a part of the CSP engineering GUI framework which provide domain specific visualization of the CSP status and configuration at all levels of abstraction. CSP.LMC engineering GUIs provide overall rolled-up status of the CSP equipment and status of each sub-array, as well as drill-down to the individual sub-elements and Capabilities, all the way to the lowest level of CSP components.

3.2 Support Environment

3.2.1 On-site Support

On-site support is required to perform regular maintenance of CSP.LMC equipment, replace failed hardware (servers and network switches installed in cabinets) and investigate and fix the cause in the case of loss of communication with CSP.LMC.

The following support tasks must be performed on-site (for MID: KAP-B Karoo building, for LOW: CSP building in Western Australia):

- Replace server or network switch.
- Replace network connection.
- Replace air filters (if applicable).

3.2.2 Remote Support

CSP.LMC is operated remotely, from the SKA operator/maintainer facilities or any other computer authorized to access CSP network. CSP.LMC can be accessed and operated via TM and via CSP provided engineering interfaces. The telescope operator uses TM provided HMIs. Access to CSP engineering HMIs is restricted to personnel responsible for maintenance.

Note that in addition to CSP.LMC custom built HMIs, it is possible to login into CSP.LMC servers directly in order to monitor, deploy or start software processes, modify system parameters, access system log, and similar. Such access is password protected and restricted to personnel responsible for maintenance.

The following support tasks can be performed either locally or remotely (by authorized personnel from the SKA operator/maintainer facilities or any other computer authorized to access CSP network):

- Operating system maintenance and upgrades.
- Data base maintenance, upgrades and backups.
- Commercial and open source software packages (software infrastructure and software environment) maintenance and upgrades.
- CSP.LMC software maintenance and upgrades.
- Diagnostics and troubleshooting.

3.2.3 Maintainer Role

CSP.LMC consists of COTS equipment (servers and network switches), operating system, commercial and open source software packages and custom built CSP.LMC software. CSP.LMC monitors system health parameters and reports when the pre-set thresholds are crossed (and other events that may require operator/maintainer attention). Regular maintenance tasks may be restricted to applying patches and upgrades for operating system and other commercial and open source software packages and data base backups.

The maintainer role is to:

- Monitor system health parameters and indicators (TBD) and intervene when necessary.
- Perform regular maintenance tasks (TBD).

- Investigate errors and failures reported by the system itself and by operators; find the cause of the problem (error/failure/malfunction); return the system in the normal operational state and remove the issue/problem that caused the system to fail or malfunction.

3.3 States and Modes

At this time the definition of the common SKA modes and states is not finalised. When the definition of the SKA modes and states is available, any non-compliance with the SKA standards will be clearly indicated and justification will be provided (for example if a particular state does not apply to CSP.LMC or other entity).

In the absence of the system-level documentation the definition of mode and state is provided here:

- **Mode** - The term ‘mode’ is used for parameters that indicate the intended mode of operation set by the user or the parent entity. Modes are implemented as read-write parameters. Mode is set by outside authority in order to change behaviour of the entity.
- **State** - The term ‘state’ is used for parameters that indicate state of the entity as derived by the entity itself (and in some cases by the entity that reports on behalf of another entity). External entity or authority cannot directly set the state of another entity, but can initiate a state transition by issuing a corresponding command. States are implemented as read-only parameters.

Description of the modes and states provided here is an attempt to define a comprehensive set of modes and states that can be used to monitor and control:

1. CSP as a whole (CSP.LMC reports on behalf of CSP Element).
2. CSP sub-arrays
3. CSP Capabilities
4. CSP.LMC sub-element as a whole
5. CSP.LMC hardware and software components.
6. Other CSP sub-elements (Correlator/Beamformer, Pulsar Search Engine, Pulsar Timing Engine), and their components and Capabilities. Each of the CSP sub-elements defines the set of states and modes in the relevant Design Document. As the design is still in progress, the states and modes identified and defined by other documents in their Design Documents may not exactly match the description provided here. Possible discrepancy is the result of the paralleled design effort by CSP teams. CSP.LMC team will review all the material produced by various CSP groups and will make an attempt to create a coherent definition acceptable to all sub-elements.

Table 3-1 States and Modes - Overview

State/Mode + values	CSP (overall)	CSP.LMC sub-element	Other CSP sub-elements	LRUs, h/w components as applicable	Sub-arrays	Capabilities (receptor-input, beams)
Operational State INITALIZING, HIBERNATE, SLEEP, READY, FAILED, SHUT-DOWN, OFF, UNKNOWN	R/O	R/O	R/O	R/O	-	-
Health (State) OK, DEGRADED, NOT_AVAILABLE	R/O	R/O	R/O	R/O	R/O	R/O
Usage State IDLE, USED	R/O	-	R/O	R/O	R/O	R/O
Redundancy Status ACTIVE, STANDBY	-	-	-	R/O where provided	-	-
Observing Mode IDLE, IMAGING, PSS, PST, VLBI	-	-	R/O (inherited from sub-arrays)	R/O (inherited from sub-arrays)	R/W	R/O (inherited from sub-array)
Administrative Mode ENABLED, DISABLED, MAINTENANCE, NOT-FITTED	R/W (TBC)	-	R/W	R/W	R/W	R/W
Test Mode R/W parameter where implemented	TBD	TBD	TBD (optional)	TBD (optional)	TBD (optional)	TBD (optional)
Simulator Mode R/W parameter where implemented	-	R/W	TBD (optional)	TBD (optional)	TBD (optional)	TBD (optional)
Remote vs Local Control Mode R/W parameter where implemented	TBD	TBD	TBD (optional)	TBD (optional)	TBD (optional)	TBD (optional)

R/W – Implemented as read-write parameter

R/O – implemented as read-only parameter

3.3.1 Operational State

CSP.LMC reports Operational State on behalf of:

- CSP Element
- CSP.LMC sub-element
- Individual CSP.LMC components
- Other CSP sub-elements. Status of other CSP sub-elements is reported as reported by the sub-element itself; unless the sub-element is unresponsive status is reported as UNKNOWN.

- Individual components of the other CSP sub-elements (as reported by the sub-element).

CSP.LMC derives and reports status of the CSP.LMC sub-element as listed in Table 3-2.

Operational State of individual CSP.LMC hardware components is reports as defined in Table 3-2.

Table 3-2 CSP.LMC Operational State Values

CSP.LMC Operational State	Description
OFF	In this state CSP.LMC hardware is in powered off state. This will occur only when the mains AC power is off or the power supply in the rack that houses CSP.LMC is off. CSP.LMC state may be reported as OFF by TM (or other entity), but never by CSP.LMC itself (when OFF CSP.LMC is not able to report its state).
INITIALIZING	This is a transient state. CSP.LMC enters this state upon power-up, reboot and reset. During initialisation CSP.LMC starts software processes and initializes its setup from the local non-volatile memory (file and/or data base). When initialisation is successfully completed CSP.LMC transfers to READY state. If, during initialisation, CSP.LMC detects a failure that causes CSP.LMC to be unusable for its core functions, CSP.LMC transfers to FAILED state.
LOW-POWER / HIBERNATE	CSP.LMC does not implement LOW-POWER (HIBERNATE or OFF-DUTY) state. CSP.LMC power consumption is a fraction of the overall CSP power consumption. In addition, CSP.LMC functionality is required in order to command power-up, power-down and other state transitions for CSP as a whole. When power is connected, CSP.LMC begins INITIALISATION, transitions to READY state and waits for TM to command transition to READY state for other sub-elements.
READY	This is the normal operational state; CSP.LMC is available for use. CSP.LMC may report READY state although some functions are compromised or not available; in which case CSP.LMC health is reported as DEGRADED.
FAILED	CSP.LMC cannot be used for its core functionality but is able to report its own status. This status may be reported when a basic CSP.LMC process responsible for CSP.LMC start-up is active but is not able to launch and bring to operational state software processes that perform CSP monitor and control. When Operational Status is reported as FAILED, Health Status must be reported as FAILED.
SHUTTING-DOWN	This is a transient state. CSP.LMC enters this state on TM request, i.e. upon receipt of the command to shut-down. CSP.LMC shut-down consists of shutting down software process and should be completed in few seconds. CSP.LMC exits this state when the shut-down procedure has been completed (which results in the loss of communication with CSP.LMC).
OFF	CSP.LMC state may be reported as OFF by TM (or other entity), but never by CSP.LMC itself (when OFF CSP.LMC is not able to report its state).
UNKNOWN	CSP.LMC state may be reported as UNKNOWN by TM (or other entity), but never by CSP.LMC itself.

CSP.LMC derives and reports CSP Operational State as listed in Table 3-3.

Operational State of other CSP sub-elements (CBF, PSS and PST) is reported using the same values (some differences may be identified as design progresses).

Table 3-3 CSP Operational State Values (as reported by CSP.LMC)

CSP Operational State	Description
OFF	All CSP equipment is powered-off. This will normally occur only when the mains AC power is off, or when power supplies in each rack are off. This state is never reported by CSP.LMC, as CSP.LMC is also OFF and unable to report status.
INITIALIZING	This is a transient state. CSP Operational State is reported as INITIALIZING when status of CSP.LMC and/or CSP.CBF is reported as INITIALIZING. When CSP.LMC and/or CSP.CBF are INITIALIZING, CSP is not able to perform any of the core functionality, sub-arrays are not available for use (for observing). CSP enters this state when the power is connected (the mains AC power is connected and power supplies in racks are on) and the servers boot-up.
HIBERNATE	CSP is non-operational; sub-arrays are not available for use (not ready for observing). CSP.LMC is operational (READY). Monitor and control servers, network switches and other support equipment that automatically starts-up when power is connected are also operational; CBF, PSS and PST sub-elements are able to report their status. However, sub-arrays are not available for use as signal processing equipment is not operational. Details to be specified by each sub-element. CSP Enters this state when power is connected and CSP.LMC completes INITIALISATION. CSP leaves this state on TM request; TM can request transition to OFF or to SLEEP.
SLEEP	CSP is non-operational; sub-arrays are not available for use (not ready for observing). In this state CSP equipment is gradually powered up, FPGA are booted with the default bitstreams. Overall power consumption stays <15% of the maximum power usage. Details TBD by each sub-element. CSP enters and laves this state on TM request. When CSP is in this state, TM may request transition to HIBERNATE or READY state.
READY	CSP is operational. Sub-arrays are available for observing (unless health is compromised). Transition from SLEEP to READY state is gradual. CSP.LMC reports CSP state as READY as soon as at least one sub-array and at least one receptor can be used for observing (in at least one of the supporting modes). The exact details of transition from SLEEP to READY state are TBD (and are implementation dependent).
FAILED	CSP cannot be used for its core functionality but is able to report its status. Subarrays are not available for observing. Overall CSP status is reported as FAILED when all core functionality is not-available. Sub-arrays are not available for observing. This may occur in the case of failure of CSP.LMC monitor and control hardware or software, complete loss of connectivity with receptors (dishes, LFAA), and similar. When Operational Status is reported as FAILED, Health Status must be reported as FAILED, and vice versa. CSP documentation shall clearly define under which circumstances the Operational State is reported as FAILED.
POWER-DOWN	This is a transient state. CSP enters this state on TM request, upon receipt of the command to power-down CSP equipment. CSP.LMC and other CSP sub-elements implement staged power-down of CSP equipment. CSP first transitions to SLEEP state and after that, if commanded from TM, to HIBERNATE. The power-down command may allow TM to specify the target state. If required, in addition to SLEEP and HYBRNATE, TM may have an option to request a complete shut-down of CSP servers.
UNKNOWN	TM may report status of CSP as UNKNOWN when connectivity with CSP.LMC is lost. CSP.LMC may report state of other sub-elements as UNKNOWN when connectivity is lost, but in such case, the overall CSP Operational State should be reported as FAILED; in other words, CSP.LMC should never report this Operational State on behalf of CSP.

3.3.2 Health Status Indicator

Health indicates availability of the CSP to produce output products, meta data and auxiliary data that accompanies output products. For entities that do not produce output products (e.g. CSP.LMC), Health status indicator describes the ability to perform the core functionality.

The CSP.LMC derives and reports the Health status as follows:

a) Overall CSP health indicator,
b) For each Sub-array,
c) For each Capability (each receptor-input and each PSS/PST/VLBI),
d) CSP.LMC Sub-element (overall),
e) Individual CSP.LMC components (LRUs, software processes).

CSP.LMC also reports heath on behalf of other CSP sub-elements (CBF, PSS and PST), and their components, as reported by other sub-elements.

Note: Although words used to describe Health Status are the same as those used to report CSP availability, the CSP reported Health Status should not be confused with the CSP availability. Health Status reports the status of CSP equipment and functionality as detected and perceived by CSP, while the actual availability is determined based on many more parameters and cannot be determined in real-time.

Table 3-4 Health Status Values

Health Status Indicator	Description
OK	CSP is READY, available for use and able to produce output products.
DEGRADED	CSP is partly available. For example, a sub-array Health is reported as DEGRADED when output products for IMAGING mode can be provided only for a sub-set of baselines (not for all baselines).
NOT-AVAILABLE	CSP is completely unavailable for observing. *If the CSP Operational State (see Section 3.3.1) of is not READY, Health must be reported as NOT-AVAILABLE.*

Example: A compute node that performs search and produces output (pulsar candidates) for a particular Pulsar Search beam is switched-off; consequently the Health for that beam is reported as NOT-AVAILABLE. The Health for the sub-array to which the failed beam belongs is reported as DEGRADED. (Unless the failed beam is the only PSS beam in the sub-array and the Observing Mode is Pulsar Search, in which case the sub-array Health is reported as NOT-AVAILABLE).

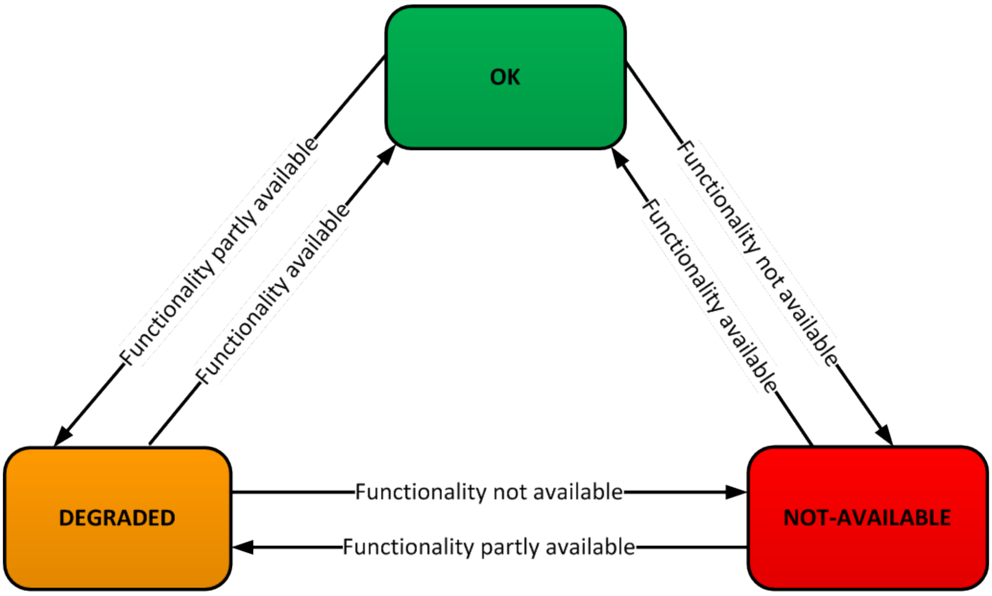


Figure 3-1 Health Status Transitions

3.3.3 Redundancy Status Indicator

To meet availability requirements, some of the CSP components provide hot or warm redundancy[5]. The entities that implement redundancy shall provide detailed documentation regarding the type of redundancy, transition mechanism, election mechanism (how does entity decide whether it is ACTIVE or STANDBY), etc.

Transition from ACTIVE to STANDBY usually occurs when the ACTIVE fails. In addition, user/maintainer, via Telescope Manager, may trigger the transition by temporarily disabling the ACTIVE entity (e.g. user via TM may request restart or reboot of the ACTIVE component).

Note: Operational State (Table 3-2) is reported both for the ACTIVE and STANDBY entity. An entity can report state as READY & ACTIVE or READY & STANDBY. In the latter case, READY means that the STANDBY is ready to take over if the ACTIVE fails.

Table 3-5 Redundancy Status Values

Redundancy Indicator	Description
ACTIVE	Component is active.
STANDBY	Component is providing backup capacity to be used when the ACTIVE fails.

[5] It is expect that CSP.LMC as a single point of failure will provide redundancy.

3.3.4 Usage Status Indicator

Usage State indicates whether CSP is used for observing (i.e. for its core functionality). It is to be determined whether the entities that are not directly involved in the observing shall report Usage Status Indicator (for instance, CSP.LMC is always used).

The CSP.LMC reports the Usage State for:

- CSP as a whole,
- Capabilities,
- CBF, PSS and PST sub-elements,
- Individual components (LRU, software and hardware components - granularity TBD based on the design and functionality provided).

Usage status for subarrays is reported via Observing Mode. If the Observing Mode is IDLE, subarray is not used, if Observing Mode is anything but IDLE, subarray is used.

Table 3-6 Usage Status Indicator

Usage Indicator	Description
USED	Entity is used (for observing).
IDLE	Entity is not used (for observing).

If the Usage Status is reported as USED, CSP.LMC also reports the list of sub-arrays that use the entity.

Status may be reported as USED even for a FAILED Element or Component to indicate that the failed equipment should be used for current observation(s).

Component or Capability that belongs to a non-IDLE sub-array may be IDLE if the current Observing Mode uses only a sub-set of equipment and Capabilities assigned to the sub-array.

3.3.5 Modes of Operation

CSP, CSP sub-elements and individual components implement various modes of operation that can be set by Telescope Manager, as requested by the operator or maintainer.

Not every entity implements all modes.

The following is the list of the modes of operation identified so far, that may be implemented by some CSP components/entities:

- Administrative mode – it is TBD whether CSP is required to make provision for TM to DISABLE/ENABLE CSP, CSP sub-elements and/or individual CSP components. Such command/parameter may be used to indicate that a component should not be used for observing (or other function) without shutting-down the component. Maintenance mode – some components may implement a special maintenance mode. If implemented MAINTENANCE mode may be defined as one of the ADMINISTRATIVE modes implemented by CSP. In the same manner as Test Modes, Maintenance Mode control should be implemented as additional commands and parameters and should not affect Operational State and Health reporting.

- Test mode – CSP_Mid.CBF implements test mode per sub-array that allows user/maintainer to turn on antenna signal emulators, so that signal processing may be performed in the absence of the input from antennas. This is just one example of the test mode implemented by CSP components. Some sub-elements and components may implement more than one test mode. Commands and controls for test modes should be implemented as additional commands and parameters, test mode indicator should be reported independently from the Operational State and Health reporting (i.e. Test Mode of operations should be perceived/reported as an operational state).
- Local vs remote control mode – some components may allow user/maintainer to set mode of operation where commands are accepted only from the CSP engineering interfaces (local) or only from the Telescope Manager (remote). If implemented, control of the local/remote control mode should be implemented as a read-write parameter. Setup and status of the control mode should be reported in addition to and independently from the Operational State and Health reporting. *It is to be defined (TBD) whether CSP is required to implement the Local Control Mode, i.e. is it a requirement that CSP.LMC implement the Local Control Mode on behalf of CSP. So far such need has not been identified within CSP itself. In the case that the Local Control Mode is required and supported the following has to be defined (TBD): Does CSP (and its sub-elements and components) when set in Local Control Mode continue to report status (alarms, logs, monitor points) and meta-data to TM.*
- Simulator mode – some components may implement mode of operation where they function as simulators. For CSP.LMC may implement simulator mode it responds to the commands without forwarding commands to the sub-elements. Other sub-elements may also implement similar functionality to allow for testing of the monitor and control functionality in the absence of the signal processing equipment. If implemented, control of the simulator mode should be implemented as a read-write parameter. Setup and status of the simulator mode should be reported in addition to and independently from the Operational State and Health reporting.

3.3.6 Sub-arrays

The following state indicators are reported for sub-arrays:

- Health (OK, DEGRADED, NON-AVAILABLE)
- Usage (USED, IDLE)
- Observing Mode – multiple Observing Modes can be simultaneously active in the same sub-array. (IMAGING, PULSAR-SEARCH, PULSAR-TIMING)

In addition to the health indicator, CSP.LMC reports the percentage of the output products that are being generated (or, if sub-array is IDLE, the percentage of the output products that sub-array would be able to generate for each observing mode).

For further consideration: At the beginning of a scan, during re-configuration not all components will start signal processing and output product generation at the same time. Although the Health is reported as OK, the output of a sub-array may be degraded (incomplete). Sub-array state reporting requires further work.

The same indicators (Health, Usage and Observing Modes) are reported for the CSP Capabilities (receptor-input and beams).

4 ASSUMPTIONS

ID	Category	Assumption	Retirement Date
1	Design Constraint		
1.1		Communication with Telescope Manager is via TANGO Controls framework.	Relevant SKA Standard Defined
1.2		Communication with all CSP sub-elements is via TANGO Controls framework.	Relevant SKA Standard Defined
2	Environmental Conditions		
3	Analysis & Calculation Methods		
4	Maintenance Constraints		
5	Access Constraints		

5 SUB-ELEMENT ARCHITECTURE DESCRIPTION

5.1 Sub-Element Overview

CSP.LMC is responsible for the overall monitor and control of the CSP including start-up, shut-down, state management, configuration, coordination of the sub-element functionality, upgrades and interfacing to the parent controller (Telescope Manager). CSP.LMC makes provision for Telescope Manager (TM) to monitor and control CSP as a single entity, using a single point of access in each telescope. CSP.LMC provides a level of abstraction to make provision for TM to execute observations without a need to be aware of the details of the CSP implementation. When needed, CSP.LMC makes provision for TM (via the same interface) to obtain status, configure and control individual CSP components. High-level, more abstract, view of the CSP is used during normal operations, to monitor overall status and conduct observations. More detailed views are used for engineering purposes, e.g. for commissioning, testing, troubleshooting, analysis and for experimental (non-standard) observing.

The complete list of the CSP.LMC requirements is provided in the document “SKA1 CSP LMC Requirement Specifications” [AD2].

Overall scope and purpose of the SKA1 element Local Monitor and Control, which applies to all the SKA1 Elements, is described in the document “SKA1 Element LMC Scope and Responsibilities” [RD13]. Standards and conventions to be followed by all the SKA1 Elements are defined in the document “SKA1 Element LMC Interface Guidelines” [RD14]. Note: the document [RD14] is work in progress; many aspects of monitor and control are still not well defined, therefore in many cases choices and concepts presented in this document are made by the author and are likely to change.

As defined in the CSP ADD [AD3], the responsibility for the CSP monitor and control is shared between the CSP.LMC sub-element, which is responsible for the interface with TM and overall CSP monitor and control, and other CSP sub-elements (CBF, PSS and PST) which are responsible for the internal sub-element monitor and control.

5.2 Architecture Overview

5.2.1 Functional Overview

1. CSP.LMC makes provision for TM to monitor overall CSP status and health. In order to report to TM overall CSP status, CSP.LMC monitors status of CSP sub-elements, including itself.

2. CSP.LMC monitors CSP hardware and software and provides meaningful and complete information regarding health, status and setup at all levels of CSP hierarchy (i.e. for the CSP Element, for each CSP sub-element and individual components). Relevant information is collected from other CSP sub-elements in order to report to TM.

3. CSP.LMC implements monitor points and reports their status to TM. Status of monitor points may be reported periodically and/or when a pre-defined threshold is crossed. The frequency of reporting and thresholds are configurable parameters.

4. CSP.LMC detects and reports to TM errors and faults, including threats to safety of equipment (e.g. overheating, power surges). CSP.LMC provides advice to TM on the severity and scope of reported errors and faults, and their impact on the quality of CSP output (i.e. observed data).

5. CSP.LMC implements and autonomously executes corrective actions where possible; suggest corrective actions when TM and/or human intervention is required. In many cases, automatic corrective actions are implemented by the CSP sub-element which reported the error or fault, however there may be cases where CSP.LMC intervention is necessary. CSP.LMC implements corrective actions for failures detected within the CSP.LMC itself.
6. CSP.LMC maintains a local log of detected errors, faults and events reported to TM and makes provision for TM to access, search and copy the last 200.000 logs (TBC).
7. CSP.LMC supports FMECA activities of TM, operators and engineers, by providing drill-down capabilities that conform to a defined consistent reporting structure to enable standardized drill-down and diagnostics capabilities (standards TBD).
8. CSP.LMC represents CSP functionality through Capabilities, i.e. provides a level of abstraction, so that TM can monitor and control observations (signal processing) without being aware of the details of the CSP implementation. CSP.LMC implements the following Capabilities: receptor-input, Pulsar Search beam, Pulsar Timing beam and VLBI beam.
9. CSP.LMC makes provision for TM to configure sub-arrays, set observing mode, start and stop processing of observed data in each sub-array independently, and to monitor and control parameters related to observing (signal processing) for each sub-array independently. CSP.LMC provides meaningful and complete information regarding health, status and setup of sub-arrays and Capabilities.
10. CSP.LMC makes provision for TM to command, via a single point of access, mode and state changes without being aware of the details of the CSP implementation. CSP.LMC implements internal command and coordination of CSP sub-elements required to execute TM commands. State changes include, but are not limited to, power-up and power-down of the CSP equipment; and reboot, reset and restart of individual components where applicable.
11. CSP.LMC makes provision for TM to configure CSP sub-elements, components, sub-arrays and Capabilities; CSP.LMC provides read-write access to all configurable parameters of the CSP Element, CSP sub-elements, components, sub-arrays and Capabilities.
12. CSP.LMC provides support for remote upgrade of the CSP software and firmware.

5.2.2 Implementation - Overview

CSP.LMC consists of software running on COTS computers. Open source framework TANGO Controls is used as infrastructure for development of CSP.LMC software.

Following TANGO approach, the CSP element, CSP sub-elements and major components are defined as TANGO devices. CSP.LMC implements at least two TANGO devices:

1. CSP - this TANGO device implements interface with TM, reports on behalf of the CSP Element as a whole and handles commands issued at CSP level (for example to power-down entire CSP, including all sub-elements).
2. CSP.LMC – this TANGO device implements CSP.LMC monitor and control and reports on behalf of the CSP.LMC sub-element.

It is to be defined (TBD) whether sub-arrays and even individual Capabilities will be implemented as TANGO devices.

Figure 5-1 shows proposed TANGO devices in CSP_Mid. The diagram for the CSP_Low would be similar, with a possible exception that CSP_Low.CBF does not use TANGO for communication among CSP_Low.CBF components.

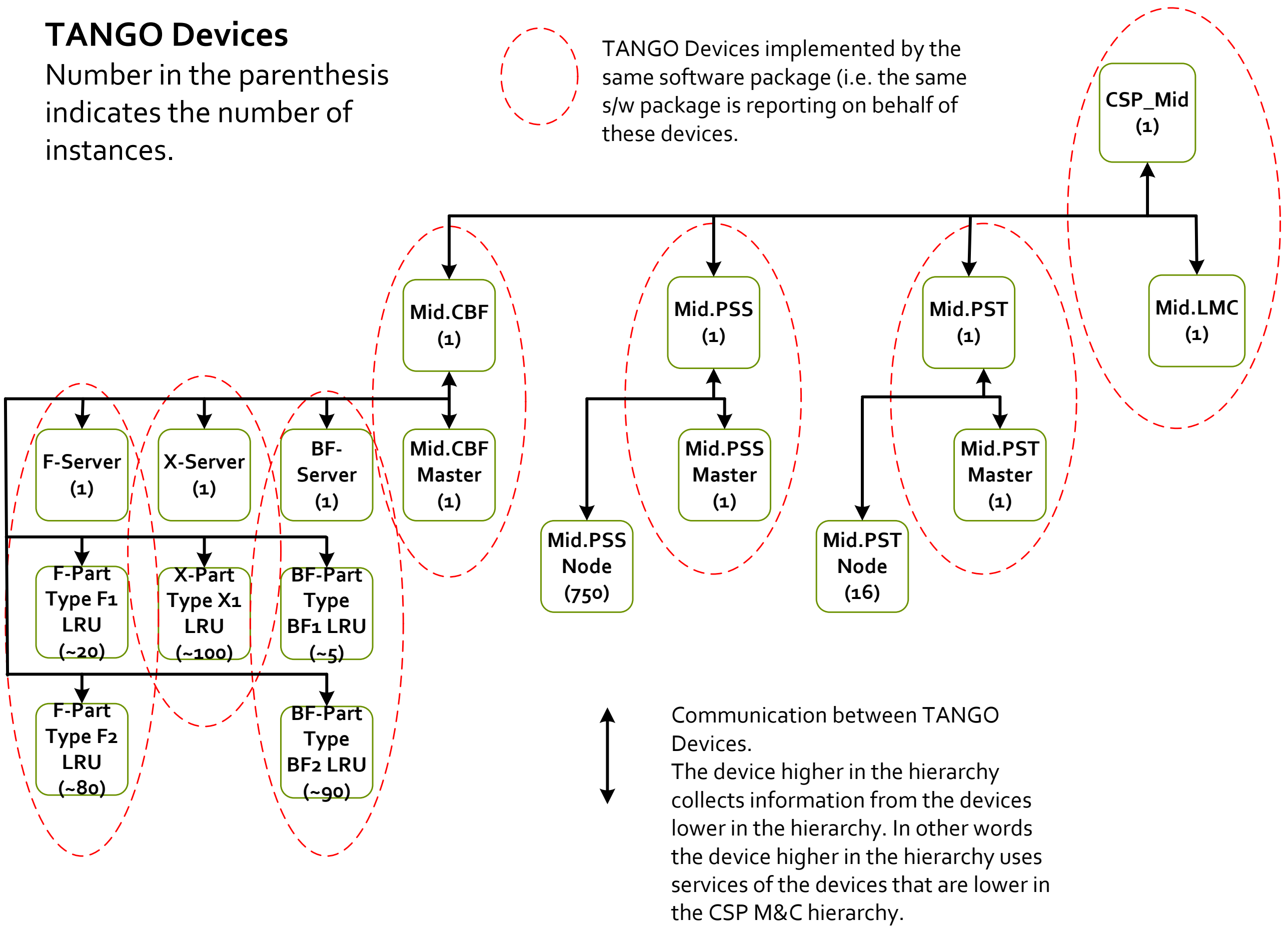


Figure 5-1 Overall view of the TANGO devices in CSP_Mid.

5.3 Sub-element First Level Static Decomposition

An instance of CSP.LMC sub-element exists in each SKA1 Telescope. The first level static decomposition of CSP.LMC is according to deployment in different telescopes, namely on CSP_Low.LMC and CSP_Mid.LMC.

In addition, a top level component CSP_Common.LMC has been defined as a placeholder for the components common to all CSP.LMC instances; as described in Table 5-1 on page 46, CSP_Common.LMC comprises the software packages developed by CSP.LMC team that implement functionality common to all CSP.LMC instances, which are used as a base for the development of telescope-specific software components.

Table 5-1 shows two levels of static decomposition. Brief description for the second level components is provided in Section 5.3.2 below.

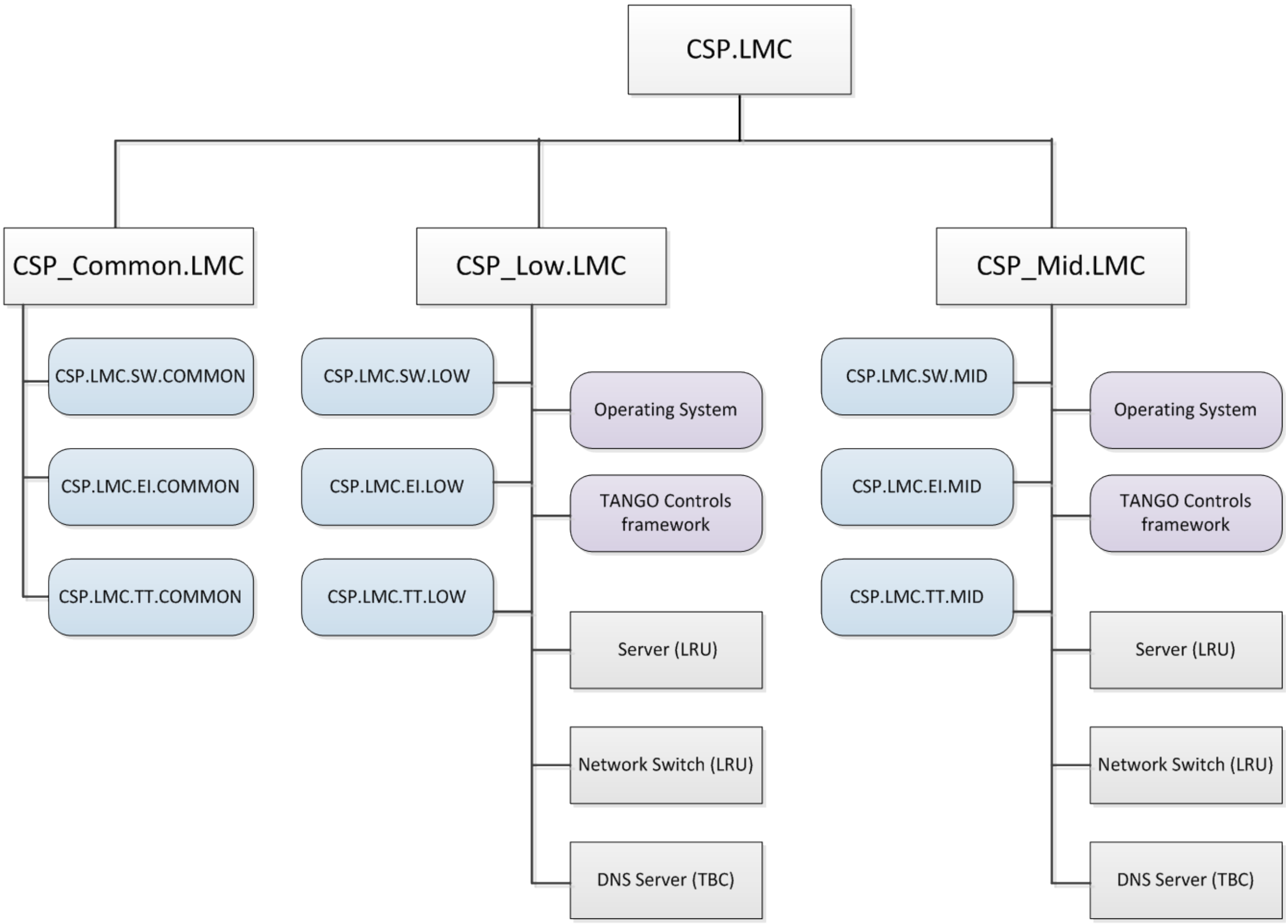


Figure 5-2 CSP.LMC - first and second level static decomposition

5.3.1 External Entities

Figure 5-3 shows entities CSP.LMC interfaces with.

SKA1 Element Telescope Manager (TM) is responsible for the overall monitor and control of the SKA1 Telescopes. There is an instance of TM in each SKA1 Telescope (SKA1-Low and SKA1-Mid). At last part of the TM equipment for each telescope is installed in the same facility where CSP is installed. TM provides user interfaces, so that operators and maintainers can operate the telescope from remote locations. All Human-Machine Interfaces are provided by TM, with exception of engineering interfaces built during construction and testing, that are provided by CSP.

SKA1 Element Signal and Data Transport (not shown in the diagram) provides a network connection for the interface with TM. SaDT provides physical, data link and network layer for the 10G Ethernet connection.

CSP sub-elements Correlator and Beamformer (CSP.CBF), Pulsar Search Engine (CSP.PSS) and Pulsar Timing Engine (CSP.PST) are described in the Sections 1.5.1.1 and 1.5.2.1.

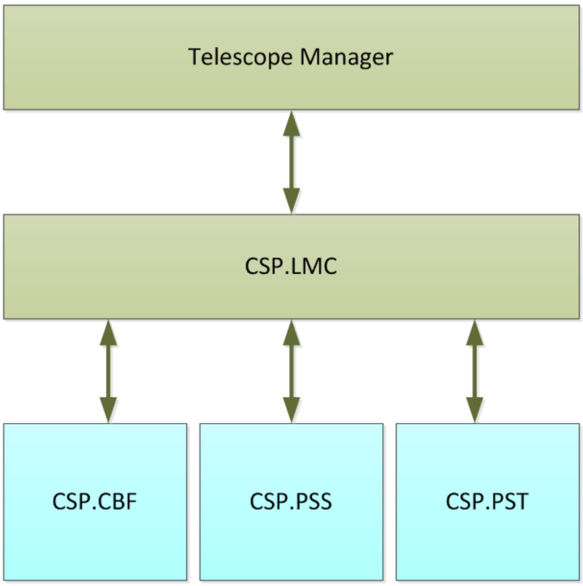


Figure 5-3 CSP.LMC External Interfaces

5.3.2 Top Level Components

Brief description of the CSP.LMC top level components is provided in Table 5-1, Table 5-2, and Table 5-3.

Table 5-1 Common CSP.LMC Top Level Components

	Component	Description
1	Software package CSP.LMC.SW.COMMON	The package CSP.LMC.SW.COMMON implements functionality common to both telescopes; which is virtually all the required CSP.LMC functionality. Most of the differences between the CSP_Low.LMC and CSP_Mid.LMC are in the observation specific functionality, for example: • Different receptors (stations vs dishes, number of receptors, frequency bands). • Some aspects of the CSP.CBF implementation are different in Low and Mid (although the functionality is almost the same). • CSP_Low does not implement VLBI beamforming. • Different number of Pulsar Search beams. To minimize work required to adapt common CSP.LMC software to LOW and MID, wherever possible, CSP.LMC.COMMON parametrizes the number of components and capabilities. Software package CSP.LMC.SW.COMMON is not deployed as is; this software package is used as a base for other CSP.LMC software packages.
2	Engineering interfaces CSP.LMC.EI.COMMON	Engineering interfaces developed by the CSP.LMC team for testing. Some or all of these interfaces will be integrated into the SKA1 engineering interface framework. In the same manner as CSP.LMC core software, common engineering interfaces are used as a base for development of engineering interface for CSP_Low.LMC and CSP_Mid.LMC.
3	Test tools CSP.LMC.TT.COMMON	Test tools used by CSP.LMC team for development, verification and acceptance testing. This includes simulators for the entities CSP.LMC interfaces with. . In the same manner as CSP.LMC core software, common test tools are used as a base for development of test tools for CSP_Low.LMC and CSP_Mid.LMC.

Table 5-2 CSP_Low.LMC Top Level Components

	Component	Description
1	CSP_Low.LMC server	COTS server. General purpose rack mounted server (dual redundancy).This is a server running CSP.LMC software.
2	Operating system	General purpose operating system. CSP.LMC will use the SKA standard flavour of LINUX.
3	Communication framework	TANGO Controls. TANGO Control System has been selected as the monitor and control framework to be used for interface between TM and other SKA Elements, including CSP. As defined in [AD8], TANGO is used for communication between CSP.LMC and other CSP sub-elements. TANGO uses CORBA and ZeroMQ as communication infrastructure. TANGO is not a just communication protocol, TANGO is a monitor and control framework, i.e. it provides a framework for implementation of the monitor and control functionality. Prototyping and investigations are still under way, it is still to be defined what aspects of the TANGO approach and functionality will be adopted and incorporated in the CSP and the SKA telescopes in general.
4	Software package CSP.LMC.SW.LOW	CSP.LMC.SW.LOW is based on CSP.LMC.SW.COMMON. Functionality provided by CSP.LMC.SW.COMMON is modified and augmented, as needed, to meet CSP_Low.LMC requirements. For example number of stations, input bandwidth, number of PSS beams, details of CSP_Low.CBF implementation, etc.
5	Engineering interfaces CSP.LMC.EI.LOW	Engineering interfaces developed by the CSP.LMC team and used for development testing, verification and commissioning. Some or all of these interfaces will be integrated into the SKA1 engineering interface framework and used by maintainers for diagnostics. Most CSP.LMC.LOW engineering interfaces are based on the software package CSP.LMC.EI.COMMON.
6	Test tools CSP.LMC.TT.LOW	Test tools used by CSP.LMC team for development, verification and acceptance testing. This includes simulators for the entities CSP_Low.LMC interfaces with. These test tools are mostly based on the software package CSP.LMC.TT.COMMON.
7.	Network switch	COTS Ethernet Switch.
8.	Domain Name Server	It is TBD whether CSP.LMC is responsible for the Domain Name Server used by CSP for name resolution, and does that include TANGO name resolution. This would be a COTS server, probably same as the main CSP_Low.LMC server.

Table 5-3 CSP_Mid.LMC Top Level Components

	Component	Description
1	CSP_Mid.LMC server	COTS server. General purpose rack mounted server (dual redundancy).This is a server running CSP_Mid.LMC software.
2	Operating system	General purpose operating system. CSP_Mid.LMC will use the SKA standard flavour of LINUX.
3	Communication framework	TANGO Controls. TANGO Control System is used for interface between TM and other SKA Elements, including CSP. As defined in [AD8], TANGO is used for communication between CSP_Mid.LMC and other CSP_Mid sub-elements. TANGO uses CORBA and ZeroMQ as communication infrastructure. TANGO is not a just communication protocol, TANGO is a monitor and control framework, i.e. it provides a framework for implementation of the monitor and control functionality. Prototyping and investigations are still under way, it is still to be defined what aspects of the TANGO approach and functionality will be adopted and incorporated in the CSP_Mid and the SKA telescopes in general.
4	Software package CSP.LMC.SW.MID	CSP.LMC.SW.MID is based on CSP.LMC.SW.COMMON. Functionality provided by CSP.LMC.COMMON is modified and augmented, as needed, to meet CSP_Mid.LMC requirements. For example: number and type of receptors (dishes), input bands, number of PSS beams, details of CSP_MID.CBF implementation, etc. Also, CSP_Mid implements VLBI beamforming.
5	Engineering interfaces CSP.LMC.EI.MID	Engineering interfaces developed by the CSP_Mid.LMC team and used for development testing, verification and commissioning. Some or all of these interfaces will be integrated into the SKA1 engineering interface framework and used by maintainers for diagnostics. Most CSP.LMC.MID engineering interfaces are based on the software package CSP.LMC.EI.COMMON.
6	Test tools CSP.LMC.TT.MID	Test tools used by CSP_Mid.LMC team for development, verification and acceptance testing. This includes simulators for the entities CSP_Mid.LMC interfaces with. Most of these test tools are based on the software package CSP.LMC.TT.COMMON.
7.	Network switch	COTS Ethernet Switch.
8.	Domain Name Server	It is TBD whether CSP_Low.LMC is responsible for the Domain Name Server used by CSP_Low for name resolution, including TANGO name resolution. This would be a COTS server, probably the same as the main CSP_Mid.LMC server.

5.3.3 External Interfaces

Table 5-4 CSP.LMC External Interfaces

Entity	Type	Interface Control Document
Telescope Manager (TM)	SKA1 Element	[AD4] and [AD5]
Signal and Data Transport	SKA1 Element	[AD9] and [AD10]
CSP Correlator and Beamformer (CSP.CBF)	CSP sub-element	[AD8]
CSP Pulsar Search Engine (CSP.PSS)	CSP sub-element	[AD8]
CSP Pulsar Timing Engine (CSP.PSS)	CSP sub-element	[AD8]

SKA1 Element Signal and Data Transport (SaDT) provides physical, data link and network layer for the 10 G Ethernet connection between CSP and TM.

Interface between TM and CSP.LMC is data exchange interface; TM and CSP.LMC exchange hi-level messages. As defined in [AD4] and [AD5] flow of information between TM and CSP.LMC is asymmetric:

1. TM originates commands.
2. CSP.LMC executes TM commands and responds to TM as required.
3. CSP.LMC reports errors, failures and events that require TM and operator attention (alarms and events).
4. CSP.LMC reports status of monitor points, periodically or when a change is detected.

Interface between CSP.LMC and other CSP sub-elements (CBF, PSS and PST) is data exchange interface; CSP.LMC and other CSP sub-elements exchange hi-level messages. As defined in [AD8] flow of information between CSP.LMC and CBF, PSS and PST is asymmetric:

1. CSP.LMC originates commands.
2. CSP.CBF, CSP.PSS and CSP.PST execute CSP.LMC commands and respond to CSP.LMC as required.
3. CSP sub-elements report status and events that require CSP.LMC, TM and/or operator attention (as alarms and events).
4. CSP sub-elements report status of monitor points, periodically or when a change is detected.
5. CSP sub-element collects and sends to TM auxiliary data to be stored and/or used by Science Data Processor and/or for off-line data processing.

5.3.4 Internal Interfaces

Internal interfaces will be described in the future releases of this document.

5.4 Hardware / Mechanical Components

CSP.LMC consists of the custom developed software running on the general purpose rack mounted COTS computers. The model is yet to be selected.

CSP.LMC provides an Ethernet switch to which SaDT connects in order to provide 10G network connection for interface with TM. Other CSP sub-elements connect to the same switch.

5.5 Firmware Components

CSP LMC consists of software running on the general purpose rack mounted COTS computers, firmware development is not required.

5.6 Software Components

Software packages CSP.LMC.SW.COMMON, CSP.LMC.SW.LOW and CSP.LMC.SW.MID consist of the same components, listed in50. All components listed in Table 5-5 exist in all three software packages: CSP.LMC.SW.COMMON, CSP.LMC.SW.LOW and CSP.LMC.SW.MID.

More details will be provided in the future releases of this document.

Table 5-5 Software Package CSP.LMC.SW Design Components

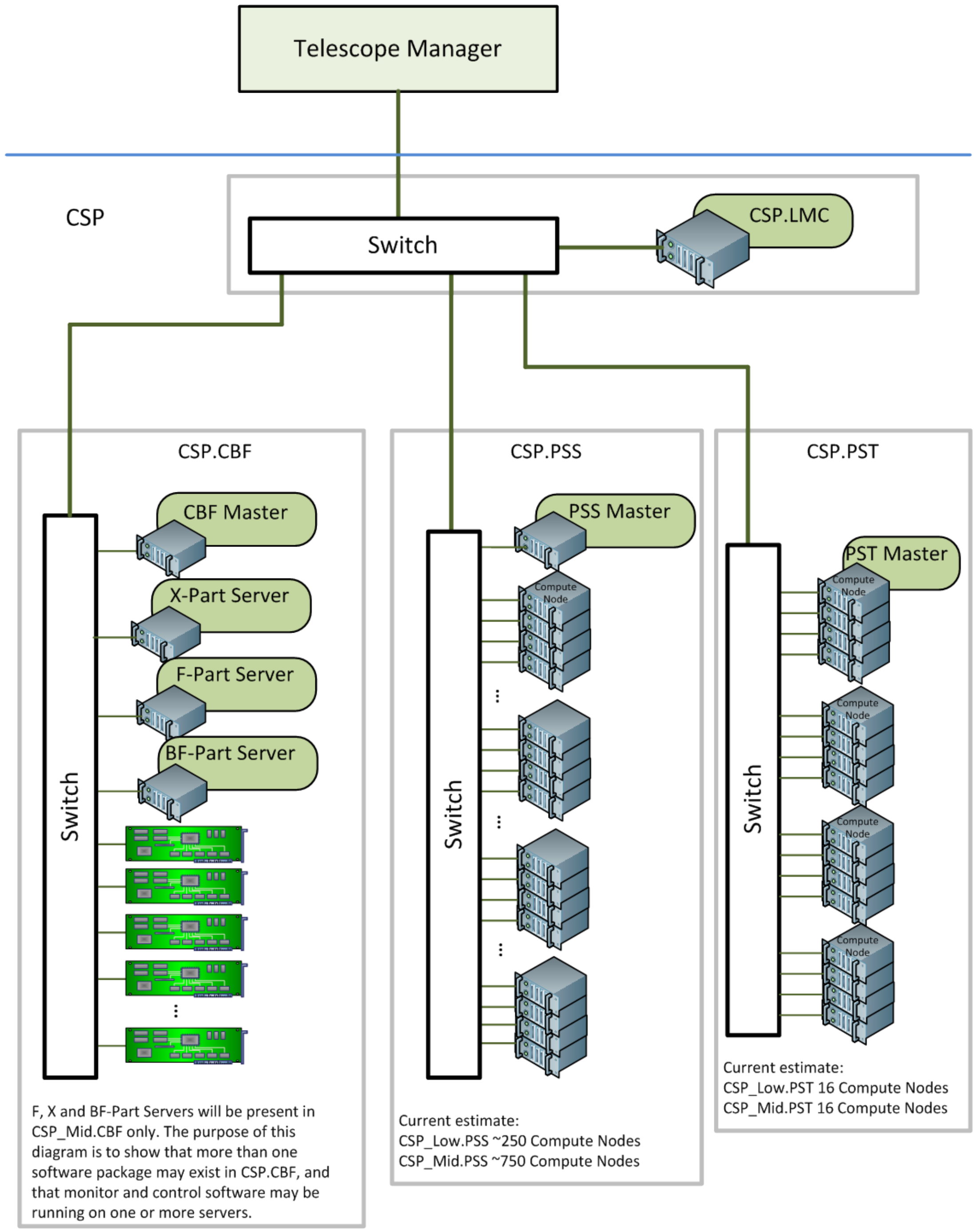
Component	Description
CSP Monitor and Control	This component maintains overall CSP status, configuration of sub-arrays and allocation of Capabilities, performs mapping of TM commands to command for individual CSP sub-elements, and maintains the model of the CSP instantiation, implements interface with TM and with other CSP sub-elements. It is implemented as a TANGO Server comprising one or more TANGO Devices that implement interface with TM and overall CSP monitor and control. This component maintains overall CSP status and handles CSP alarms, events and other messages received from the CSP sub-elements. Includes: - TM command handler – which handles TM commands including mode changes, setup, state transitions and queries. This includes handling of the Activation Queue (queue of scheduled commands waiting to be executed). - Sub-array Handler – possibly implemented as TANGO Device (one or each sub-array). - Capability Handler - possibly implemented as TANGO Devices. - TANGO Clients that communicate with CSP sub-elements. - CSP Monitor(monitors status of all sub-elements, sub-array and components and derives overall CSP status) - CSP Alarm Handler.

Component	Description
CSP.LMC Monitor and Control	TANGO Server comprising one or more TANGO Devices that implement CSP.LMC monitor and control, maintains CSP.LMC status, handles TM commands and queries, and alarms, events and other messages received from CSP.LMC components.
CSP.LMC Log Handler	Maintains the CSP Log File and provides access to the CSP Log File.
CSP.LMC Watchdog	Monitors of the CSP.LMC processes and restart the process if failure is detected. Also responsible for CSP.LMC start-up (launch of CSP.LMC software and other software processes).
CSP.LMC Redundancy Handler	Monitors status of the ‘mate’, handles state transitions.

6 PHYSICAL VIEW

Figure 6-1 is a conceptual representation of the CSP equipment, monitor and control software and network. Colour green is used to show monitor and control software and network connections. Internal implementation for other CSP sub-elements is provided to increase understanding of the overall architecture. Although all devices are connected to the same monitor and control network, software is implemented so that communication is hierarchical, as shown in Figure 6-1.

Figure 6-1 Hi-level overview of the CSP monitor and control implementation



7 DYNAMIC VIEW

To be provided in the next release,

8 SCENARIOS

8.1 CSP.LMC Related Scenarios

- CSP.LMC start-up
- CSP.LMC shut-down
- Monitoring and reporting CSP.LMC status
- Monitoring and reporting CSP.LMC monitor points
- State transitions (requested by TM).
- CSP.LMC error reporting.
- CSP.LMC failover to redundant server.
- CSP.LMC software upgrade

8.2 CSP Related Scenarios

- CSP start-up
- CSP power-down
- Other TM requested CSP state transitions (to HIBERNATE, READY, SLEEP, SHUT-DOWN)
- Monitoring and reporting CSP status
- CSP error reporting
- CSP software upgrades
- CSP firmware upgrades
  Handling TM configuration commands

8.3 Sub-array Related Scenarios

- Sub-array configuration (add/remove receptors, add/remove beams).
- Sub-array configuration - change bands (MID only)
- Sub-array Observing Mode Imaging: configure, start scan, execute scan, end scan
- Sub-array Observing Mode Pulsar Search: configure, start scan, execute scan, end scan
- Sub-array Observing Mode Pulsar Timing: configure, start scan, execute scan, end scan
- Sub-array Observing Mode VLBI beamforming: configure, start scan, execute scan, end scan

9 DESIGN DECISIONS

D.1. CSP.LMC consists of custom made software, open source software packages (see D.2), operating system (TBD flavour of LINUX), running on commercial off-the-shelf (COTS) computers.

D.2. TANGO Controls framework is used for communication with TM. This decision has been made at the project level. All SKA1 Elements use TANGO for communication with TM. TANGO is not just a communication platform, TANGO is a framework that provides overall approach and support for monitor and control functionality. Prototyping is still under way and it is yet to be defined to what extent TANGO design approach will be incorporated by CSP.

D.3. CSP.LMC communicates with a single entity within each CSP sub-element (CBF, PSS and PST); this entity is referred to as the Sub-element Master. Each Sub-element Master reports on behalf of the sub-element. CSP.LMC sends all commands destined for a sub-element to the Sub-element Master. This is design decision made at CSP Element level (Level 2) and is document in the CSP ADD [AD3].

D.4. TANGO Controls framework is used for communication between CSP.LMC and other CSP sub-elements (CBF, PSS and PST), as documented in internal ICD [AD8].

D.5. TM, CSP.LMC, the Sub-element Masters are connected to the same network. It is to be confirmed whether all CSP components that implement monitor and control functionality are connected to the same monitor and control network (in other words is internal sub-element monitor and control network isolated from CSP.LMC).

D.6. CSP.LMC server has a single network interface (and communicates with TM and CSP sub-elements via the same monitor and control network).

D.7. It is assumed that to meet the high availability requirements, dual-redundancy has to be provided for the CSP.LMC server. Each of the two servers runs an instance of the CSP.LMC software. At any time one instance of the LMC software is ‘active’ and the other ‘standby’. A so-called, ‘warm’ redundancy is provided; standby is up and running, bit not aware of the current sub-array configuration, i.e. Observing Modes and such.

D.8. In each telescope CSP consists of a large number of components; to minimize delays in execution of commands CSP makes provision for TM to send time-dependent commands in advance, so that commands and configuration changes can be distributed to affected CSP components in advance and executed simultaneously by all components.

D.9. CSP.LMC implements a queue of scheduled commands that are waiting to be executed (Activation Queue). CSP.LMC has capacity to keep a large number of scheduled commands in the Activation Queue, and is able to handle commands received out of chronological order.

Prototyping and design are still in progress, many design decisions still have to be made, for example:

a. Is CSP implemented as a single TANGO facility or is each CSP sub-element implemented as a TANGO facility. The latter may be practical during construction and testing, so that each sub-element can be run as an independent facility. Pros and cons have still to be considered. Perhaps the decision can be postponed, as it seems that TANGO facilities can be easily reconfigured, as needed. Further prototyping and design effort is required.

b. Are all CSP components that implement monitor and control functionality connected to the same (monitor and control) network? An advantage of such configuration would be that all components (TANGO devices) would be able to send alarms and monitor points to the same repository.
c. Logging system has to be selected.

10 PERFORMANCE

It is a requirement that CSP.LMC should be able to forward a command received from TM to CSP sub-elements (as appropriate) in 5 seconds. The current estimate is that CSP.LMC will be able to meet this requirement. Note: This requirement applies for commands that should be immediately executed, when a command with the Activation Time more than 60 seconds (TBC) in the future, CSP.LMC may decide to delay forwarding of the command.

CSP implements the Activation Queue, i.e. a queue of scheduled commands waiting to be executed. CSP.LMC has capacity to keep a large number of scheduled commands in the Activation Queue, and is able to handle commands received out of chronological order; however, TM and users/operators should be aware that the number of messages in the queue can impact CSP.LMC performance. TM design should take this in consideration and transmit configuration requests as needed. For example, a massive configuration requests should be sent to CSP in advance so that CSP has enough time to prepare for re-configuration (guidelines will be provided). However, the queue should be kept relatively short, as inserting newly received configuration in the Activation Queue may require re-processing of previously received configurations (if configuration is received out of chronological order). Therefore, the number of future configurations held in the CSP.LMC Activation Queue per sub-array should be kept low.

CSP.LMC generates alarms as follows:

a) When an error or fault is detected by CSP.LMC itself. In such case an alarm message is generated and transmitted within 3 seconds of the event which led to the alarm (SKA1-CSP-LMC_REQ-2312-00-01).
b) When an alarm is generated by other CSP sub-element and CSP.LMC has to forward alarm to TM. It is a requirement that, in such case, latency from the receipt of an alarm generated by other CSP sub-element to transmission is no more than 1 second (CSP-ASS-OPS-014-00-LMC-00). Overall approach to alarm handling within CSP is still to be defined, but early estimates are that CSP.LMC will be able to meet this requirement.

Note: Overall approach to implementation of monitor and control in SKA telescopes is still to be defined. If the decision is made that all CSP components send alarms to the same (TANGO) data base, latency requirements many be redefined to include data base access.

11 RELIABILITY, AVAILABILITY AND MAINTAINABILITY

11.1 Reliability

The relevant reliability drivers and approaches are listed below.

The CSP.LMC environment:

1. Temperature: High temperatures impose severe stress on electronic components and cause progressive deterioration of reliability. The CSP Facilities in Australia and South Africa will provide adequate cooling to the CSP racks and the rack cooling design will maintain the temperature of the CSP.LMC LRUs within an acceptable operating range.
2. Shock and vibration: Shock and vibration during transportation and installation reduce reliability of electronics. The CSP.LMC LRUs will be shipped in transport cases to protect them from the shock and vibration in transit. Installation instructions will be provided to installers to ensure that the LRUs aren't exposed to undue shock and vibration.
3. Dust: A dust build-up on electronics reduces the effectiveness of equipment cooling which then reduces equipment reliability. The CSP Facilities in Australia and South Africa will provide a dust free environment to prevent a build-up of dust.
4. Humidity: High levels of humidity increases the rate of moisture penetration and potentially corrodes materials such as lead, copper and zinc alloys. The CSP Facilities in Australia and South Africa will provide environment with a low level of humidity (< 20% relative humidity).
5. EMI: Electromagnetic effects such as electrostatic discharge (ESD) and power transients negatively impact the reliability of electronics. The CSP Facilities in Australia and South Africa will provide uninterrupted high quality power (i.e., damaging power effects such as transients will be removed and will protect the CBF from excessive and harmful EMI. The CBF design will protect the electronics from potentially damaging ESD, EMI and limited power related effects.

The CSP.LMC design:

1. Provides redundancy for higher system reliability where practical.
2. COTS hardware will be selected to meet the reliability requirements.
3. CSP.LMC software is designed to intercept and gracefully handle software exceptions.
4. CSP.LMC watchdog process periodically checks that all LMC processes are running and re-starts the failed process as needed.

11.2 Availability and Maintainability

Availability denotes the ability of a system to be kept in a functioning state. Maintainability is determined by the ease at which the product or system can be repaired or maintained.

CSP.LMC provides dual redundancy for the CSP.LMC servers, so that a standby can immediately take over when the active server fails.

Redundancy for CSP.LMC provided network switch will be considered. A cold spare may be provided so that it can be replaced if the active one fails.

In the case of a complete CSP.LMC failure, on-site staff will be required to investigate and fix the problem. This may include replacement of the failed equipment and/or restart of the network switch and/or server. CSP.LMC hardware consists of rack mounted equipment.

12 SAFETY

Safety denotes the risk for harming people, the environment, or any other assets during a system's life cycle.

CSP equipment consists of COTS computers and digital hardware; safety concerns are related to power surges and overheating of the CSP equipment. Each CSP sub-element implements voltage and temperature sensors and implement protection mechanisms to ensure safety of own equipment. CSP.LMC is not responsible for safety of CSP equipment.

CSP_Mid.LMC servers are COTS equipment, specifications related to safety will be provided by the manufacturer (TBD).

12.1 Environmental Safety

CSP.LMC equipment does not contain not emit any toxic substances.

12.2 Personal Safety

Rack stability - When racks fall over due to human or seismic induced forces, they may cause human injury or death and destruction of equipment. CSP.LMC equipment is placed in racks provided by CSP_Low.CBF and CSP_Mid.CBF. Rack stability is addressed by the CSP sub-elements that provide rack space for CSP.LMC.

Airflow and fan noise - Airflow and fan audible noise generated by CSP.LMC will not exceed the safety standards for continual exposure (>85 dB at 1m for longer than 8h). However, CSP.LMC will be located in the CSP Facilities where overall noise may exceed safety standards. Maintenance personal, and other personal installing or handling CSP.LMC equipment should wear ear protection. CSP.LMC does not require human presence, except for the CSP.LMC installation and maintenance.

Weight - CSP.LMC LRUs weighing more than 15 kg are fitted with clearly visible permanent label “warning lifting hazard”. CSP.LMC LRU’s with a mass of more than 15kg and less than 40kg have carrying handles and indicate that two persons are required to lift it. CSP.LMC LRUs with a mass of more than 40 kg will have an integral lifting arrangement such as eye-bolts so that a lifting gear can be used to transport it.

CSP.LMC LRUs will be designed to eliminate sharp (edge radii less than 2 microns) edges, access openings and corners. Protection covers or coatings will be applied if sharp edges are unavoidable in the design.

Laser light - CSP.LMC LRUs which contain laser diode or laser generating items which present a high risk of human optical damage will be fitted with permanent durable warning labels and automatic shutters wherever possible.

During CBF installation, verification, operation and maintenance, Personal Protective Equipment (PPE) need to be used and safety procedures followed to reduce possible risk of personnel safety.

12.3 Electrical Safety

CSP.LMC uses COTS equipment. CSP.LMC COTS equipment will be designed, installed and certified in accordance with the Australian and South African standard for the IT equipment, as applicable or with equivalent regulations, codes and standards.

12.4 Asset Protection

CSP.LMC equipment safety concerns are related to overheating and power consumption surges.

All CSP equipment is equipped to detect overheating and autonomously shut down when overheating is detected.

CSP.LMC is not responsible for safety of other CSP equipment, with exception of the following scenarios:

1. CSP.LMC implements gradual power-up and power-down of CSP equipment (to prevent power surges). Most likely, the each CSP sub-element will implement gradual power-up and power-down of its own equipment, CSP.LMC will be responsible for coordination (sequencing) of the power-up and power-down CSP sub-elements (and for coordination of other state or mode transitions that result in significant increase or decrease of power consumption).
2. In the case of the prolonged loss of communication with Telescope Manager, CSP.LMC commands gradual transition to low-power mode of all CSP sub-elements. Exact definition of the phrase ‘prolonged period’ is TBD.

13 ENVIRONMENTAL

CSP.LMC uses COTS equipment, environmental impact and instructions for decommissioning will be provided by the manufacturer.

CSP.LMC consists of commodity off-the-shelf hardware. No specialized transportation, storage facilities, or packaging material will be required. The purchase, transport, and storage of the servers and any spare parts (such as replacement disks) will make use of readily available systems that have already been developed for the commercial market.

14 DEVELOPMENT SUPPORT

14.1 Development Plan

- Development plan is specified in the document "SKA-1 CSP Local Monitor and Control Sub-element Development Plan" [RD3].

14.2 Design for Integration and Testing

The following design aspects have been added to support integration and testing:

- Engineering Interfaces for all custom developed CSP.LMC software components are provided to allow for status monitoring and diagnostics from any computer/location authorized to access the CSP monitor and control network.
- CSP.LMC maintains a local logging file and makes provision for TM to display (read) and search content.
- CSP.LMC makes provision for TM to set logging level and to enable/disable logging of messages received and transmitted on LMC interfaces.
- CSP.LMC implements parameters that enable TM to monitor LMC status (set of parameters TBD).

LMC content of the log records and logging levels as conform to SKA standards (TBD).

14.3 Verification Plan

Verification procedures are described in SKA-1 CSP Local Monitor and Control Sub-element Test Specification [RD2].

14.4 Test and Integration Plan

All aspects of testing and integration at sub-element level are addressed in the following documents:

- "SKA-1 CSP Local Monitor and Control Sub-element Test Specification" [RD2] and
- "SKA-1 CSP Local Monitor and Control Sub-element Development Plan" [RD3].

CSP Element integration plan is provided in "SKA CSP Assembly, Integration and Test Plan" [RD6].

15 PRODUCTION AND MANUFACTURING

CSP.LMC uses COTS equipment; production and manufacturing are not required.

16 SYSTEM COMMISSIONING

Commissioning Plan for the CSP Element is provided in SKA CSP Element Commissioning, Operation and Maintenance Plan [RD7].

17 INTEGRATED LOGISTIC SUPPORT

Plan for the Integrated Logistics Support for CSP Element is specified in SKA CSP Element Logistic Engineering Management Plan [RD8].

CSP.LMC consists of commodity off-the-shelf hardware. No specialized transportation, storage facilities, or packaging material will be required. The purchase, transport, and storage of the servers and any spare parts (such as replacement disks) will make use of readily available systems that have already been developed for the commercial market.

CSP Local Monitor and Control Sub-element Life Cycle Cost analysis (development, operation, maintenance, training, spares) is provided in SKA CSP Local Monitor and Control Sub-element Development and Operational Cost [RD4].

RAMS (Reliability, Availability, Maintainability, and Safety) analysis will be performed during detail design phase, the results will be documented in Chapter 11.Requirements derived from RAMS analysis related to Integrated Logistic Support will be document here.

A APPENDIX: REQUIREMENTS AND DESIGN TRACEABILITY MATRIX

Requirements and design traceability matrix is provided in the document SKA1 LMC Requirements Specification [AD2].

B APPENDIX: INTERNAL INTERFACE CONTROL DOCUMENT

TBD

B1 Heading 8

B1.1 Heading 9

C APPENDIX: DEVELOPMENT PLAN (HARDWARE AND/OR SOFTWARE DEVELOPMENT PLAN)

C1 Heading 8

C1.1 Heading 9

D APPENDIX: ASSEMBLY, INTEGRATION AND TEST PLAN

D1 Heading 8

D1.1 Heading 9

E APPENDIX: MANUFACTURING PLAN

Not applicable.

F APPENDIX: INTELLECTUAL PROPERTY DECLARATION

This document does not contain IP.

F1 Organisation A

F1.1 Background IP Declaration

F1.2 Foreground IP Declaration Justification for IP

G APPENDIX

G1 Heading 8

G1.1 Heading 9

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