SKA CSP Pulsar Search LMC Detailed Design Document

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LIST OF ACRONYMS AND ABBREVIATIONS

ADD	Architecture Design Document
AIV	Assembly, Integration and Verification
CBF	Correlator and Beam Former
CDR	Critical Design Review
CIDL	Configuration Item Data List
CISPR22	CISPR standard for Information Technology Equipment-Radio Disturbance Characteristics-Limits and Methods of Measurement
CM	Configuration Management
COTS	Commercial Off-The-Shelf
CSP	Central Signal Processor Element or Consortium
DDD	Detailed Design Document
DLC	Direct Liquid Cooling
DM	Dispersion Measure
DSP	Digital Signal Processing
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interface
FDAS	Fourier Domain Accelerations Search
FFT	Fast Fourier Transformation
FIR	Finite Impulse Response
FLDO	Folding and Optimisation Function
FMECA	Failure Modes, Effects and Criticality Analysis
FOP	Filter Output Plane
FPGA	Field Programmable Gate Array
FTA	Fault Tree Analysis
GPU	General Processing Unit
HDL	High Level Design Language
ICD	Interface Control Document
ILS	Integrated Logistic Support
INAF	National Institute for Astrophysics
INFRA	Infrastructure Element or Consortium
IP	Intellectual Property or Internet Protocol
LMC	Local Monitor and Control
LRU	Line Replaceable Unit
MATLAB	MATLAB simulation language and application
MTTR	Mean Time To Repair
NIP	Non-Imaging Processor

OPS	Operations Per Second
PDR	Preliminary Design Review
PSS	Pulsar Search Sub-element
QA	Quality Assurance
RAM(S)	Reliability, Availability, Maintainability (and Safety)
RFI	Radio Frequency Interference
SADT	Signal and Data Transport Element or Consortium
SCL	Sifted Candidate List
SDP	Science Data Processor
SKA	Square Kilometer Array
SKAO	SKA Organisation (or office)
SOW	Statement of Work
SPS	Single Pulse Search
TCP	Transmission Control Protocol
TDR	Time Domain Resampling
TDT	Time Domain Team
UDP	User Datagram Protocol

1 INTRODUCTION

1.1 Purpose of Document

The purpose of this document is to describe the Detailed Design for the SKA Phase 1 CSP Pulsar Search Sub-element LMC (PSS.LMC), with a solution that applies to both SKA Phase 1 Mid (CSP_Mid) and SKA Phase 1 Low (CSP_Low) as defined in the SKA1 CSP Element Statement of Work (SOW) [AD1]. In this document we present the Arcetri contribution to the **SKA CSP Pulsar Search Detailed Design Document** along with some general presentation (Author A.Kastergiou and the SKA TDT Team).

1.2 Telescope Overview

See CSP Architecture Design Document [AD4].

1.3 CSP Element Overview

See CSP Architecture Design Document [AD4].

2 APPLICABLE AND REFERENCE DOCUMENTS

2.1 Applicable Documents

The following documents influence the content of this document and therefore take precedent.

Table 1: Applicable Documents

Ref No	Document/Drawing Number	Document Title	Issue Number
AD1	SKA-TEL-CSP-0000159	SKA1 CSP Element Statement of Work	5
AD2	313-000000-001	SKA1 CSP Mid Pulsar Search Sub-element Requirement Specifications (ED-1a)	3
AD3	113-000000-009	SKA1 CSP Low Pulsar Search Sub-element Requirement Specifications (ED-1b)	2
AD4	SKA-TEL-CSP-0000014	SKA1 CSP Element Architecture Design Document (SE-5)	4
AD5	311-000000-009	SKA1 CSP Mid Correlator and Beamformer to Mid PSS Interface Control Document (SE-7c)	3
AD6	111-000000-009	SKA1 CSP Low Correlator and Beamformer to Mid PSS Interface Control Document (SE-7f)	3
AD7	300-000000-020	SKA1 MID CSP to INFRA SA Interface Control Document	2
AD8	100-000000-020	SKA1 LOW CSP to Infrastructure Australia Interface Control Document	2
AD9	100-000000-002	SKA1 Low SDP - CSP Interface Control Document	4
AD10	300-000000-002	SKA1 Mid SDP - CSP Interface Control Document	4
AD11	100-000000-023	Interface Control Document CSP to SADT Low	2
AD12	300-000000-023	Interface Control Document CSP to SADT Mid	2
AD13	SKA-TEL-CSP-0000019	SKA1 CSP.LMC to CSP Sub-elements Interface Control Document (SE-7b)	5
AD14	SKA-TEL-CSP-0000102	SKA1 CSP Local Monitoring and Control Sub-element Detailed Design Document (EG-2a)	2
AD15	SKA-TEL-CSP-0000163	SKA CSP Element EMI/EMC Control Plan (SE-42)	2
AD16	SKA-TEL-CSP-PSS_0000016	PSS Product Breakdown Structure (contained in SKA-TEL-CSP-0000242, AD36)	1
AD17	SKA-TEL-CSP-PSS_0000017	PSS RAM Analysis (contained in SKA-TEL-CSP-0000242, AD36)	1
AD18	113-000000-011	Low PSS Logistics Data	1
AD19	313-000000-011	Mid PSS Logistics Data	1
AD20	SKA-TEL-CSP-PSS_0000001	A study of DDTR on FPGA platforms (contained in SKA-TEL-CSP-0000242, AD36)	1
AD21	SKA-TEL-CSP-PSS_0000002	A study of SPDT on FPGA platforms (contained in SKA-TEL-CSP-0000242, AD36)	1

AD22	SKA-TEL-CSP-PSS_0000003	A study on FPGA platforms (contained in SKA-TEL-CSP-0000242, AD36)	1
AD23	SKA-TEL-CSP-PSS_0000004	A study of PSS Data Flow for FPGA processing (contained in SKA-TEL-CSP-0000242, AD36)	1
AD24	SKA-TEL-CSP-PSS_0000005	Effect of ambient temperatures on FPGAs (contained in SKA-TEL-CSP-0000242, AD36)	1
AD25	SKA-TEL-CSP-PSS_0000006	A study of FPGA Capacity Estimation for FFT (contained in SKA-TEL-CSP-0000242, AD36)	1
AD26	SKA-TEL-CSP-PSS_0000007	Plan for MID PSS FDAS FT Convolution (contained in SKA-TEL-CSP-0000242, AD36)	1
AD27	SKA-TEL-CSP-PSS_0000008	Plan for MID PSS FDAS Harmonic Summing Module (contained in SKA-TEL-CSP-0000242, AD36)	1
AD28	SKA-TEL-CSP-PSS_0000009	Plan for MID PSS Median Filtering Module (contained in SKA-TEL-CSP-0000242, AD36)	1
AD29	SKA-TEL-CSP-PSS_0000010	A study of FDAS Template Matching on FPGA platforms (contained in SKA-TEL-CSP-0000242, AD36)	1
AD30	SKA-TEL-CSP-PSS_0000011	A study of CXFT on OpenCL FPGA platforms (contained in SKA-TEL-CSP-0000242, AD36)	1
AD31	SKA-TEL-CSP-PSS_0000012	A study of Power Measurements on Prototype Hardware (contained in SKA-TEL-CSP-0000242, AD36)	1
AD32	SKA-TEL-CSP-PSS_0000013	FDAS Requirements and Architecture (contained in SKA-TEL-CSP-0000242, AD36)	1
AD33	SKA-TEL-CSP-PSS_0000014	FLDO Requirements and Architecture (contained in SKA-TEL-CSP-0000242, AD36)	1
AD34	SKA-TEL-CSP-PSS_0000023	Prototype Test Report for the GPU Single Pulse Search Pipeline (contained in SKA-TEL-CSP-0000242, AD36)	1
AD35	SKA-TEL-CSP-PSS_0000025	Prototype Test Report for the GPU FDAS pipeline (contained in SKA-TEL-CSP-0000242, AD36)	1
AD36	SKA-TEL-CSP-0000242	SKA1 CSP Pulsar Search Sub-element Work-in-Progress Support Files	1
AD37	SKA-TEL-CSP-0000247	SKA1 CSP Pulsar Search Sub-element Work-in-progress Document List	1

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 their date and/or revision number do not make this document out of date.

Table 2: Reference Documents

Ref No	Document/Drawing Number	Document Title	Issue Number
RD1	SKA-TEL-CSP-0000085	SKA1 CSP Pulsar Search Sub-element Signal Processing MATLAB Model (ED-7)	4
RD2	111-000000-003		1

		SKA1 CSP Low Correlator and Beamformer Sub-element Detailed Design Document (EA-4a)	
RD3	311-000000-003	SKA1 CSP Mid Correlator and Beamformer Sub-element Detailed Design Document (EB-4a)	1
RD4		André Offringa et al: post-correlation radio frequency interference classification methods, Monthly Notices of the Royal Astronomical Society, Vol 405:1, 2010.	
RD5		André Offringa et al.: A morphological algorithm for improving radio-frequency interference detection Astronomy & Astrophysics, Volume 539, Issue A95, March 2012.	
RD6		Ransom, S. M., Eikenberry, S. S., & Middleditch, J. 2002, Fourier Techniques for Very Long Astrophysical Time-Series Analysis", AJ, 124, 1788 (Section 2).	
RD7		Camilo et al., 2000, ApJ, 535, 975C.	
RD8		Middleditch & Kristian, 1984, ApJ, 279, 157	3
RD9		Knispel PhD Thesis, 2011, Leibniz Universität	
RD10		Sigproc software package: http://sigproc.sourceforge.net	
RD11		Eatough 2009, PhD Thesis, The University of Manchester.	
RD12		Andrew Faulkner, PhD Thesis, University of Manchester, 2004	
RD13		George Hobbs, PhD Thesis, University of Manchester, 2002	
RD14	SKA-TEL-CSP-0000237	SKA1 CSP Pulsar Search Sub-element Construction Capex and Opex Costing (PM-7a10)	1
RD15	SKA-TEL-CSP-0000083	SKA1 CSP Pulsar Search Sub-element Development Plan (ED-5)	2
RD16	113-000000-003	SKA1 CSP Low Pulsar Search Sub-element Test Specification (ED-3a)	1
RD17	313-000000-003	SKA1 CSP Mid Pulsar Search Sub-element Test Specification (ED-3b)	1
RD18	SKA-TEL-CSP-0000116	SKA1 CSP Pulsar Search Sub-element Prototype Plan and Test Report (Proto-PS)	3
RD19	SKA-TEL-SKO-0000661	Fundamental SKA Software and Hardware Description Language Standards	2
RD20	113-000000-011	SKA1 CSP Low Pulsar Search Sub-element Logistics Data (SE-20a3)	1
RD21	313-000000-011	SKA1 CSP Mid Pulsar Search Sub-element Logistics Data (SE-20b3)	1
RD22	SKA-TEL-SKO-0000202	SKA EMI/EMC Standards and Procedures	3
RD23		Adamek. K. and Armour, W., 2016, A Real-time Single Pulse Detection Algortihm for GPUs, ArXiv 1611.09704	
RD24		Lyon, R. J. “SKA-TestVectorGenerationPipeline”, https://github.com/scienceguyrob/SKA-TestVectorGenerationPipeline .	
RD25		Lorimer, D.R., D'Amico, N., Lyne, A.G., Seiradakis, J.H., Athanasopoulos, A., Camilo, F., Jessner, A., Kramer, M., Wielebinski, R., Xilouris, K.M., “The European Pulsar Network Pulse Profile Database”, Joint European and National Astronomical Meeting, JENAM-97. 6th European and 3rd Hellenic Astronomical Conference, held in Thessaloniki, Greece, 2-5 July, 1997.	
RD26		Keith, M. J., “The EPN database of pulsar profiles”, http://www.epta.eu.org/epndb/ .	

RD27		Docker, https://www.docker.com.	
RD28		Lyon, R. J., “scienceguyrob/docker”, https://hub.docker.com/r/scienceguyrob/docker/ .	
RD29		Hobbs, G., Edwards, R., Manchester, R., “*Tempo2: a New Pulsar Timing Package*”, Chinese Journal of Astronomy and Astrophysics, vol. 6, S2, 2006.	
RD30		Hobbs, G., Edwards, R., Manchester, R., “Tempo2”, http://www.atnf.csiro.au/research/pulsar/tempo2/	
RD31		ATNF Pulsar Catalog: http://www.atnf.csiro.au/people/pulsar/psrcat/ .	
RD32		PRESTO software package: http://www.cv.nrao.edu/~sransom/presto/	
RD33	000-000000-010	SKA1 Control System Guidelines	
RD34		The TANGO Control System Manual	9.2

3 ARCHITECTURE DESCRIPTION

The Pulsar Search Sub-element is a non-imaging, signal-processing subsystem of the CSP, designed to discover new radio pulsars and time-domain, fast radio transients. It comprises high performance COTS computational hardware hosting highly specialised bespoke software. The PSS is designed as a cluster of 500 and 167 compute nodes for Mid and Low, respectively. Each cluster includes compute accelerators, more specifically Graphics Processing Units (GPU) and Field Programmable Gate Arrays (FPGA), to provide optimum computing performance. High speed Ethernet interconnects between the Mid and Low Correlator and Beamformers, CBF.MID and LOW, and the PSS compute nodes, as described in the CBF.MID and LOW PSS Interface Control Documents [AD5 and AD6] respectively, support the real-time data throughput requirements. Each PSS node is designed to carry out all the functionality of pulsar search signal processing of up to three tied array beams coming from the beamformer.

3.1 PSS context

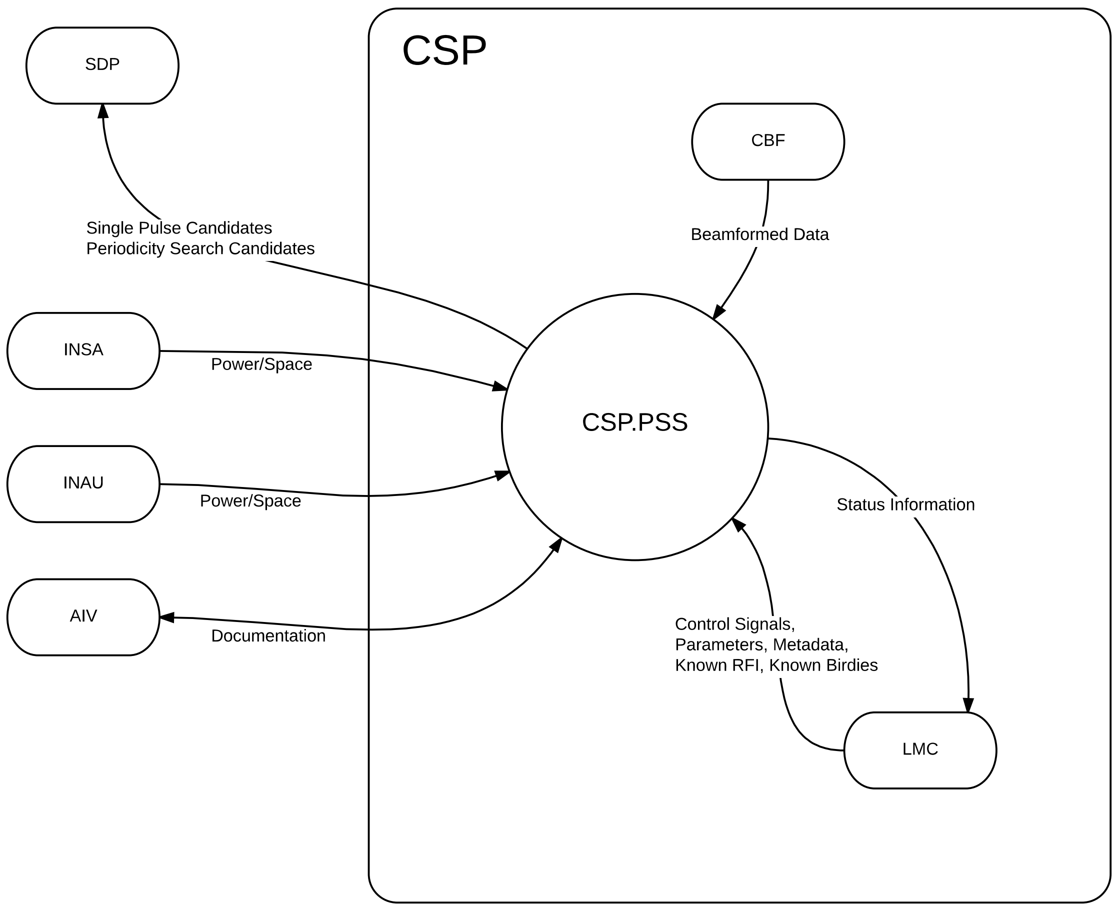

Figure 1: Context diagram for PSS showing item flows

Figure 1 shows the context of the PSS. SDP is the SKA Science Data Processor. SDP receives the output data products from PSS, via SADT, Signal and Data Transport.

LMC is CSP Local Monitor and Control. LMC provides control parameters and metadata and receives monitoring data.

CBF is the CSP Correlator and Beamformer as defined by SKA1 CSP Low and Mid Correlator and Beamformer Sub-element Detailed Design Documents [RD2 and RD3]; CBF provides beamformed data for searching.

INAU and INSA refer to the SKA Infrastructure elements for the two telescope sites (Australia and South Africa) and AIV refers to element / sub-element Assembly, Integration and Verification.

3.2 Design Considerations

The primary, overriding, requirement of the system is to achieve the requisite data processing in real-time. All modules will be configurable to achieve the real-time requirement also on limited subsets of the parameter space as defined in the requirements. By nature of the software and hardware architecture design, it is easy expand to the full range as better algorithms and technologies become available.

3.3 Solution Summary

Given the statement of the problem and the design considerations above, we are proposing the following structure for PSS.

The hardware architecture consists of (Mid=500, Low=167) COTS built computer nodes, to process (MID=1500, LOW=500) tied array beams generated from the MID and LOW arrays, in whichever way these are formed (e.g. including MeerKAT dishes, different sub-arrays). In terms of hardware, the PSS also consists of network switches, one control node for each of MID and LOW, and racks within which the cluster is hosted.

The design presented here takes up (MID=33, LOW=11) standard HPC racks, and operates within an envelope of (MID=318, LOW=110) kW of power (Section 20).

Each of our nodes consists of host CPUs and accelerator hardware (FPGAs, GPUs). Each node is responsible for the full processing of a number of tied array beams. Each node is connected to a single Master node which serves to start, stop and monitor the cluster and is the gateway to the CSP.LMC. The purpose of the cluster is to massively reduce the volume of data coming from the beamformer. The input data from CBF.MID are detected data products (Stokes parameters) while those from CBF.LOW are complex frequency channels which are subsequently detected by PSS. The output data are candidates for pulsars and fast transients, as well as associated metadata.

3.4 External Interfaces to the PSS

3.4.1 The PSS-CBF interface

The PSS-CBF interface is described within the Mid and Low PSS-CBF ICDs [AD5 and AD6 respectively]. In summary, CBF generates network streams of beamformed data. Each PSS node receives a total of 3 beamformed data streams from CBF. The data from MID are powers (no phase information), full polarization and channelized time series data and added metadata as described in Mid PSS-CBF ICD [AD5]. The data from LOW are voltage data, dual polarization time series and associated metadata as described in Low PSS-CBF ICD [AD6].

On the PSS side, the PSS-CBF interfaces are realised by the data receptor software module running within the PSS common pipeline on each processing node. The module for each of MID and LOW has information on the interface to properly interpret the data and metadata.

3.4.2 The PSS-SDP and PSS-SaDT interfaces

The PSS-SDP interface, as defined by AD9 and AD10 for Low and Mid respectively, connects the output of the PSS pipelines to SDP. In summary, PSS generates two types of candidates, single pulses from the single pulse sub-pipeline, and pulsars from the pulsar search sub-pipeline. The candidates, including data and metadata, are handled by this interface.

Physically, the interface will be realised by the output modules of the PSS pipelines and the PSS network on the PSS side. The physical layer of the output interface is between PSS and SaDT, described in detail in the Mid and Low PSS-SaDT ICDs [AD11 and AD12 respectively].
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3.4.3 The LMC PSS-CSP interface

The LMC interface connects the CSP.LMC to the PSS-LMC as described in the SKA1 CSP.LMC to CSP Sub-elements Interface Control Document [AD13]. In summary, the CSP.LMC communicates only with the PSS MASTER (or simply MASTER) component for all monitoring and control purposes.

3.4.4 Internal Interfaces

All internal interfaces are software interfaces, which are described in Section 4.1.

4 VIEW OF SOFTWARE AND FIRMWARE COMPONENTS

This Section contains a description of the PSS software and firmware.

4.1 Data Processing Software

4.1.1 Gross Pipeline View

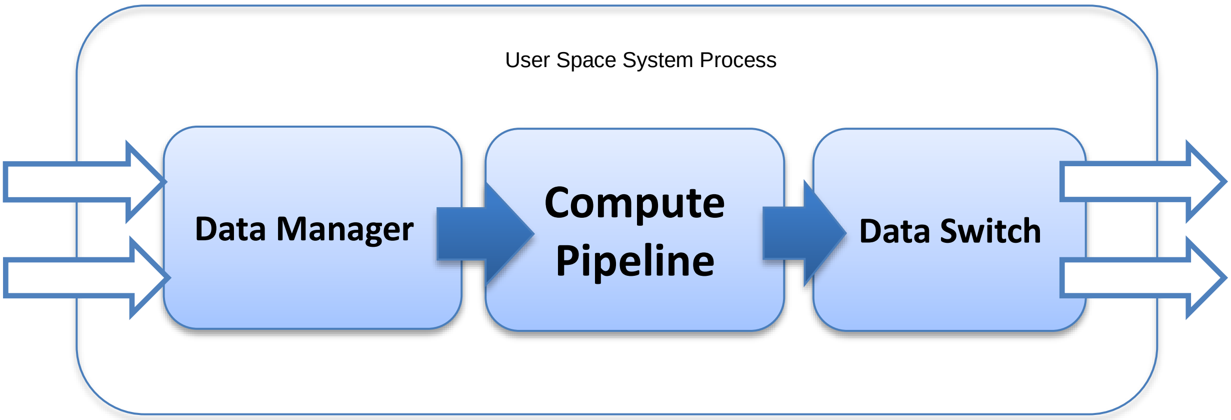

Figure 2: Gross Data Flow through a Pipeline Process

Figure 2 shows data flowing through the pipeline process. Outline arrows represent all input and output data products, while filled in arrows represent data flowing through the pipeline.

4.1.2 Element Catalogue

4.1.2.1 The Pipeline Process

The elements in

Figure 2, all exist in a single CPU based user process (an executable). The arrows show the progression of data through the process. Empty arrows represent data sinks or sources that ultimately connect to resources outside of the process.

This executable will have options and configuration parameters received from CSP.LMC, and these are assumed, unless otherwise stated, to be static. That is to say they are set at the beginning of the process via a configuration file, and a restart of the process is required should these options or parameters change.

4.1.2.2 Monitor and Control System

The pipeline is configured and launched by a Monitoring and Control system, the PSS-LMC (section 4.2), to which it will also report status and error conditions via the default LMC syslog logging system.

4.1.2.3 The Data Chunks

Data chunks are the data structures used by the pipeline to describe and pass data between the various elements. Each type of data is associated with its own class, and interfaces between modules are configured to accept only appropriate types of data. They are passed between modules as either references or pointers to avoid unnecessary copy operations.

4.1.2.4 The Data Manager and Data Producers

This module provides an interface for the ingest of data from external data streams. A module that handles any particular data stream is called a Producer, and its role is to fill the data chunks provided by the Data Manager. The Data Manager also defines an interface for accessing and locking data chunks, to ensure they do not go out of scope whilst it is still in use by other downstream modules in the pipeline.

4.1.2.5 Compute Pipeline

This represents a collection of modules that actually perform the data processing (See following subsections for details)

4.1.2.6 The Data Switch and Data Sinks

These provide a data export interface for the compute pipeline. The actual data sink to be used shall be configurable by the LMC. In normal operation this will be the Candidate data output streamer sink, but in other modes may be saved to a local file rather than processing via a sink, or directed to some local monitoring tool. The data switch, responsible for sending data to a sink, shall not exclude the possibility of sending data to more than one data sink.

4.2 Monitoring and Control System

The Telescope Manager interacts with the PSS via the CSP.LMC system. Its role is to ensure the correct start up/shut down of PSS systems and processing pipelines as well as passing status information, setting and confirming parameter changes, etc.

The PSS-LMC consists of two software components: MASTER (Section 4.3.2) and CTRL (Section 4.3.1). The MASTER is responsible for communicating to the other nodes via a CTRL process daemon running on every other PSS node.

The document "SKA1 Control System and Guidelines" [RD33] defines the TANGO Control System (TANGO CS) [RD34] as the framework for implementation of monitor and control functionality in the SKA1 Telescopes. The document [RD33] recommends the implementation of TANGO API for CSP internal components, to provide a seamless access to all components for monitoring, archiving and control. The PSS Local Monitor and Control System is based on the TANGO Controls framework, the communication between CSP.LMC and MASTER and between MASTER and CTRL components is via TANGO API.

Main monitor and control functionalities, as well as hardware and part of software components of the PSS sub-element are modelled by means of TANGO Devices. To be accessible to any TANGO Client, PSS TANGO Devices and related TANGO Servers register with a TANGO Facility Database that for CSP Sub-elements is implemented by the CSP.LMC: each CSP instance (Mid and Low) implements its own TANGO Facility Database. Any TANGO Device registered with a TANGO Facility is univocally identified by its TANGO Fully Qualified Domain Name (FQDN). SKA nomenclature standard is defined in RD33.

4.3 Software Components

Below is a list of software modules that provide the software functionality of the PSS. Combinations of these modules that make up the most computationally expensive parts of the PSS software and their specific implementations are described in DDD document's Appendices. Data objects passed between modules contain, in general, both data and metadata (the latter being true even when not explicitly stated).

1. RCPT - Receptor of Beam Formed Data
2. DMGR – The Data Manager Software Component
3. DSWT – The Data Switch for Exporting Data
4. DDBC - Dedispersion buffer creator
5. RFIM - Radio frequency interference mitigation component description
6. FFBC - Full filterbank buffer creator component description
7. DDTR - Dedispersion transform component description
8. PSBC - Periodicity search buffer creator component description
9. CXFT - Complex Fourier transform component description
10. BRDZ - “Birdie” zapping to remove known RFI
11. DRED - Spectrum Dereddening
12. iCXFT - Inverse Complex Fourier transform component description
13. TDRT - Time domain resampler transform component description
14. PWFT - Fourier transform and power spectrum component description
15. HRMS - Harmonic summing component description
16. TDAO - Time domain spectral peak detection and candidate list output component description
17. SIFT - Candidate Sifting Component Description
18. FLDO - Folding and Optimization of Final Candidates Component Description
19. CTRL - Control Monitoring Component Description
20. CDOS - Candidate data output streamer component description
21. FDAS - Fourier domain acceleration search and harmonic matching component description
22. FDAO - Optimisation and output of Fourier domain accelerations search crude candidate list component description
23. SPDT - Single Pulse Detector
24. SPSIFT - Candidate Single Pulse Sifting Component Description
25. SPOPT - Single Pulse Optimiser
26. MASTER - LMC Interface node software

4.3.1 CTRL – Pipeline Control and Monitoring Component Description

4.3.1.1 Component identifier

The Control, Monitoring and Master-node interface component will take the component ID CSP-NIP-PSS-DDD-CTRL.

4.3.1.2 Type

The CTRL is a software module which runs in each PSS node. While integrated with the data analysis pipeline, CTRL is not formally a pipeline internal module. CTRL is a TANGO Device, derived from the abstract SKA TANGO Device (see SKA Control System Guidelines [RD33]) implementation that will be provided by the SKAO during construction. The TANGO Device names registered into the TANGO database (see section 4.2) is CTRL_XX_YYZ, where XX identifies the rack where the current node resides, YY is the node number inside the rack, and Z is a letter identifying the pipeline.

Figure 3 shows the control and monitoring of processing pipelines for one of the PSS node:

- Oval figures represent TANGO Devices performing configuration, monitor and control functions for signal processing. The component with bold outline is not involved in these operation and is reported only for completeness, to show the organization of TANGO Devices inside a PSS node.
- Green lines with arrows represent the flow of monitored data, going from the producer devices to the upper monitor control entities.
- Blue dashed lines represent the flow of configuring and control commands, coming from CSP.LMC via the MASTER and dispatched by the Rack component to the target CTRL modules (MASTER module is described in section 4.3.2).
- Blue bold lines show the *shell commands* executed by CTRL modules to spawn a Cheetah pipeline.
- The bold white lines show the flow of output data produced by each Cheetah pipeline and collected by each CTRL module.

4.3.1.3 Purpose

The CTRL performs the control and monitoring of a Pulsar Search processing pipeline. The CTRL module is implemented as a TANGO Device: on each PSS node three instances of the CTRL TANGO Device run concurrently, one for each implemented pipeline. The CTRL module receives commands and configuration parameters for the processing pipeline module from MASTER which, in turn, receives them from TM via CSP.LMC. Via the same interface the CTRL returns a small amount of data (mainly processing and data statistics useful for QA) produced by the RFIM, BDRZ, DRED and CDOS pipeline modules.

4.3.1.4 Function

The main CTRL module functions are configuration, control and monitoring of the processing pipeline.

The CTRL TANGO Device supports the configuration and control of the associated processing pipeline exposing a set of commands (methods) and attributes that allows MASTER to configure and control each pipeline independently.

The operational parameters are TANGO attributes received during scan configuration as a table in JSON format. They are supplied to Cheetah pipeline as arguments at pipeline start-up and, on request, they are available by means of the LMC infrastructure. Table 4 gives the current version of the table structure.

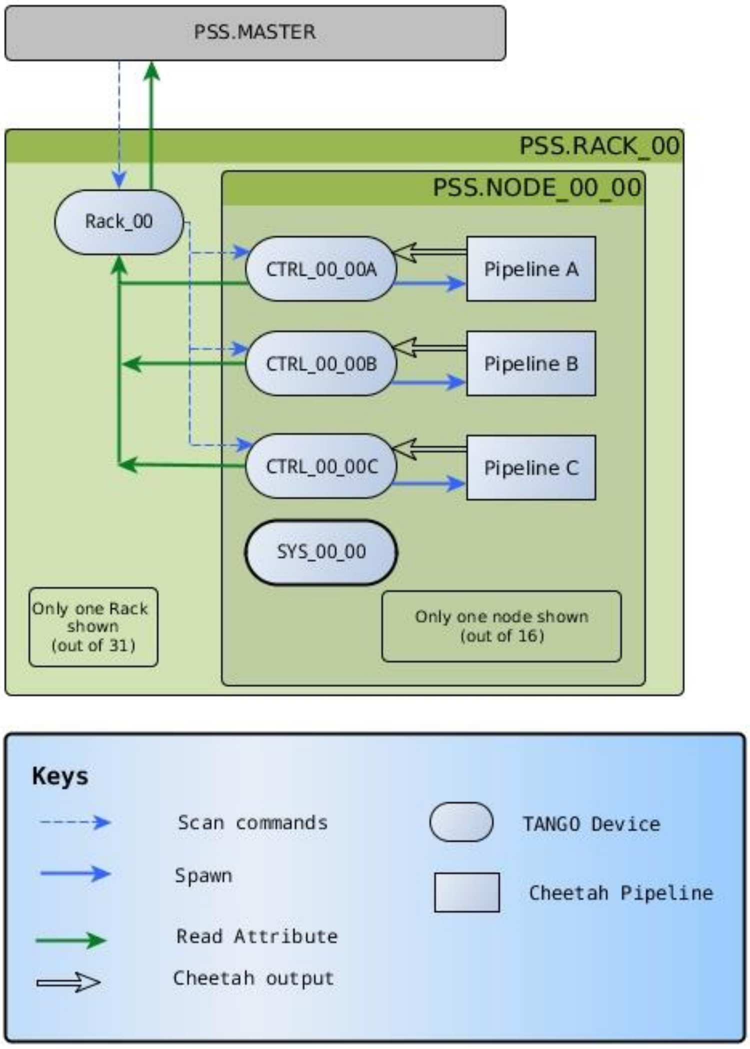

Figure 3: CTRL pipeline process control and monitoring (MID version)

Some permanent reference tables (listed in Table 3) are also accessible by means of the same interface. The data to be transferred back to the MASTER are stored in a separate space.

The CTRL receives commands and configuration parameters for PSS signal processing from the MASTER via the Rack TANGO Device shown in Figure 3 and described in section 4.3.2.4. These commands relate to the configuration, start, pause, resume and stop of the computing pipeline. On request, the CTRL reports the status and other pipeline information.

During signal processing, CTRL collects the statistics generated by specific modules (RFIM, BDRZ, DRED, CDOS), the Cheetah framework working status, warnings, errors and the advancement progress report from the Cheetah output.

The CTRL module implements the monitoring of the Cheetah pipeline reading its log output and storing pipeline information in local TANGO attributes. The PSS components responsible for monitoring the CTRL subscribes the attributes to get regular updates or updates on attribute change. The upper level monitoring components can also request the current value of a set of attributes using the TANGO built-in command read_attributes().

The CTRL module signals unexpected or worrisome events or situations to the PSS Alarm Handling module (see 4.3.2.4) which is in charge to handle such events. Based on a events-actions matrix the Alarm Handling module, running on the PSS Master node, will take appropriate actions, as raising or dropping alarms, calling the operator or proceeding to an emergency shutdown (see Table 7).

4.3.1.5 Subordinates

The CTRL has no subordinates.

4.3.1.6 Dependencies

The CTRL starts at the node boot and will remain active until shut-down.

4.3.1.7 Interfaces

CTRL shall receive configuration parameters and commands via the interface described in the CSP.LMC internal ICD [AD13]. Parameters and configuration data, stored locally in a table, are, accessible by all framework modules.

The start and stop of the computing framework will be implemented by means of *spawning* of shell command scripts. Those operations imply the need for CTRL to run under root privilege or to have access to “setuid” scripts.

4.3.1.8 Resources

CTRL implements a set of TANGO attributes to store the configuration parameters, the physical telemetry and the statistical output of the framework data processing. Table 4 summarizes configuration parameters.

CTRL stores and makes accessible to the framework modules some permanent information, detailed in Table 3. These information are updated by TM and/or SDP as appropriate.

Table 3: Permanent Reference Data

Table	Type	Size	R / RW	Updated by
-Known pulsars	Name / position / period	Now 2x10^3 Up to 10^5 rows	R/W	TM / SDP
-Long term RFI	Direction / frequencies table	10^3	R/W	TM/LMC
-Short term RFI	Direction frequencies table Time active	10^4	R/W	TM/LMC
-Satellite positions	Instantaneous position or Orbital Parameters	10^4 / (now 7000)	R	TM
-BRDZ list	Direction / frequencies table / Time active / Number of harmonics	< 10^5 rows	R/W	TM/SDP

Table 4 summarizes the parameters and permanent tables needed by each module, and the information that some modules send back to the CTRL module.

Table 4: CTRL Pulsar Search Observing Mode Parameters

CSP_PSS Parameter	CTRL Name	Type	Range	Modules
Sub-array ID	sub_array_id	ASCII String	0-16	All
Action	action	ASCII String	Set	All
Activation Time	activation_time	Date & time	UTC	All
Duration	duration	Integer	0-2100s	All
Scan ID	scan_id	Integer	64-bit	All
Observing Mode	observing_mode	ASCII String	Pulsar and/or Single pulse	All
Pointing Name	pointing_name	ASCII String	Ascii string	All
Pointing coordinates	pointing_coord	ASCII String	Astronomical Coordinates	CDOS
Specified for each sub-array				
Beam BW	beam_bw	Double	96 MHz LOW, 300MHz MID	FLDO, RCPT
Number of bits per sample	bit_per_sample	Integer	1-32	FLDO, RCPT
Acceleration Search	accel_search	Boolean	Enable Disable	CTRL, Cheetah
Single Pulse Search	single_p_search	Boolean	Enable Disable	CTRL, Cheetah
Integration time	integration_time	Double	Up to 1,800 seconds	FLDO, RCPT, Cheetah

Acceleration Range	accel_range	Double	+/-350 m/s^2 Default=0	FDAS, TDAS
Number of Trials	trials_number	Integer	0-Maxint (band dependent)	FDAS, TDAS
Time Resolution	time_resolution	Double	50-800 µs (2n * 50 µs)	FLDO, RCPT
Dispersion Measure	disp_measure	Double	0-3000 pc cm-3	DRED, FDAS, TDAS, DTR
SPS_Dispersion Measure	sps_disp_measure	Double	0-3000 pc cm-3	DRED, SIFT, SPD
Number of Frequency Channels	freq_channels	Integer	1000-8192	All
Time Sample per Block	num_samples	Unsigned long	Up to (integration time) / (time resolution)	All
Sub-bands	sub_bands	Integer	Up to 64	FLDO,
Input Buffer Size	input_size	Integer	2^18-2^24	RCPT
Harmonic summing control parameter	harmonic_folds	Integer	1-32	HRMS
Complex FFT Control Parameters	cfft_control	String	Label or Structure	CXFT
Candidate Sifting Parameters	candidate_sifting	String	Label or Structure	SIFT
Candidates Output Parameters	candidate_out	String	Label or Structure	SIFT, CDOS
Single Pulse Threshold	single_threshold	Double	Tuned to system noise and RFI environment	SIFT, SPD
Single Pulse Optimization Parameters	single_optimize	String	Label or Structure	SPD
DRED Control Parameters	dred_statistic	String	Label or Structure	DRED
CDOS Control Parameters	cdos_control	String	Label or Structure	CDOS
FLDO Control Parameters	fldo_control	String	Label or Structure	FLDO,
RFIM Control Parameters	rfim_control	String	Label or Structure	RFIM
Specified for each beam				
Parameters Beam ID	beam_id	Integer	0-Maxint	All
Destination address	dest_address	String	IP address and port	CDOS
Beam co-ordinates	beam_coord	String	Astronomical Coordinates	CDOS
Checksum	checksum	Long	long	CTRL

4.3.1.9 References

SKA1 CSP.LMC to CSP Sub-elements Interface Control Document [AD13] and SKA Control System Guidelines [RD33].

4.3.1.10 Processing

Processing Diagram for CSP.LMC, MASTER and CTRL can be found in Figure 4. The initialization and operative commands originate from TM. They are propagated by the SKA LMC structure to elements and sub-elements. The TM also generates the scan configurations from the Scan Blocks (hereafter SB) and those configurations are transferred to the lower level components as *json strings*. The PSS related scan configurations are received from MASTER and their relevant portion are forwarded to CTRL. CTRL stores the contents of scan configurations in TANGO parameters and uses them to generate the configuration file passed as configuration to the Cheetah pipeline. The output of Cheetah pipeline are used to monitor its processing status, and it is logged or forwarded to the Alarm daemon as appropriate.

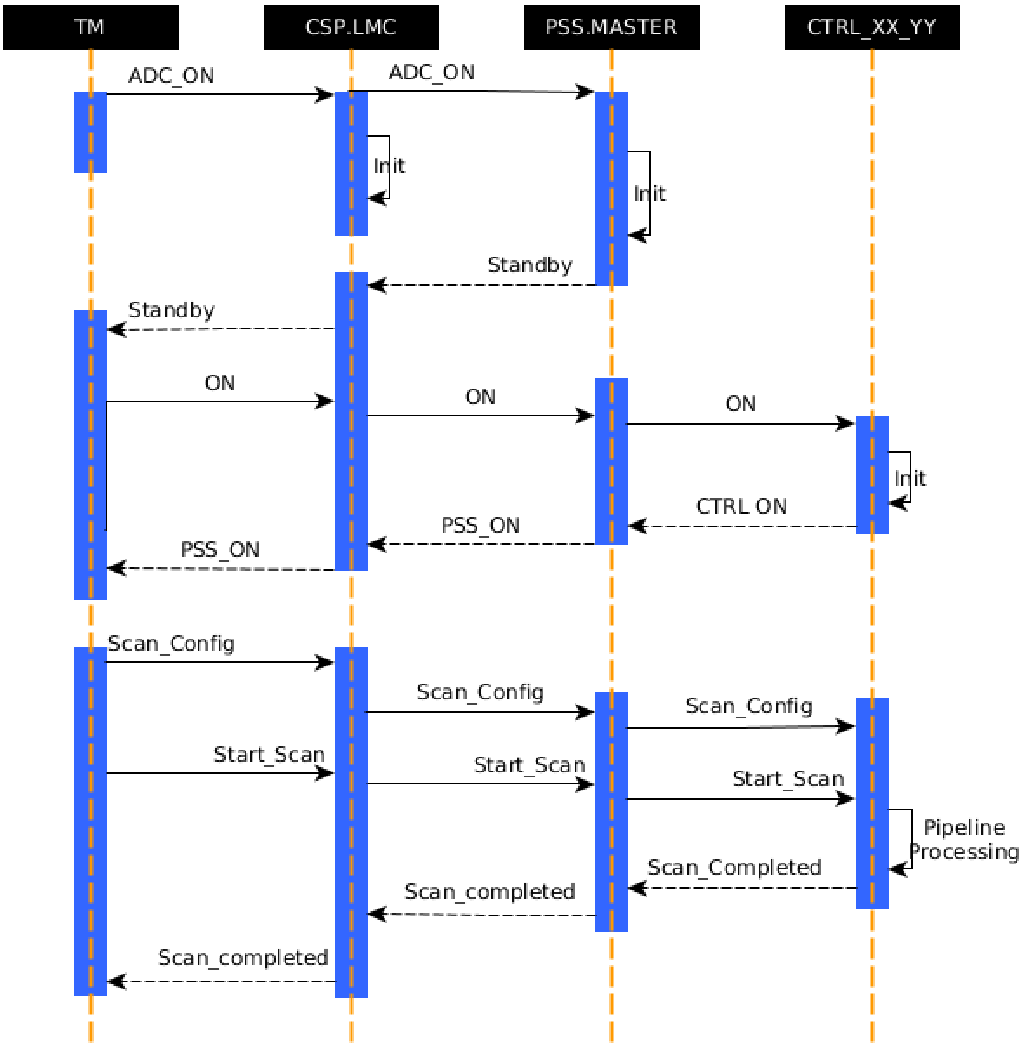

Figure 4: Process diagram for LMC-PSS

4.3.1.11 Data

CTRL receives programming and operational data mainly from TM via the LMC framework. Its main upward connection is with the MASTER module running on the PSS Master-node. Some statistical data comes from a few Framework modules (RFIM, BDRZ, DRED, CDOS) and node hardware telemetry comes from the Host Operating system services. The telemetry data are made available to the MASTER module by means of TANGO interface. The data rate for CTRL telemetry depends on the Cheetah output. The telemetry data rate for a single node is of the order of tens of bytes/sec.

4.3.2 MASTER – LMC Interface software

4.3.2.1 Component identifier

The Control, Monitoring and LMC interface software has the component ID CSP-NIP-PSS-DDD-MASTER.

4.3.2.2 Type

MASTER is a collection of software components performing the monitoring and control of the PSS sub-element. These components are implemented as TANGO Devices running on the Master Node and PSS nodes, organized in a hierarchical structure as shown in Figure 5**Error! Reference source not found.**. The figure is relative to Mid.PSS, but the differences with Low.PSS are relative only to the number of racks and nodes (see Table 5). Elements in orange represent the MASTER component.

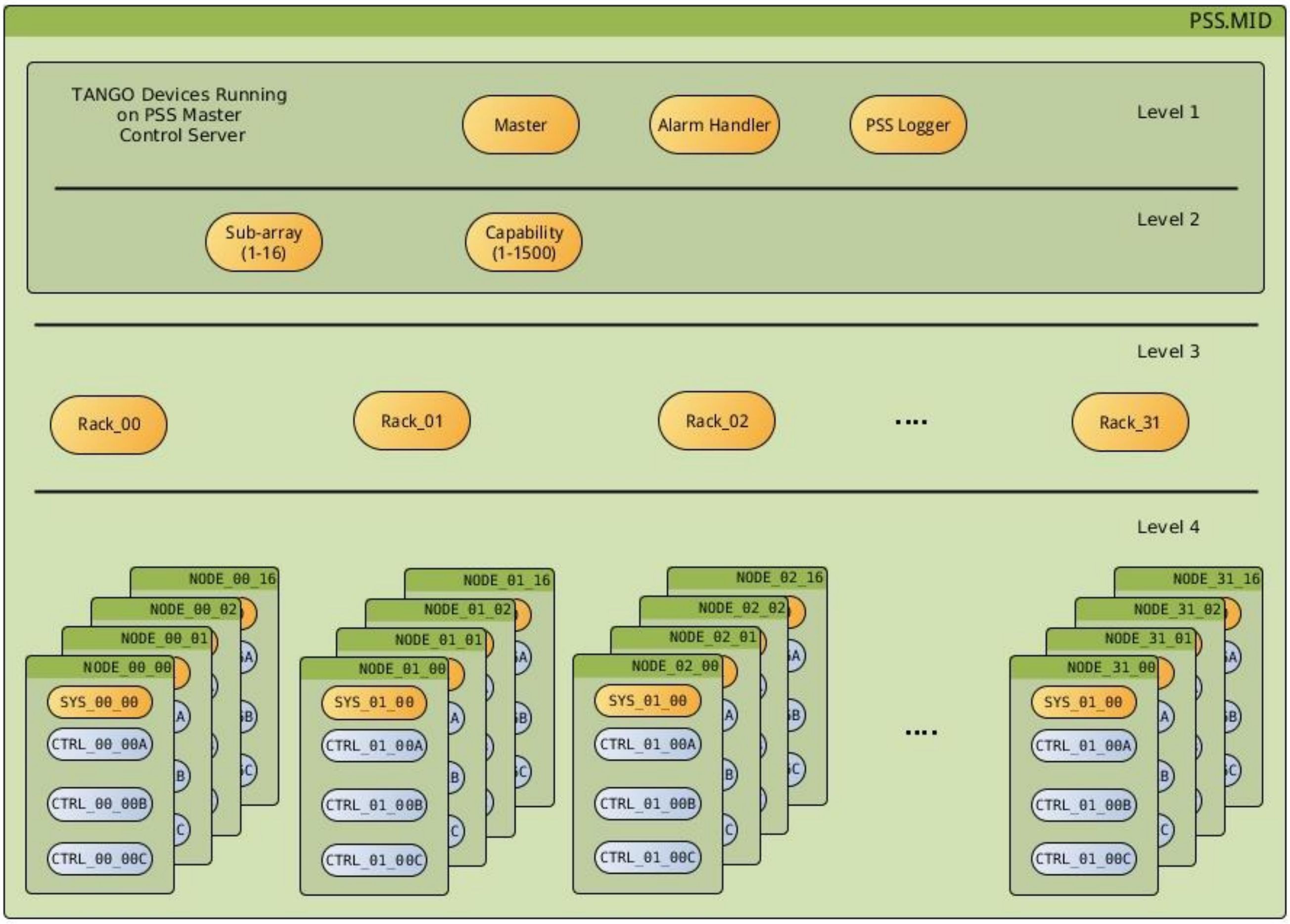

Figure 5: PSS.MID TANGO Devices hierarchical structure.

The hardware component of Master node is a COTS PC.

MASTER provides connections to the CSP.LMC and to the CTRL modules of all PSS nodes.

The interface towards CSP.LMC is described in the internal ICD [AD13].

Table 5: MASTER software components

Element	Type	Number of instances in MID	Number of Instances in LOW	Description
Master	TANGO Device	1	1	The Master models the PSS sub-element as a whole. It provides to CSP.LMC the main access point for instrument control, exposing commands and attributes for the basic housekeeping operations: power-up, power-down, state and mode transitions and monitoring. It receives commands from CSP.LMC and forwards them to the individual components. It maintains and reports to CSP.LMC the telemetry data of PSS sub-element as a whole.
Rack	TANGO Device	31	11	The Rack TANGO Device describes a physical PSS rack and allows to manage, control and monitor as a group the whole set of PSS nodes installed in the physical rack. This device forwards to the final destinations all the PSS.LMC requests for the nodes installed in the rack. It also make accessible the specific rack telemetry data (see Table 6).
Alarm	TANGO Device	1	1	PSS Alarm Handler subscribes to alarms generated by all major components including all CTRL TANGO Devices. Based on pre-configured events-actions matrix takes appropriate actions, such as rising or dropping alarms, calling the operator or proceeding to an emergency shutdown. The Alarm Handler also signals unexpected or worrisome events to the CSP.LMC which is in charge to forward such events to TM.
Logger	TANGO Device	1	1	The Logger TANGO Device implements commands that allow TM, via CSP.LMC to set the PSS logging system. It also provides application the stream of logging messages to an external Log Viewer GUI for a real-time display.
Subarray	TANGO Device	16	16	This device models the behaviour of PSS sub-arrays. It provides to CSP.LMC a point of access for configuration, execution and monitoring of signal processing functionality for each sub-array independently. Sub-array devices receive configuration per scan from

Element	Type	Number of instances in MID	Number of Instances in LOW	Description
				CSP.LMC. A scan configuration consists of the list of receptors, the list of tied-beams, and the parameters associated to the PSS processing mode.
Capability	TANGO Device	1500	500	The Capability TANGO Device maintains the configuration of a PSS Search Beam as well as the information about the hardware and software associated.
Sys	TANGO Device	500	167	The Sys TANGO Device implements commands related to shutdown, reboot, mode and state transition. Monitors the PSS node hardware (voltages, temperatures, memory used, etc) and software components (running applications, revisions, etc).

4.3.2.3 Purpose

MASTER component implements internal PSS monitor and control and provides a data exchange interface with CSP.LMC. Via this interface the CSP.LMC, on behalf of TM, can configure, monitor and control the status of the PSS equipment as well as the Pulsar Search processing functions. The MASTER module relies on the same interface to transfer back to TM the small amount of data generated by pipeline modules during Pulsar Search signal processing.

4.3.2.4 Function

The main MASTER functions are:

- Command and control.
- Scan configuration and control.
- Monitoring.
- Logging.

4.3.2.4.1 Command and Control

MASTER receives commands from the CSP.LMC [see AD13] via the PSS Master TANGO Device that is the main access point for control and monitor of PSS sub-element. These commands relate to the housekeeping operations such as power-up, power-down, reboot, upgrade, and transition to and from low power state of the PSS hardware components (nodes).

PSS Master TANGO Device is derived from the SKA Element Base Class defined in the “SKA1 Control and Configuration System” document [RD33] and is described in Table 5.

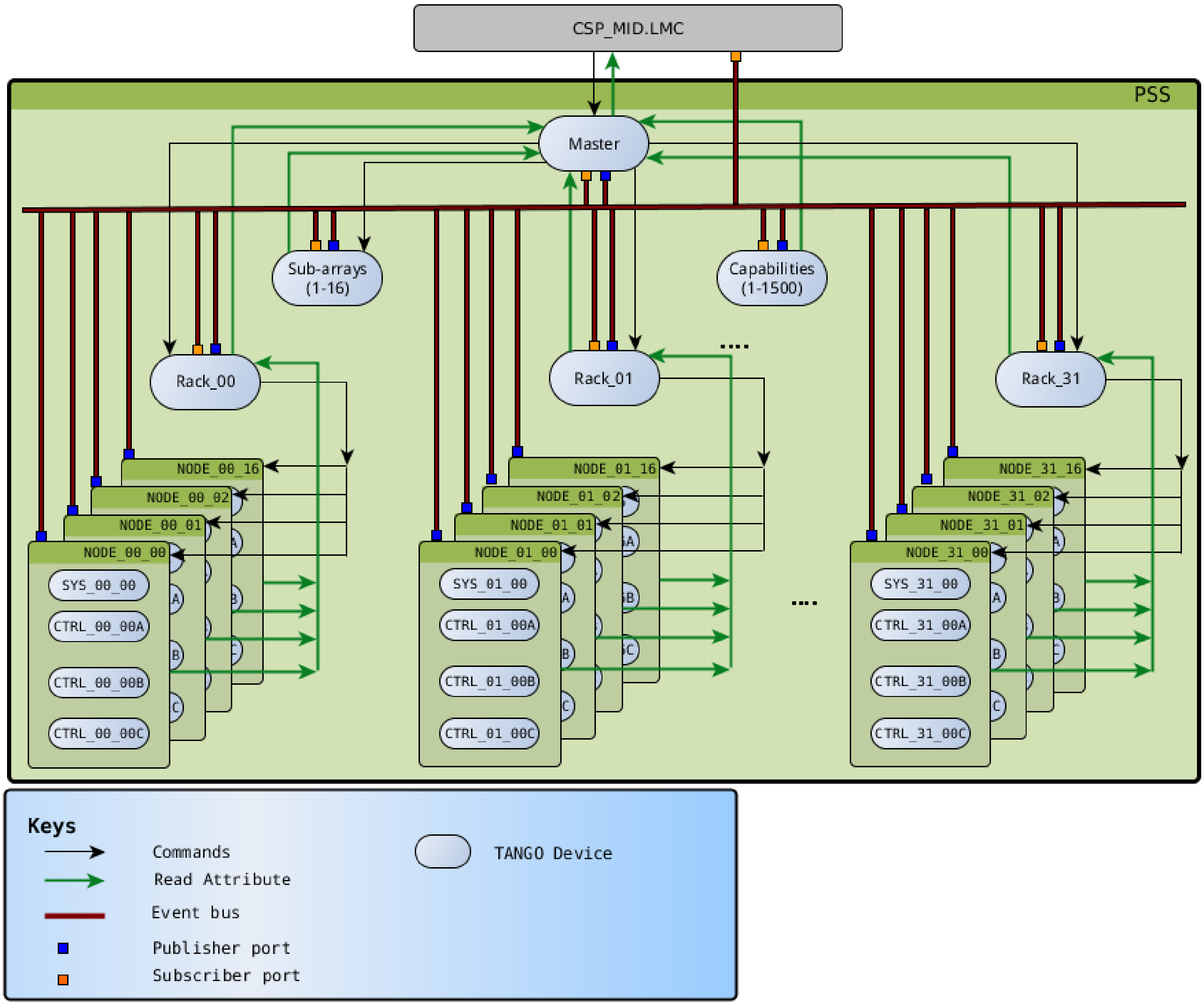

Figure 6. MASTER Command and Control view for Mid.PSS.

Figure 6**Error! Reference source not found.** shows the MASTER elements and the control commands and data flow:

- Ovals represent TANGO Devices.
- Black lines show flow and direction of housekeeping commands such as power-up, power-down, reboot, and state transitions. Commands are forwarded by each Rack device to all the Sys running on each node of the Rack.
- Green bold lines with arrows show the flow of the monitored data.
- Brown lines show the event bus. The component interactions via events are based on the publish/subscribe mechanism: if a TANGO Device is interested in the changes of another TANGO Device attribute, it subscribes the change event on that attribute. When the specific event occurs, the new attribute value is delivered and the subscriber device catches the signalled event. The publisher/subscriber mechanism is implemented in via the TANGO Event System.

The PSS Master Device forwards the control commands to the lower tier of the device hierarchy. At this level belong the Rack devices, instances of the Rack TANGO Device described in Table 5. For network efficiency the Rack TANGO Device can run on a randomly chosen node on each PSS rack.

The Rack TANGO Device acts as a proxy for communications between the PSS Master TANGO Device and the PSS nodes, allowing PSS Master to access to groups of nodes at the same time. For this purpose the Rack device relies on the TANGO Group API [RD34]. In this context, the Rack TANGO Device connects to the group of Sys TANGO Devices to complete the requests received from the PSS Master. Each PSS node runs and is managed by an instance of the Sys TANGO Device that exposes commands and attributes to control and monitor the hardware and the system software running on it.

MASTER software implements asynchronous commands and I/O operations when a request is forwarded through several tiers of the TANGO Devices hierarchy.

4.3.2.4.2 Monitoring

The monitoring is implemented by the MASTER modules using the TANGO design pattern: each attribute to be monitored by an upper control level is properly configured by setting the event threshold, the polling period and change conditions with related change criteria. Cadence and thresholds for reporting are attribute properties set during system initialization and can be updated as needed.

MASTER components declare the interest on an attribute implemented by another TANGO Device subscribing it for updates that are generated periodically or change depending on the attribute configuration.

Monitoring is executed at each level of the device hierarchy, with lower level devices reporting to the above layer devices (see Figure 6). The PSS Master TANGO Device collects and reports to the CSP.LMC summary data coming from all PSS nodes and all Cheetah pipelines. Telemetry data are related to the physical health status of the nodes (temperatures, voltages, fan speed and so forth) as well as to pipelines status, pipeline processing advancement indicators.

TM or any other authorized TANGO Client can have direct access to all levels of monitoring hierarchy, thus providing drill-down capability for diagnostics and testing. The complete list of PSS attributes to monitor and their configuration will be completely defined during the construction phase.

Attributes configured with thresholds trigger an alarm condition on threshold crossing, invalidating the attribute value and modifying its quality factor[1]. This mechanism, implemented into the TANGO core, is not sufficient to handle a complex systems such as PSS and consequently CSP.

PSS sub-element implements an AlarmHandler TANGO Device to provide fast and effective method to handle alarms. The PSS AlarmHandler, which is part of MASTER, has the responsibility to interpret the conditions within the sub-element and raise alarms for whatever conditions the TM need to know of. Figure 9 reports the main components of the Telescope Alarm System and show the alarms flow.

The PSS AlarmHandler TANGO Device is based on SKA Alarm Handler Base Class and on the guidelines defined in the “SKA1 Control and System Guidelines” document [RD33].

PSS alarms are configured as a rule-based aggregation based on attribute values, quality actors, devices states and modes and each alarm is exposed by the PSS AlarmHandler TANGO Device as a TANGO attribute that can be subscribed by the CSP AlarmHandler or directly by the Central

[1] The quality factor of a TANGO attribute indicates if the attribute value is valid, invalid, or has reached the warning or alarm threshold.

Alarm Handler for better latency. When a set of events verifies one of the configured alarm rules, the associated attribute changes, the alarm is raised and can be caught by the upper level AlarmHandler in the hierarchy.

An example of event-action processing tree is shown Figure 7.

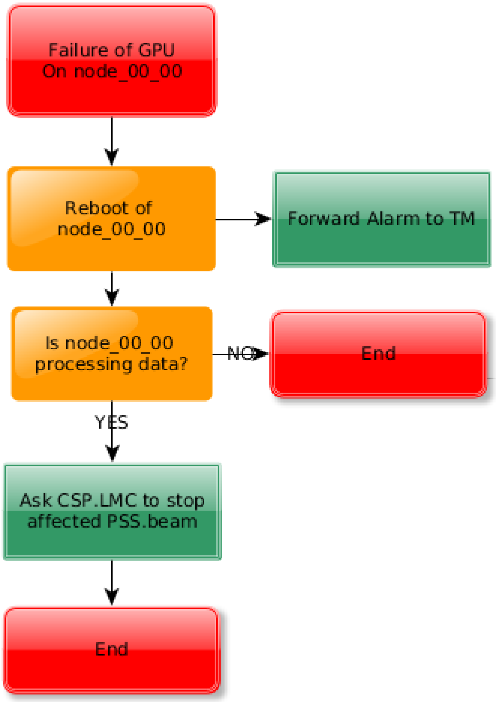

Figure 7. An example of event-action processing tree for Alarm

4.3.2.4.3 Scan Configuration and Execution

PSS signal processing configuration and control is via sub-arrays and scans. TM via CSP.LMC assigns tied-array beams to sub-arrays either in advance (via the “add resources” command) or as a part of a scan configuration.

Figure 8 shows the PSS TANGO Devices involved in scan configuration and control operations: Table 5 reports a brief description for each element. For clarity, the figure shows only two working sub-arrays relative to MID configuration. For LOW the situation is similar, only the number of instances is different.

Sub-array configuration

PSS Beam Capabilities (or Search Beams) can be added to (or removed from) a sub-array independently of a scan configuration. Black lines in Figure 8 represent the flow for the requests coming from CSP.LMC related to the commands to add/remove resources to/from a sub-array. The “add/remove resources” command specifies as input argument a list of Search Beams that TM request to assign or remove to/from a particular sub-array. The sub-array configuration requests arrives to the PSS Master Device that issues the sub-array appropriate command. In turn the sub-array accesses the Search Beams, Rack and CTRL devices to reserve for itself the resources assigned to it by the command.

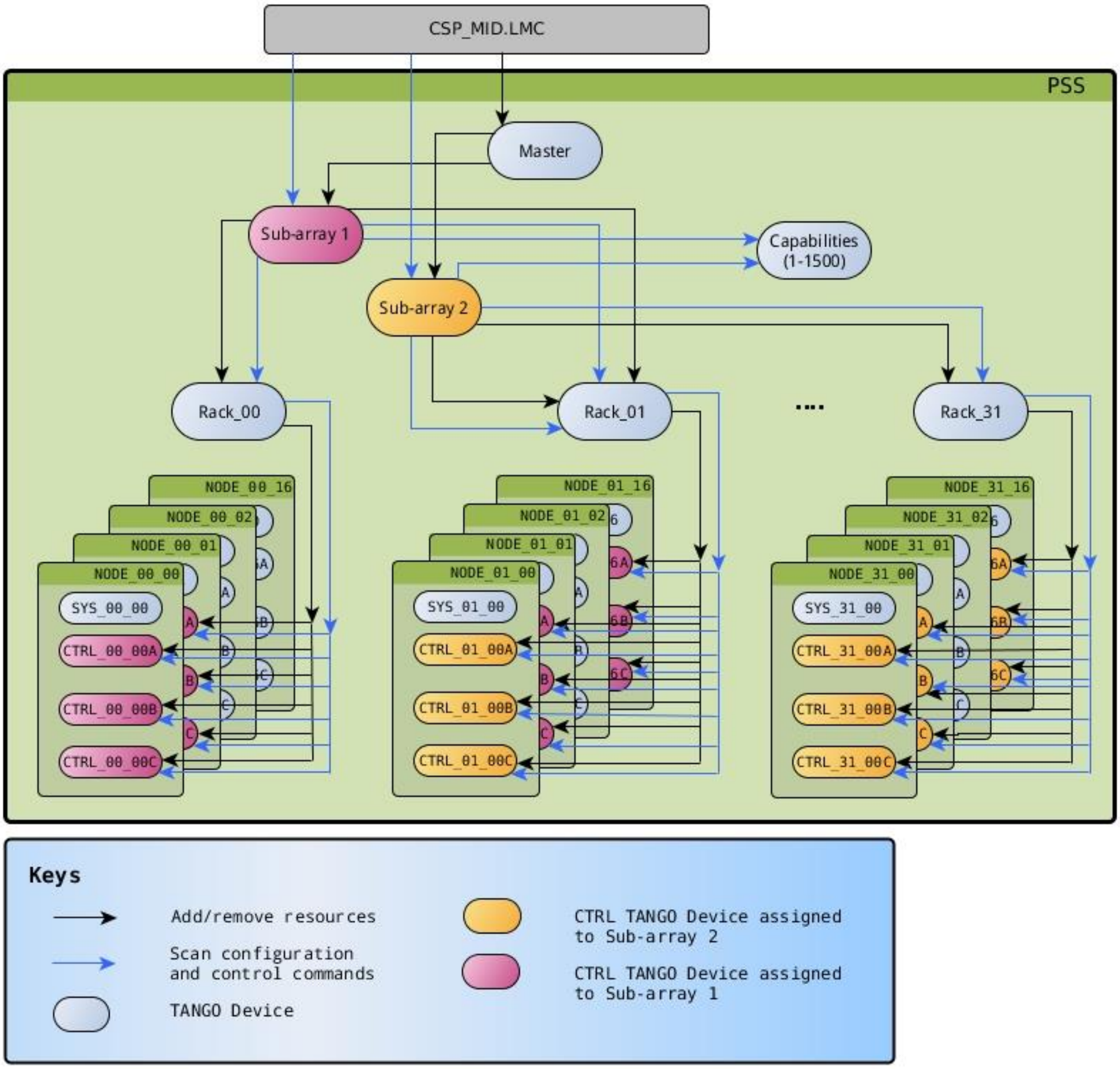

Figure 8: Scan Configuration and Control view for PSS.Mid.

The correspondence between a Search Beam Capability and the set of hardware and software components associated to that Capability is built after initialization time by the PSS Master, and it is stored in the Capability Device as TANGO attributes. The PSS Master Device accesses Search Beam devices (or a dedicated device) to get and maintain information about how many Capability instances are available, how many instances are used and on request or with publish mechanism reports these information to the CSP.LMC.

The Pulsar Search signal processing implementation imposes that all the Search Beams processed by the same PSS node cannot be used for different observations, consequently Search Beams are assigned to a sub-array in group of three. This is clearly shown in Figure 8 where are represented the PSS resources assigned to two sub-arrays: sub-array 1 (violet) and sub-array 2 (orange).

Scan configuration and execution

For scan configuration and control the CSP.LMC access directly the PSS Sub-arrays. The PSS Sub-array device provides the command “configure scan” which takes as input argument a JSON string specifying the complete set of parameters for a scan. The list of PSS parameters is reported in **Error! Reference source not found.**

A sub-array device forwards the scan configuration to all the Rack devices that “own” the CTRL TANGO Devices associated with the Search Beams listed in the JSON string: Figure 8 shows sub-array1 (violet) and sub-array2 (orange) forwarding scan configuration requests (blue lines) only to Racks hosting CTRL devices belonging respectively to sub-array1 and sub-array2.

In the same way, a sub-array device issues the scan commands related to start, pause, resume and stop of the signal processing pipelines on the appropriate set of CTRL devices.

Via the Rack devices the sub-array devices, as well the PSS Master and any authorized TANGO Client, can access to the pipeline observation parameters, their status and to their processing status if the associated sub-array is doing observation.

During a scan the MASTER requires regular update for the parameters related to beams (see Beam section of **Error! Reference source not found.**). TM provides these parameters via CSP.LMC: the delivery method will be finalized at construction time.

4.3.2.4.4 PSS Logging System

The PSS Logging System manages the collection, viewing, shipping and storage of the additional data generated by the whole PSS sub-element. The implementation of the PSS Logging System is based on the TANGO Controls framework and TANGO Logging Service for configuration and viewing support, and on the standard syslog service for log storage. The PSS Logging System is composed of the:

- PSS Log Storage, a temporary storage to maintain the syslog data generated by all PSS devices. The syslog service running on the PSS Master node can be configured to ship log data to the CSP Log Storage that has the responsibility to forward them to a long term repository implemented at TM level.
- PSS Logger element, implemented as a TANGO Device whose main functionalities are derived by the SKA Element Logger Base Classes defined in [RD33].
  The PSS Logger device implements the commands that allow TM, via CSP.LMC to configure the PSS Logging System. Configuration allows filtering the amount of log data sent to a destination (or *logging*) target, where in TANGO CS a target can be a file, the standard output or another TANGO Device implementing a Log Consumer interface (see [RD33]). Messages generated by a device with a severity level less than the one configured for the output target are not sent to it.
  The “SKA1 Control and System and Guidelines” [RD34] document defines the group of standard logging targets that can be associated to any CSP TANGO Device.
  The PSS Logger provides also the stream of logs to an external Log Viewer application that shows them in real-time. The Log Viewer can be used by TM, or by any other client that has access to PSS network, to access directly to the logs of PSS sub-element.

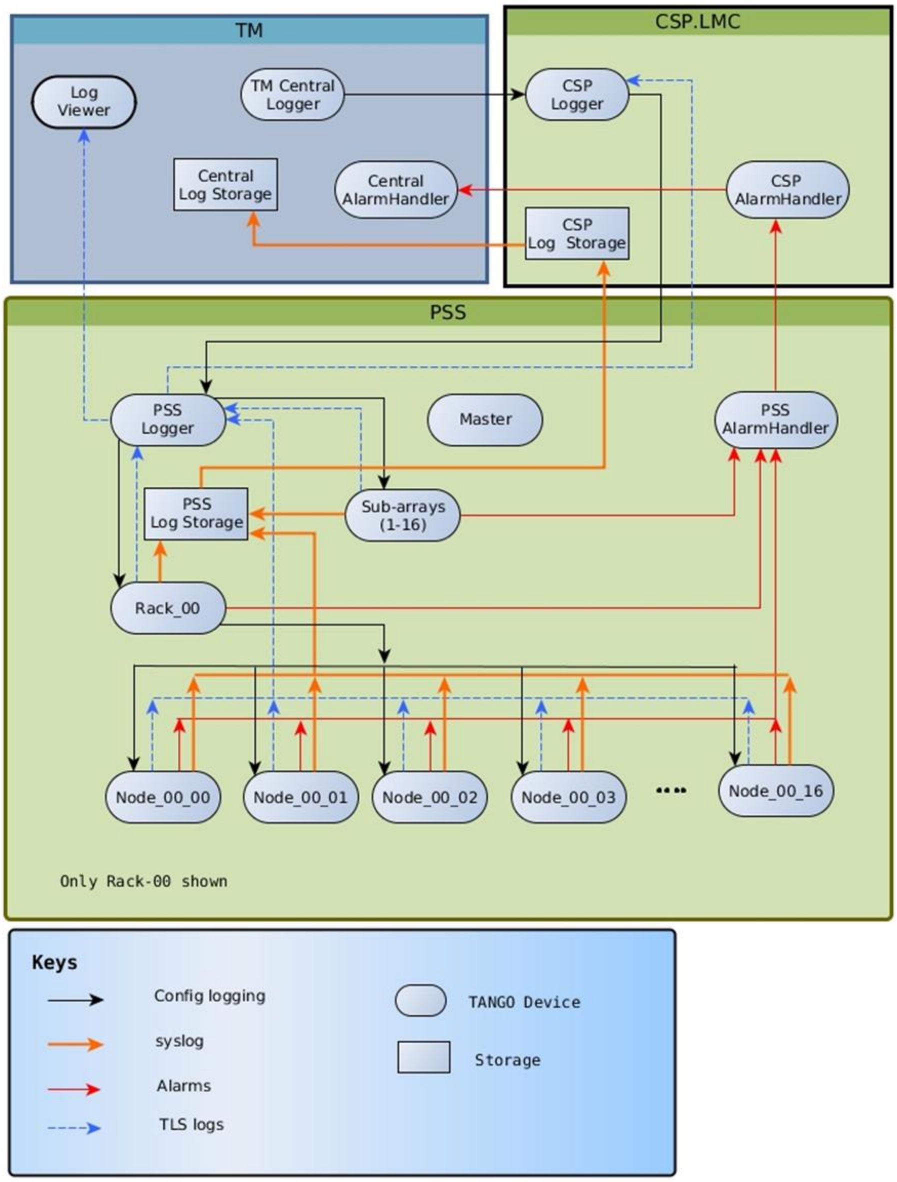

Figure 9. Alarms and Logs main view

Each PSS TANGO Device defines at least two logging targets: the PSS Log Storage and the PSS Logger. Figure 9**Error! Reference source not found.** show a general view of the log data flow:

- Dashed blue lines represent the log stream of data generated by the TANGO Devices and sent to TANGO Logger Devices for viewing.
- Orange bold lines represent the syslog output produced by all PSS TANGO Devices.

Some other details of the TANGO behavior of MASTER can be found in the CSP.LMC DDD [AD14].

4.3.2.5 Subordinates

The MASTER will start at the PSS start-up and will remain active until PSS power-down.

MASTER module is composed by three main device drivers: Master, Alarm and Rack, and some minor components, as Log and Capabilities.

4.3.2.6 Interfaces

MASTER receives configuration parameters and commands via the interface described in the SKA1 CSP.LMC to CSP Sub-elements Interface Control Document [AD13]. Parameters and configuration data, stored locally as TANGO attributes, are accessible by the appropriate TANGO calls and commands.

MASTER sends to each PSS node via the Sys TANGO Device the commands to halt, reboot, and to transit to low power mode by means of TANGO commands.

4.3.2.7 Resources

MASTER requires storage for the configuration parameters, the physical telemetry and the statistical output of the framework data processing. Table 4 summarizes configuration parameters. MASTER also makes accessible to the framework modules some permanent information, detailed in Table 3. Table 4 summarizes the parameters needed by each CTRL, and the information which some Cheetah pipeline modules send back to the MASTER module.

The telemetry values are summarized in Table 6. The default data rate for physical telemetry is a measure every 10s, but this value can be adjusted as needed by means of TANGO standard tools. The resulting data transfer rate is less than 5Kb/s with cited measurement interval and scale linearly with the data rate.

Table 6: Telemetry components for MASTER

Monitoring items	Number of points	Type of points	Total numbers
Node telemetry (500)	10	Temperatures, Fan status, running time, pipeline status, data chunks processed	5000
Rack Telemetry (75)	7	Temperatures, Power statuses, number of servers,	425

4.3.2.8 References

SKA1 CSP.LMC to CSP Sub-elements Interface Control Document [AD13].

4.3.2.9 Processing

The processing diagram for CSP.LMC, MASTER and CTRL can be found in **Error! Reference source not found.**. The initialization and operative commands originate from TM. They are propagated by the SKA LMC structure to elements and sub-elements. The TM also generates the scan configurations from the Scan Blocks (hereafter SB) and those configurations are transferred to the lower level components as *json strings*. The PSS related scan configurations are received from Master and their relevant portion are forwarded to CTRLs by means of Racks and Sub-arrays components.

Table 7: Preliminary list of alarms generated by CSP_Mid.PSS

Alarm ID	Fault Type	Maintenance task
1	Failure of compute accelerators (FPGA, GPU) in CSP PSS Compute node	Soft/hard reboot of the concerned compute node with an interruption to the observation for the affected node (implied hereafter); replace faulty host
2	Failure of power supply in CSP PSS Compute node	Replace the faulty power supply of the concerned node
3	Failure of CSP PSS Compute host	Soft/hard reboot of the concerned compute node with an interruption to the observation; replace faulty host
4	Failure of CSP PSS Compute node storage	Replace faulty storage disk or replace faulty host.
5	CPU and/or System temperature	Soft/hard reboot of the concerned compute node with an interruption to the observation; replace faulty host
6	CPU and/or System status	Soft/hard reboot of the concerned compute node with an interruption to the observation; replace faulty host
7	CPU and/or System voltages	Soft/hard reboot of the concerned compute node with an interruption to the observation; replace faulty host
8	Fan speeds	Soft/hard reboot of the concerned compute node with an interruption to the observation; replace faulty host
9	Power supply status	Soft/hard reboot of the concerned compute node with an interruption to the observation; replace faulty host
10	Bad formatted data: network stream does not comply with the specification	Stop observation.
11	Interruption on input data stream of more than 10 sec	Stop observation.
12	A node is not meeting the real-time requirement	Soft/hard reboot of the concerned compute node with an interruption to the observation; reprogram faulty host
13	A node report an internal fault	Soft/hard reboot of the concerned compute node with an interruption to the observation; replace faulty host
14	Data don't meet the specified standards for RFI interference	Stop observation.
15	Received data without a previous start signal.	No action. Data are discarded until buffer becomes empty.
16	Runtime failure of any functional blocks due to unmodeled software errors	Soft/hard reboot of the concerned compute node with an interruption to the observation; replace faulty host.
17	Inconsistent or invalid input parameter(s).	Stop observations.

4.3.2.10 Data

MASTER gets programming and operational data from TM via CSP.LMC. Some statistical data comes from a few Framework modules (RFIM, BDRZ, DRED, CDOS). Node hardware telemetry comes from all CTRL modules, while rack hardware telemetry comes from selected CTRL nodes. Following the general schema of RD33, telemetry data are transmitted to the CSP-LMC Master module to be make available to TM. The default data rate for physical telemetry is a measure every 10s, but this value can be adjusted as needed by means of TANGO standard tools. The telemetry data rate for a single node will be of the order of tens of bytes/sec.

MASTER collects telemetry values from all computing nodes and it stores them locally. The values are summarized in Table 6. The default data rate for physical telemetry is a measure every 10s, but this value can be adjusted as needed by means of TANGO standard tools. The resulting data transfer rate is less than 5Kb/s with default measurement.

MASTER stores the log messages locally in a disk file and forwards the higher level ones to the general TM Central Log repository. The local storages are implemented by a syslog engine whose retention period can be configured according to the available disk space and debug necessities. The log data rate depends on the pipeline verbosity; in the current state each pipeline generates less than 10 bytes/sec, for a grand total of less than 15KB/sec. This generates about 10GB/week of uncompressed data. The expected data rate in the final machines is expected to be significantly lower. Log rotation compress data older than a day by more than 95%.