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Executive Summary

The SKA Telescope Manager Consortium (also referred to as the "TM Consortium" in these documents) will be formed by a number of international members who are either research institutions or self-funded industry partners. These members have come together with the common interest to work on the Telescope Manager work package, with the National Centre for Radio Astrophysics (NCRA) from India as the Lead Organisation. In addition, a significant amount of work will be carried out via work contracts to industry funded by the home country of the industry.

In this document which has been redacted from pages 11 to 29 of the **SKA-TEL.MGR.RFP-TMC-MAIN-001-1** document for Telescope Manager, we describe the technical details of the Telescope Manager concept.

Table of Contents

1 Purpose and Scope ... 9
1.1 Purpose of this document ... 9
1.2 Scope of this document ... 9
2 Applicable and Reference Documents ... 9
2.1 Applicable Documents ... 9
2.2 Reference Documents ... 9
3 Telescope Manager Technical Description ... 12
3.1 Functional Description ... 12
3.1.1 Observation Management ... 12
3.1.2 Telescope Management ... 12
3.2 Key Component Characteristics ... 15
3.2.1 Observation Management ... 16
3.2.2 Telescope Management ... 16
3.2.3 Local Monitoring and Control ... 17
3.2.4 Local Infrastructure ... 18
3.3 Key Element Level Requirements ... 19
3.3.1 Telescope Management ... 19
3.3.2 Observation Management ... 20
3.3.3 Communication and Interfaces ... 21
3.4 Performance analysis against requirements ... 22
3.4.1 Latencies ... 22
3.4.2 Simultaneous sub-arrays ... 23
3.4.3 Availability and Reliability ... 23
3.4.4 Safety and Security ... 24
3.4.5 Meta-data ... 24

List of Figures

Figure 1: Telescope Manager 14

List of Abbreviations

Abbreviation	Expanded Form
AIV	Assembly, Integration and Verification
ALMA	The Atacama Large Millimeter Array
ASKAP	Australian Square Kilometre Array Pathfinder
ATC	Astronomy Technology Centre, UK
CAM	Control and Monitoring
CDR	Critical Design Review
CoDR	Conceptual Design Review
COTS	Commercial Off-The-Shelf
CSIRO	Commonwealth Scientific Industrial and Research Organisation, Australia
CSP	Central Signal Processor
DBL	Design Baseline
DDBL	Detailed Design Baseline
DSH	Dishes
EIT	Element Interface Team
EMC	Electromagnetic Compatibility
EVLA	Expanded Very Large Array
FMECA	Failure Modes, Effects and Criticality Analysis
FTE	Full Time Equivalent
GRIT	Grupo de Radioastronomia do Instituto de Telecomunicações, Portugal
ICD	Interface Control Document
ILS	Integrated Logistic Support
IMP	Interface Management Plan
INAF	Istituto Nazionale di Astrofisica, Italy

INFRA	Infrastructure
LEMP	Logistic Engineering Management Plan
LFAA	Low Frequency Aperture Array
LoI	Letter of Intent
M&C	Monitoring and Control
MGR	WBS abbreviation for Telescope Manager
NCRA	National Centre for Radio Astrophysics, India
NRC-HIA	NRC Herzberg Institute of Astrophysics, Canada
PBS	Product Breakdown Structure
PDR	Preliminary Design Review
PMP	Project Management Plan (this document)
QBL	Qualification Baseline
QR	Qualification Review
RBL	Requirements Baseline
RFC	Request for Change
RFI	Radio Frequency Interference
RfP	Request for Proposals
RR	Requirements Review
SADT	Signal and Data Transport
SDP	Science Data Processing
SEMP	System Engineering Management Plan
SE	System Engineering
SKA SA	SKA South Africa
SKA	Square Kilometre Array

SOW	Statement of Work
SRR	System Requirement Review
TELMGT	Telescope Management
TM	Telescope Manager
TRDDC	Tata Research Development and Design Centre, India
TRL	Technology Readiness Level
WBS	Work Breakdown Structure

1 Purpose and Scope

1.1 Purpose of this document

The purpose of this document is to present the Technical Description written as part of the main document during submission of the response to the RfP.

1.2 Scope of this document

The scope of this document is limited as follows:

- This bid is only for the Telescope Manager (TM, or SKA.TEL.MGR) Element.
- It is applicable only for Stage 1 and Stage 2 of the SKA1 Pre-construction phase of SKA.
- The document is limited to describing the process following the awarding of the contract to this TM consortium. Preceding this (and excluded from this document) is a period of responding to the RfP, negotiating a final agreement and placing of the contract.

2 Applicable and Reference Documents

2.1 Applicable Documents

The following documents are applicable to the extent stated herein. In the event of conflict between the contents of the applicable documents and this document, the applicable documents shall take precedence.

- [AD1] SKA REQUEST FOR PROPOSALS SKA-TEL.OFF.RFP-SKO-RFP-001
- [AD2] SKA-1 System Baseline Design SKA-TEL-SKAO-DD-001-1_BaslineDesign
- [AD3] SKA DOCUMENT REQUIREMENTS DESCRIPTIONS SKA-TEL.SE-SKO-DRD-001
- [AD4] SKA SYSTEM ENGINEERING MANAGEMENT PLAN SKA-TEL.SE-SKAO-MP-001-1_SEMP
- [AD5] SKA-TEL.MGR.RFP-TMC-MAIN-001-1

2.2 Reference Documents

The following documents are referenced in this document. In the event of conflict between the contents of the referenced documents and this document, this document shall take precedence.

- [RD1] SKA M&C CoDR documents, 2010 - Document set accepted by the SKA Office, as a result of the Concept Design Review of the Monitoring and Control work package - http://www.skatelescope.org/public/2011-11-08%20Monitor_and_Control_CoDR/

- [RD2] Design Concept Description, Yogesh Wadadekar et al. http://www.skatelescope.org/public/2011-11-08%20Monitor_and_Control_CoDR/04-WP2-005.065.020-TD-002v0.2-DCD.pdf
- [RD3] MeerKAT CAM Requirement Specification, Document Number M1500-0000-000, Rev 1A, Dated 17 May 2013 https://docs.google.com/a/ska.ac.za/file/d/0B8fhAW5QnZQWMDdGZ2RQeDE5cXc/edit
- [RD4] MeerKAT CAM Design Description, Document Number M1500-0000-006, Rev A, Dated 20 May 2013 https://docs.google.com/a/ska.ac.za/file/d/0B8fhAW5QnZQWLWhtQm9sSGluSlk/edit
- [RD5] ALMA Science Software Requirements, Document Number ALMA-70.10.00.00-002-L-SPE, Dated 2006-06-08.
- [RD6] ALMA Software Architecture, Document Number ALMA-70.15.00.00-001-J-GEN, Dated 2007-08-13.
- [RD7] Yang, Y., He, M., Li, M., Wang, Q., & Boehm, B. ,"Phase distribution of software development effort.", in Proceedings of the Second ACM-IEEE international symposium on Empirical software engineering and measurement (2008 October) (pp. 61-69),ACM.
- [RD8] Tan, T., Boehm, B., & Clark, B., "An Investigation on Application Domains for Software Effort Distribution Patterns." Transition, 12, 0-20.

3 Telescope Manager Technical Description

As indicated in the baseline design document for SKA1, the Telescope Manager is responsible for a) management of all astronomical observations b) management of all the telescope hardware and software systems that perform the observations and c) facilitating communication across the primary stakeholders, including operators and maintainers as well as systems and subsystems. In addition the TM is focused on ensuring safety at all time. Various aspects of each of the responsibilities are elaborated in the sections below.

3.1 Functional Description

The SKA Phase 1 could be thought of as 3 almost independent telescopes - SKA LOW (Sparse Aperture Array), SKA MID (Dishes), and SKA Survey (Dishes). For each of these three telescopes, the SKA Telescope Manager (TM) coordinates and executes astronomical observations, manages the functioning and behaviour of the instrument and its subsystems, monitors the health and status of the system and implements alarms and automated intervention accordingly, and provides communications and engineering information infrastructure for operators, engineers and scientific staff. It is responsible for ensuring the safety of people and equipment, in cooperation with the local monitoring and control capabilities of the various system Elements.

3.1.1 Observation Management

This enables the specification and execution of observation procedures. This includes selection, acquisition and configuration of the set of receptors needed to carry out the observations, coordinating the instrument subsystems and performing the sequence of activities necessary to execute observations, dynamically monitoring and responding to changes in instrument capability and performance, performing any reconfiguration of the instrument or aborting the observation as needed, and defining the metadata to be captured to facilitate interpretation of observation data. It also performs scheduling to determine the sequence of observations to be executed for optimum use of the telescope as well as rescheduling if adverse circumstances interfere with the execution of particular planned observations. This includes simulation of the observation management and scheduling features to enable making the scheduling decisions. It defines and implements the set of features available to users to perform observations using the telescopes, including sub-arrays, dynamic reconfiguration and coordinated control of receptors and monitoring of telescope operations.

3.1.2 Telescope Management

This is responsible for all engineering system functions, including startup and shutdown of the telescopes and each of their components, configuration and setup, coordinated system functioning, monitoring the behaviour and operational parameters of the system as a whole and all its components, detecting and responding to adverse situations, providing status monitoring dashboards and control interfaces to operators, and supporting commissioning, troubleshooting, upgrades and other engineering operations. Its responsibilities include system security, safety, reliability and availability of the systems and subsystems, managing system performance and monitoring the environment.

In addition to providing monitoring and control interfaces for operators, scientists and engineers, TM also provides general-purpose communication capabilities enabling interaction and co-operation between operators, engineers and scientists. It supports remote troubleshooting, enabling engineers to access and manage devices from remote locations. It includes operations support databases to maintain engineering information (e.g. system status, capabilities, change history, engineering contacts) and makes them available to users of the instrument. The context diagram below indicates the mutual responsibilities and interactions between TM and other SKA Elements. The Telescope Manager interfaces with every other part of the system to collect monitoring data, issue high-level control commands, and provide system level handling of alarms, either through automated response and/or through operator intervention. In addition, it has specific responsibilities towards other elements, including supply of metadata to the Science Data Processing to be recorded along with the observations, supply system and environment operating parameters to CSP and SDP for use in their processing, and to implement feedback control responses from their systems. It consumes resources and services from SADT/SAT and Infrastructure.

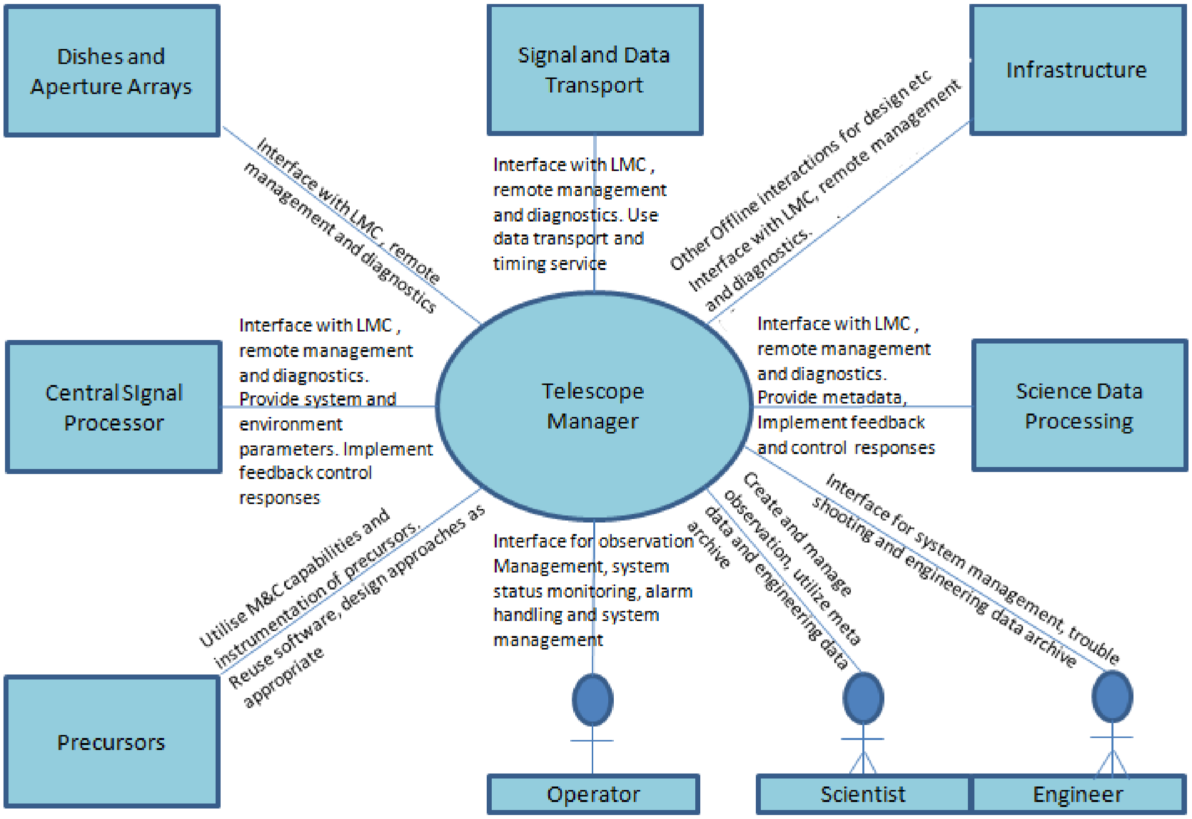

Figure 1: Telescope Manager

Each of the three telescopes have receptors with different capabilities and control needs, and differences in observation management procedures. The requirement to integrate precursors may also introduce variabilities from an engineering perspective. The goal is to have as much commonality as possible in the Telescope Manager across the three telescopes in terms of software and instrumentation in order to reduce lifecycle costs, with the ideal being to have a single common TM architecture and software framework, with all the variations being supported through configuration, plug-ins and scripts.

One of the early activities to be done on the Telescope Manager is to analyze the impact of the need to control multiple telescopes and integrate precursors on the architecture of the Telescope Manager and the implications for its design and implementation. It is possible that the results of this activity may necessitate significant rework of the plans and effort estimates for the Element. The current cost, effort estimates and plans represent a median path that is likely to be able to accommodate a variety of design possibilities with appropriate readjustments.

The scope of responsibility of Telescope Manager does not include the internal monitoring and control of components e.g. dishes, power equipment, networking equipment etc. Instead, each Component is responsible for its own local monitoring and control, including detection and handling of safety situations. The scope of responsibility of the Telescope Manager is primarily for coordination, control, detection and response functions that involve multiple subsystems. As part of its overall responsibilities towards system safety, the Telescope Manager is also responsible for handling alarms raised by Components, and for backup safety actions.

The Telescope Manager has responsibility for ensuring safety of both people and equipment. Many safety issues will be local to a particular element or subsystem, and the responsibility of Telescope Manager will be limited to providing backup detection and handling capabilities. In other cases, the detection and handling may involve coordination across multiple elements or subsystems e.g. severe weather situations may be detected by a weather station but the response may need to be implemented by antennas and power equipment apart from aperture arrays, computer networks and regional M&C. In these cases, the Telescope Manager has primary responsibility for handling the safety scenario. Each scenario must include a backup detection and response mechanism, in this case usually implemented by the Telescope Manager central controller that serves as a backup to the regional controllers. Regions should be autonomous with respect to safety, so that isolation of a region does not result in unsafe situations. There will also need to be backup communication capabilities (possibly using on-demand links) for this eventuality.

The Telescope Manager has its own Local Monitoring and Control functionality that monitors and manages its own functioning. The responsibilities of this function include monitoring the platforms and instrumentation, monitoring software functioning using heartbeats and other progress measures, monitoring behaviour in terms of command response times and timely delivery of monitoring and response data, outcome monitoring in terms of observations progress and success, entries to engineering log files, and correct configuration and operation of the instrument and its subsystems. In case of problems, it will take actions as needed to reset hardware, restart software and/or raise operator alarms. This function will conform to the standard LMC interface defined for all monitored elements, so that the monitoring reports will include information on the Telescope Manager’s own functioning.

The Telescope Manager has dependencies on other Elements for defining its requirements and design. In particular, many of its requirements and design decisions depend on the overall System Concept of Operations. The unavailability of the Concept of Operation might pose a risk of not validating the requirement and design created during the PDR. The interface definitions with CSP and SDP will define key requirements in terms of systems parameters, metadata and implementation of feedback control. The design of TM software must also be coordinated with CSP and SDP because of the possibility of shared platform functions, and because of the need for shared data models to facilitate exchange of information.

3.2 Key Component Characteristics

As per the Work Breakdown Structure (WBS), the Telescope Manager is divided into four key technical sub components, which are a) Telescope Management, which manages the engineering aspects of instrument operation and lifecycle management, b) Observation Management, which is responsible for facilitating the use of the instrument to perform observations c) Local Monitoring and Control, which is a supporting component that provides capability to ensure the reliability and availability of the Telescope Manager itself, and d) the Infrastructure for Telescope Manager functioning, along with control rooms for operators. Some of the main characteristics of each of these components are discussed below.

3.2.1 Observation Management

The Observation management component will be responsible for providing interfaces to users for the preparation, creation, editing, submission, scheduling, execution and monitoring of Scheduling Blocks (or equivalent observation data entity) and science programs. The Scheduling Block usually represents the observation entity from the user's (astronomer) point of view. It normally contains parameterized information of the observation to be undertaken, instrument configuration and a description of the observation procedure (observation sequence). The name and definition of Scheduling Block has been adopted in many other radio telescopes including ALMA, EVLA, MeerKAT and ASKAP.

This component will also be responsible for the Scheduling Block data persistence and persistence of other information related to scheduling and execution such as resource availability, schedules, etc. It also provides access from other SKA TM components such as Telescope Management (internal interface in TM element) and SKA elements such as SDP.

The scheduler in the Observation Management component will have to allow for execution of pre-determined schedule as well as dynamic scheduling based on RFI, ionosphere, external triggers and so on. Hence this component will have the required software with dynamic scheduling capability.

As part of its Scheduling and Observation Execution responsibilities Observation Management must also manage and allocate required resources, particularly for the creation, allocation and destruction of sub-arrays. It must also match the visibilities and time-series data obtained to the corresponding meta-data.

Observing Projects may consist of many Scheduling Blocks, and take weeks or months to complete. In addition individual Scheduling Blocks may be executed repeatedly, to attain sensitivity or UV coverage targets, or for monitoring purposes. It is the responsibility of the Observation Management component to track and update the lifecycle of individual SBs and the Projects to which they belong, and to maintain an overview of them for the observatory.

One of the functional areas that it is not yet fully defined, and has been excluded from this RfP as per the clarification received from the Project Office is the management of the observing proposal process, including proposal submission and handling, and observation preparation. This function might reside under the Observation Management responsibility, but further discussion with the SKA SDP element and the SKA Organisation is required.

3.2.2 Telescope Management

The Telescope Manager (TM) provides much of the traditional Control and Monitoring capability to operate the SKA telescopes. It manages all the engineering aspects of the various hardware and software systems that Telescope Manager requires. Some of its key responsibilities are listed as below:

- Providing user interfaces to the various stakeholders like the operators, maintainers. And also providing capability for general communications across the users of the instrument and its subsystems.
- Managing operations, including user access control, operator shifts and operational reports.
- Providing appropriate interface with Observation Management for observation execution.
- Enabling execution of observation by configuring and controlling the SKA sub-systems through commands and feedback control and also allowing collection and distribution of responses, events and alarms across the stakeholders and subsystems. Also managing the configuration of the instruments, including operational modes.
- Collecting and archiving time-stamped monitoring data generated from all the elements of the system which include logs, alarms and general process variables such as temperatures, operating points, etc.
- Gathering and processing data to monitor the state of the system in real time and trigger actions when necessary.
- Providing capability to specify alarm conditions and managing and escalating them in the system as necessary.
- Providing common interfaces and data models reusable across all SKA elements to implement the respective element specific local monitoring and control.
- Providing support for manual and maintenance control, safety critical control and external triggers. Managing the execution of a combination of automatic or manual maintenance procedures or both.
- Handling safety operations of the instruments spanning across sub-systems or elements.
- Generating instrument meta-data and providing it to other SKA elements like the Science Data Processing for calibration, imaging data processing and science data archiving and so on.
- Providing and collecting instrument’s performance metrics, for example observation efficiency or downtime statistics.
- Providing system displays to enable users to assess in real time the state of system settings, the health of the system, and the quality of the data being captured, and to monitor and control the system as required.
- Providing API to the archived monitoring data for external users and engineering data mining applications.

3.2.3 Local Monitoring and Control

The local monitoring and control functionality of the Telescope Manager gathers data about the behaviour of the Telescope Manager itself, monitors the functioning of its hardware and software platforms, and monitors whether desired functional outcomes are being achieved. It monitors the TM and detects and responds to adverse situations, implementing hardware and software fault-tolerance capabilities. This ensures that the Telescope Manager itself has a high level of reliability and availability and does not become a source of system unavailability, instrument malfunctions or safety problems. It conforms to the standard Local M&C interface defined for monitored elements, thereby also providing feedback on the adequacy of the defined interface.

3.2.4 Local Infrastructure

The Local Infrastructure component is responsible for providing the infrastructure equipment and installations required by the Telescope Manager's key components (Observation Management, Telescope Management, Local Monitoring and Control) to provide their core functionality. This component implements the TM's mechanical, electrical and cooling interfaces to the INFRA element. The Local Infrastructure component is expected to be realised using commercial-off-the-shelf items.

The responsibilities of these work element include working in close collaboration with the INFRA Element to provide TM's requirements for physical infrastructure and co-design the needed facilities, and working with the SDP Element (based on our current understanding of responsibility boundaries) for specification and procurement of the needed computing infrastructure for TM.

The Local Infrastructure also includes the physical design and setup of the Operator Control Room. This will be performed in conjunction with the Operator Interfaces task within TELMGT.

Local Infrastructure's functions are:

- Determining TM needs for computing infrastructure, including computing infrastructure in each station to acquire and process data from each node; It should be noted that the local networking within each core and station is part of SADT
- Physical infrastructure to support the TM computing equipment
- Instrumentation for telescope management, including TM's own local monitoring & control, and any overall system instrumentation such as videocameras and weather stations that is not already included as part of another SKA Element
- Distribution of electrical power from the INFRA element to TM components
- Distribution of timing signals to computing nodes not directly connected by SAT
- Distribution of cooling within the TM
- Infrastructural support for any safety backup systems required by the design
- Providing physical infrastructure for operators and maintenance engineers, including the operator control room and maintenance access points to the TM system at stations

The design of this component will ensure the safety of humans during the component's fabrication, installation, operation, maintenance and disposal. The component design will ensure safety of integrated TM installation sets (e.g. warning labels, smoke detectors, CO2 injection nozzles).

At each telescope site, Local Infrastructure can be divided into two types of installation sets: a single, central Processing Installation Set (installed in the telescope computing facility) and the Control Centre Installation Set (installed in host country headquarters).

The Processing Installation Set may include: enclosures for the servers, networking equipment for signal and data transport (cables, switches, fibre patch panels), and power distribution units.

The Control Centre Installation Set may include: networking equipment for signal and data transport between operator workstations (cables, switches), ergonomic display consoles etc.

3.3 Key Element Level Requirements

As indicated in the documents published as part of the RfP, the SKA phase one will comprise the three telescopes namely SKA1-Low, SKA1-Mid and SKA1-Survey telescopes. In order to minimize the overall cost and create uniformity, it is essential to create as much commonality in the functionality and architecture of the key components of the Telescope Management element, responsible for operating all these telescopes. As mentioned earlier in the document, the broad functionality of TM can be categorized as Telescope Manager for managing all engineering aspects, Observation Management for management of all scientific observations and capability for communication across stakeholders and subsystems. The key requirements of each of these components are discussed below:

3.3.1 Telescope Management

The requirement for carrying out management of all the engineering aspects of Telescope Manager can be categorized into broad functionalities:

3.3.1.1 System Configuration

- Facilitate all software and hardware configuration of the system including on-line configurations and software updates.
- Maintain configuration, status, version and history for all the entities in the system, at each level of granularity.
- Facilitate system calibrations such as antenna pointing models or hardware calibration influenced by physical changes like maintenance activities and so on.
- Provide access to various existing catalogues such as source catalogues and so on.

3.3.1.2 System Monitoring

- Monitoring the health and operational status of system entities along with influencing contextual factors, including overloads and capacity shortfalls, weather conditions etc.
- Monitoring of engineering parameters of sub-arrays and detection of potential problems based on performance parameters. Providing abstracted views of resource status, allocation and utilization of supporting system resources including receptors, networking, power, cooling and computational resources.
- Monitoring the safety and security including physical site security related aspects through coordination with other systems such as INFRA and so on.
- Provide displays to show health status, faults, failure predictions, system configuration and so on.
- Providing support for query and drill down to allow visibility into the hierarchical derivation of the high-level abstracted views in the form of drill-downs, complemented by query modes that can retrieve specific parameters.

3.3.1.3 Fault management:

- Specification and detection of conditions that can lead to serious accident causing injury to support personnel or that damages equipment.
- Facilitate the various fault detection mechanisms such as specification of thresholds, timeouts, anomalies, correlations, patterns analysis that indicate potential problems, external sources such as security risks, threats and so on.

- Facilitate handling of alarms taking into account the alarm types and severity. Provide mechanism to detect urgent alarms involving safety, security, threats to equipment or severe failures that significantly affect overall system capability.
- Providing a mechanism to aggregate and propagate key alarms at a higher priority than normal communication.
- Mechanism to display and acknowledge alarms.

3.3.1.4 Safety, Security and Integrity

- Mechanisms such as watchdog and heartbeat mechanisms to detect threats.
- Mechanism to identify and present security risks.
- Mechanism to authenticate and authorize the staff for a given control center or across control stations.
- Providing indications of safety hazards as identified and reported by other telescope sub-systems.
- Taking appropriate actions in case of safety critical conditions such as stopping execution of Scheduling Blocks, Observation schedule, stowing antennas, graceful power-down of equipment that are sensitive to power failures or cooling system failures.

3.3.1.5 Comparison with MeerKAT, existing Pathfinder

The higher level functionality of MeerKAT has been analyzed to validate the above requirements. Some of the high level functionality of the Control and Monitoring (CAM) system at MeerKAT is described below

- **Manage Operations**: Includes user access control, operator shifts and operational reports.
- **Provide System Displays**: Provide system displays to enable users to assess in real time the state of system settings, the health of the system, and the quality of the data being captured, and to monitor and control the system as required.
- **Monitoring System**: Gathers and processes monitoring points to monitor the state of the system in real time and trigger actions when necessary.
- **Archive CAM Data**: Stores CAM data for future use and ensure that stored data is available and accessible to all relevant data users. It archives the configuration data, monitoring data, user logs, observation management data and proposal data.
- **Schedule and Control System**: Provides a schedule and control framework to schedule and execute observations, which supports manual and maintenance control, safety critical control and external triggers. It includes resource and sub-array management, scheduling, observation control and execution.
- **Proposal Management System**: Helps facility operators and science users with the generation, evaluation, approval and storage of proposals.

3.3.2 Observation Management

The requirement for carrying out all scientific observation using the Observation Management (OM) system is as follows:

- Providing mechanism to ingest high-level descriptions of observations, as Scheduling Blocks (SBs) or higher-level form
- Providing support to query the database of SBs to find those suitable for execution
- Providing support to schedule the execution of SBs according to some criteria
- Providing support to dispatch SBs for execution and track their execution
- Providing the required metadata to CSP and SDP, so that scientific data like visibilities or time series can be associated with the corresponding telescope configuration metadata
- Providing capability to trigger the processing of the meta-data and science data within Scientific Data Processing
- Managing the creation, use and destruction of sub-arrays and other resources to be determined
- Providing capability to interrupt a running observation and restart it or reschedule it as needed, or start a new observation with higher priority (based on an external trigger with associated latency constraints, or on dynamic scheduling decisions)
- Providing capability for multiple schedulers to allow concurrent execution of observations
- Scheduling, in parallel, the operation of the three separate arrays (low, mid and survey) including the possibility of coordinated observations, if required
- Providing tools to enable the development of applications and scripts for observation execution
- Allowing the scheduling of calibration and maintenance periods
- Tracking the status (lifecycle) of SBs and their associated projects
- Providing simulation capabilities for observation execution
- Providing simulation capabilities for scheduling
- Configuring subsystems and components for observation execution
- Providing user interfaces to:
    - Array resource management
    - Scheduling
    - Observation execution
    - Project and observation lifecycle management
    - Scheduling and projects overview
- Archiving Observation Management data - Store for future use and ensure that stored data are available and accessible to all relevant data users

The Telescope Manager executes a Scheduling Block, according to the instructions provided by the Observation Management system. The TM controls telescope sub-systems that are part of sub-arrays, as per the instruction set of a Scheduling Block while executing observations. It enables the control authority of a sub-array to control only that sub-array independently.

3.3.3 Communication and Interfaces

Following are some of the requirements for facilitating communication and providing interfaces to the stakeholders, systems and subsystems:

- Providing integration interfaces with all the local M&C systems, including its own local M&C.
- Acting as parent node to all M&C systems: it acquires monitoring data from these systems, make them available to operators and engineers, and relays commands from operators and engineers to these systems.

- Providing interface with SDP for providing it with science metadata, providing the necessary support for doing calibration, feedback for phased array observations and so on.
- Providing interface for events and alarms: the Local M&C systems will also be able to report events and alarms to observatory operators through this integration interface, in addition to reporting them through their own local engineer interfaces. Elements such as Dish, SADT, CSP etc. are likely to develop their own high level M&C system that abstracts away specific implementation details and provides system wide intelligent resource management functionality for entities within their domain. The TM will have integration interfaces with these M&C systems. For example, SADT software will be used to monitor and manage the functioning of the signal transport network.
- Providing functionality for resource management complementing its primary role of control and monitoring. Keeping a view of present resource as well as future needs and ensuring that the desired resources are provided to the dependent systems to perform effective capacity management.

3.4 Performance analysis against requirements

Key performance parameters for the Telescope Manager include the ability to carry out observations in all specified observing modes, including enabling the required number of simultaneous sub-arrays, phased array beams, operation of any third party equipment attached to the CSP spigots etc. If it is required that the SKA-mid, SKA-low, SKA-survey have the ability to perform synchronized observations, the Telescope Manager would need to enable this, most likely via the Observation Management Component. Other important performance parameters include latencies, availability and reliability, safety and security, and delivery of specified Metadata.

3.4.1 Latencies

Key timing concerns for the Telescope Manager include timeliness of monitoring parameters and metadata, latency of response to commands, latency of alarm response and in handling of large volumes of monitor data. There will be a certain amount of hierarchy built into the architecture of the Telescope Manager and this simplifies the problem of monitor data volumes because each node in the hierarchy is responsible for controlling the behaviour of a relatively small number of child elements. However, multiple hierarchical levels can potentially lead to latency issues.

Monitoring latency and command response requirements are expected to be of the order of several hundred milliseconds, relatively easy to meet with a two-level hierarchy. However, it is possible that the CSP may need some system parameter values at shorter latencies. If such requirements arise, they may necessitate the provisioning of direct data flow paths, so that CSP subsystems can subscribe to monitoring points of interest, and the data will flow directly to the subscriber without needing to be relayed up and down the hierarchy.

Event and alarms handling may have, in some cases, short and stringent timing requirements, where systems need to act quickly to prevent impacts from adverse situations. This is addressed with the hierarchical design of alarm response, assigning detection and handling responsibilities to the lowest level of the hierarchy that detects the problem. In general, the level of the Telescope Manager hierarchy that responds to a particular event or alarm must be correlated with the target latency.

Executing astronomical observations is the principal task of the TM. This includes specification and scheduling of observations as well as the actual observation execution. Latency requirements are set by, for example, survey observations which require one to rapidly switch between different sky pointings. Similarly, for transient events the TM could be expected to undertake quasi-real time execution of predefined observations in response to an external trigger. Latency issues also arise for example in generation of phased array beams, for which special calibration observations and/or back-flow of information from the SDP is required.

3.4.2 Simultaneous sub-arrays

The maximum number of simultaneous sub-arrays that can be supported is an important performance metric for the TM. The baseline design document indicates that the number of sub-arrays could be as large as the number of antennas. This places very stringent requirements across the entire TM, for example for observation scheduling, real time data quality checks, data display etc. On the other hand we note that the requirement to have a sub-array that consists of only one antenna is a common requirement at most observatories, the typical use being for maintenance/testing/debugging. The total number of simultaneous sub-arrays that need to be supported has to be factored into the architecture and design from the start.

3.4.3 Availability and Reliability

The keys to achieving high availability and reliability are comprehensive detection of hardware and software failures, identification of gaps between actual and desired behavioural parameters, and automated handling of detected gaps and adverse situations, both reducing or eliminating downtime and avoiding propagation of faults across the system.

Given the large number of components in the SKA, handling of faults arising from faults will have to assume that (1) at any given time, multiple components in the system will experience various kinds of failures and (2) multiple alarms will arise even for a short observation. Hence the Telescope Manager will have to function assuming that alarms are a routine rather than a rare occurrence. The MGT will also have to function in such a way that operator intervention is not expected for a majority of alarms, and hence automated alarm management is a key requirement.

Fault detection will be performed mainly by the local hardware and the local M&C, along with monitoring of software functioning and system behavioural parameters, with some input from the regional or higher level M&Cs as well based on analysis and correlation of monitored data. This is essential since faults can occur in a single component as well as across multiple components or in the network between them. Detection will be done based on look-up tables of allowed range of values, timeouts, pattern recognition, external input etc.

There are various issues related to alarm handling in a hierarchical multi-component distributed system like the SKA, e.g. nuisance alarms, stale alarms, progressive alarms, etc. The alarm handling by the MGT will need to ensure these issues are taken care of, by using standard industry practices like alarm aggregation, abstraction, over-riding, asynchronous notification, suppression, filtering and so on.

The Telescope Manager needs to, at a minimum,

- Impose a common interface for alarm reporting across the local M&Cs
- Collect alarm information from throughout the system
- Implement a hierarchical structure of alarm handling
- Decide on the level of seriousness and hence the required action taken
- Allow for the alarm to handled entirely at the local M&C level if needed
- Provide high level abstraction and progressive alarm escalation and handling of multiple alarms and cascades
- Present alarms through a suitable interface to the operator and users with room for evolution
- Provide drill-down capability to the operator to investigate a high level alarm
- Provide suitable information to the operator in case of shut-down of components at the local or regional level
- Provide for differentiated action from operator and users
- Support recovery from faults and operational continuity
- Support physical fault recovery operations at remote sites
- Log all alarms and action taken

3.4.4 Safety and Security

The responsibility for people and equipment safety follows the principles of local autonomy and redundancy, so that safety concerns are addressed with a high degree of reliability and with short latencies. The safety mechanisms are based on the detection and response mechanisms used for reliability and availability, except that every safety scenario includes redundant backup checks.

Security concerns include network security, physical security and system security. Networking-related threats include unauthorized intrusion, deliberate attacks as well as unintentional misuse. These concerns will need to be addressed in collaboration with SADT, in which we are a participant. Physical security concerns will be addressed by Infrastructure with supporting capabilities from Telescope Manager to monitor data, detect unexpected behaviours and implement control responses. System security against malware, unauthorized data access and commands from unauthenticated sources needs to be addressed by adding controls at appropriate points in the system.

3.4.5 Meta-data

A key performance parameter for the TM is the extent of metadata support provided. Metadata are any auxiliary data needed to interpret and process the science data. They also serve as a view of the state of the system. MGT will need to collect such metadata and send it to the operator and user as well as save them in the archive. The metadata will be abstracted from all the information the MGT system accesses directly as well as through interfaces to multiple systems. Metadata will be associated with particular datasets which can occur in different modes (astronomy observations, debugging and maintenance, commissioning etc). Metadata will be made of both static data (specified in system configuration files, of which a subset can be chosen to be passed on to the user) and dynamic (like alarms, M&C information, etc).

The set of possible metadata can be quite large and standard sets of metadata will be provided to the user based on standard profiles for different classes of observations (e.g. pulsar, continuum, line). If the user wishes, they can customize the metadata set written out for their observation. Of the metadata gathered, depending on the user privileges and modes, different subsets will be made visible (from the archive). Also, the archive should allow drill-down from the metadata down to the local level system parameters if needed. In fact, the user should be able to recreate the metadata for an observations from the engineering and science archives at any time. This would include the ability to change or delete erroneous metadata, with these changes being tracked in the logger.

The architecture of metadata collection, and its connection with the hierarchy of the MGT will need to be explored. Different metadata will be collected and stored at different time. The set of metadata to be gathered will be defined by Science Data Processing as requirements to the Telescope Manager. CSP will also provide requirements to the Telescope Manager for system parameters to be supplied and control responses to be implemented.

Monitor and metadata data collected or generated by the Telescope Manager is expected to be useful to different classes of users. For example, astronomers (primarily via tasks in the SDP work package) would use metadata regarding the instrument setup as well as monitor data regarding instrument performance/failure, etc. Operators would need a high level overview of the current state of the system. Engineers would like to examine various monitor points to assess the performance of the system/debug problems etc. Telescope operations/management would use monitor data to verify the system performance at various levels, e.g. to answer questions like: are the uptime requirements being met? Are there sub-systems whose failure rates are outside permissible limits, etc? Each of these applications would have storage times associated with them. The storage time for different classes of monitor and meta data will have to be determined after discussions with the concerned stakeholders. Meta/monitor data associated with astronomical observations could have long storage requirements, and some of these are likely to be separately archived by SDP. Evolution in both the data to be stored and the storage time is to be expected over the lifetime of the telescope. For example, as the processing algorithms evolve, it is possible that monitor data that was earlier being ignored can be used to improve the quality of the final data products.