MONITORING AND CONTROL ELEMENT LEVEL REQUIREMENTS

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TABLE OF CONTENTS

Contents

LIST OF FIGURES

LIST OF ABBREVIATIONS

AD	.....	Applicable Document
CoDR	.....	Concept Design Review
DDBH	.....	Digital Data Back Haul
DRM	.....	Design Reference Mission
DSRR	.....	Domain System Requirements Review
HMI	.....	Human Machine Interface
ID	.....	Identity
LRU	.....	Line Replaceable Unit
M&C	.....	Monitor and Control
RFI	.....	Radio Frequency Interference
SATS	.....	Synchronisation and Timing Sub-System
SKA	.....	Square Kilometre Array
SKA1	.....	Square Kilometre Array Phase 1
SRR	.....	System Requirements Review
STaN	.....	Signal Transport and Networks
TBC	.....	To Be Confirmed
TBD	.....	To Be Determined
TBW	.....	To Be Written
UTC	.....	Co-ordinated Universal Time

GLOSSARY

Central M&C: The portion of the M&C system that is located at the Operations & Maintenance Centre, and responsible for management of the system as a whole rather than a portion of it.
Domain M&C: An auxiliary M&C system that manages resources belonging to a particular domain e.g. signal transport equipment, power equipment. This is developed (or acquired) by that domain and is outside the primary M&C hierarchy.
Entity: A generic term that may span any granularity from Element to Component to Part.
Local M&C: The lowest tier of the monitoring and control hierarchy, which interfaces to the sensor and actuator hardware.
Monitoring points: Data items (including logs and reports), alarms etc. that are forwarded up the system periodically or on occurrence of events from the point of origin. Monitoring points may be processed, combined or abstracted by receivers to generate new monitoring points.
Regional M&C: M&C functionality that has primary responsibility for management of a portion of the system. This could be a station, a portion of the Core, or the collection of sensors and actuators in the system that is not associated with any station or Core.

1 Introduction

1.1 Scope of the document

This document relates to the Phase 1 SKA Monitoring and Control Domain Element and its Sub-elements. It is of maturity commensurate with a Concept level of definition of the M&C Domain and the SKA Observatory as a whole.

It also forms the working basis of the Domain Requirements Document to be prepared for the future System Requirements Review, and its Table of Contents is intended to be subject to the present Review.

1.2 Purpose of the document

The purpose of this document is to provide a summary of all flowed, derived, allocated and introduced Requirements pertaining to the full life cycle of the Domain.

2 References

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.

[1] SKA Phase 1 System Requirements Specification, T. Stevenson et. al, SKA Project Document - WP2-005.030.000-SRS-002.
[2] SKA Science Working Group, "*The Square Kilometre Array Design Reference Mission: SKA Phase 1*", report, v.1.3, January 2011.
[3] SKA Configurations Design, R. Bolton et al, SKA Project Document – WP3-050.020.000-R-002, 2011-02-17.
[4] K. Cloete et al, 'Strategies and Philosophies', document WP2-005.010.030-TR-001, Rev F.
[5] Operational Concepts WP2-001.010.010PLA-002
[6] Quality Assurance & Safety Plan WP2-005.080.010-PLA-001 TBW
[7] RFI/EMC Control Plan WP2-005.080.020.PL-001 TBW
[8] Design & Development Plan WP2-005.080.030-PL-001 TBW
[9] Environment Specification WP2-005.050.030-ENV-001 TBW
[10] Regulatory/Statutory Requirements Summary TBW
[11] SKA Reference and Applicable Standards TBW

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.

[12] Monitoring & Control Strategy, document WP2-005.065.000-R-001
[13] M&C Requirements for each Domain: Information Template WP2-005.065.050-RFI-001
[14] Inputs to M&C Development WP2-005.065.050-RFI-002

3 Requirement Overview

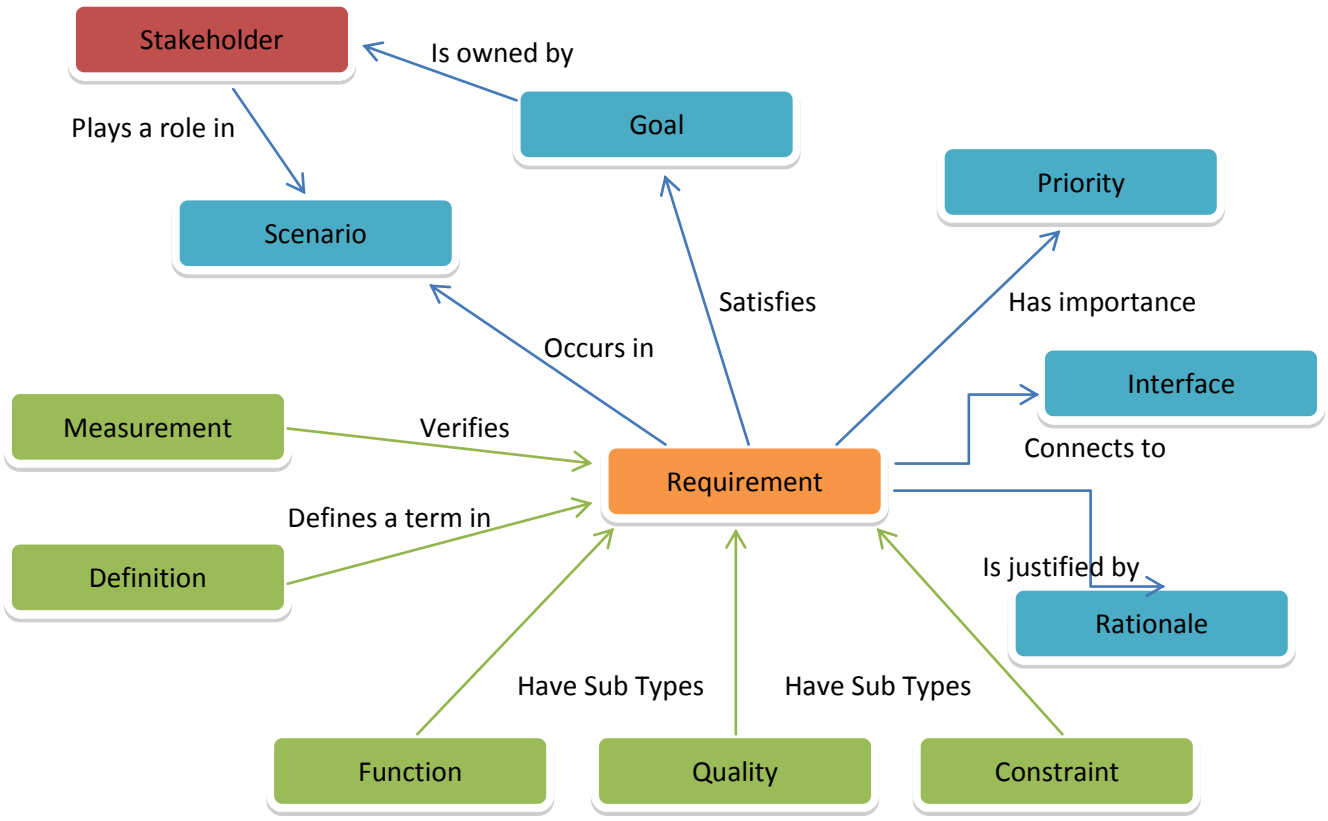

Figure 1 Requirement Context

Figure 1 (applicable to all levels of the system hierarchy) provides the context for the requirements. The interconnecting lines define the association between the blocks in the diagram. For example there are three sub types of requirement:

- Functional: A functional requirement is to define what is to be done
- Quality: A quality requirement is to change the way something is done. Quality requirements include: safety, security, reliability, performance, maintainability, and environment.
- Constraint: Constraints are restrictions or limitations on possible solutions.

Each of these requirements is to satisfy a goal owned by a particular stakeholder that plays a role in a scenario of the system. Scenarios are associated with the modes and configurations of the system and define the dynamic behaviour.

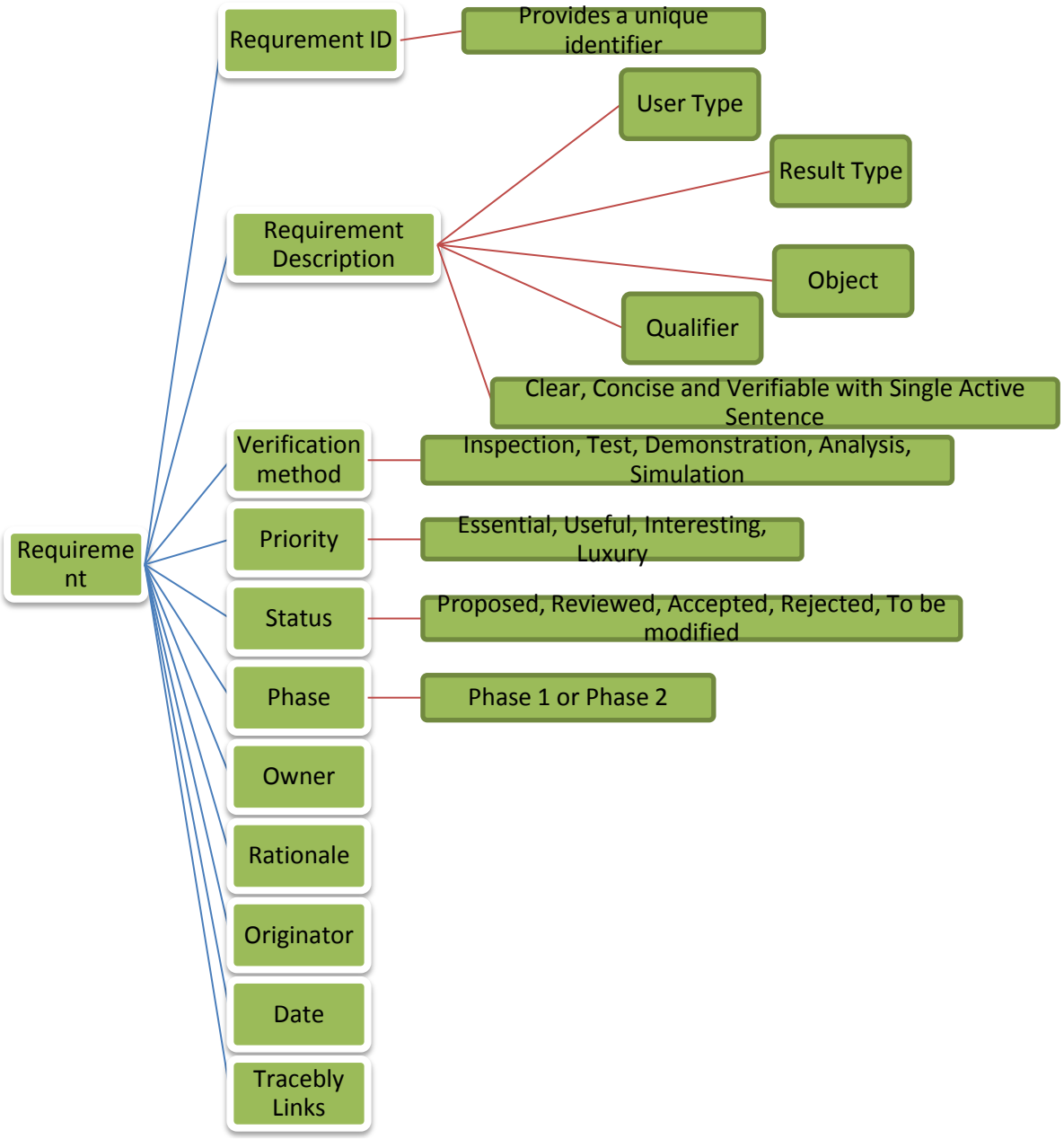

Figure 2 Requirement Structure

As detailed in Figure 2 a requirement comprises of more information than just the requirement description. This information in effect forms attributes for the requirement.

3.1 Attributes

Requirement ID

The Requirement ID provides a unique identifier for each individual requirement. The Requirement ID takes the form:

<string>_REQ_xxxx

The sting provides a unique descriptor identifying the item within the systems hierarchy that the requirement set is applicable to

xxxx is a four digit decimal number uniquely identifying the requirement within the requirement set. For example:

"SYS_REQ_0010" identifies the first requirement at the systems level.

Requirement Description

The requirement description has to be clear, concise and verifiable:
The requirement should be a single active sentence as short as possible.
The requirement should focus on naming a single desired result
Every requirement should be verifiable
Requirements should avoid conjunctions such as: "and", "or", "with" and "also" as these tend to wrap multiple requirements into one which is not desirable.
Requirements should not specify the design envelope.
The anatomy of the requirement should contain:

User type: A noun identifying the beneficiary of the requirement
Result Type: A verb identifying the action of the requirement
Object: The object that the verb is applicable to
Qualifier: Adverbal phrase identifying the desirable result of the action

An example:
The call centre operator shall be able to view details of the protected household within two seconds of issuing the query

User type: The call centre operator
Result Type: shall be able to view
Object: details of the protected household
Qualifier: within two seconds of issuing the query

Verification Method

As stated in the requirement description, all requirements are to be verifiable. The method of verification is to be attached as an attribute to the requirement. The method of verification should be one of the following:

- Inspection
- Test
- Demonstration
- Analysis
- Simulation
- Design

Priority

The priority of the requirement is to be attached as an attribute to the requirement. The priority should be identified by one of the following:

- Essential
- Useful
- Interesting
- Luxury

Status

Requirements are not static statements but have a life-cycle. The status within the life-cycle should be identified by one of the following:

- Proposed
- Reviewed
- Accepted
- Rejected
- To be modified

Phase

Whether the requirement is applicable to Phase 1 or Phase 2 of the SKA should be identified by an attribute associated with the requirement:

- Phase 1

- Phase 2

Originator

The originator of the requirement should be attached as an attribute.

Date

The date that the requirement was created should be attached as an attribute.

Rationale and Assumptions

Making assumptions explicit and connecting them to an argued rationale enables decisions to be re-visited without starting all over again. An understanding of rationale enables accurate prioritisation and is an aid to preventing essential requirements from being deleted.

Applicability

TBD

Traceability links

The bidirectional relationships between System level requirements and the domain level requirements.

3.2 Requirements Context

The requirements for M&C form part of the overall system hierarchy as illustrated in Figure 3.

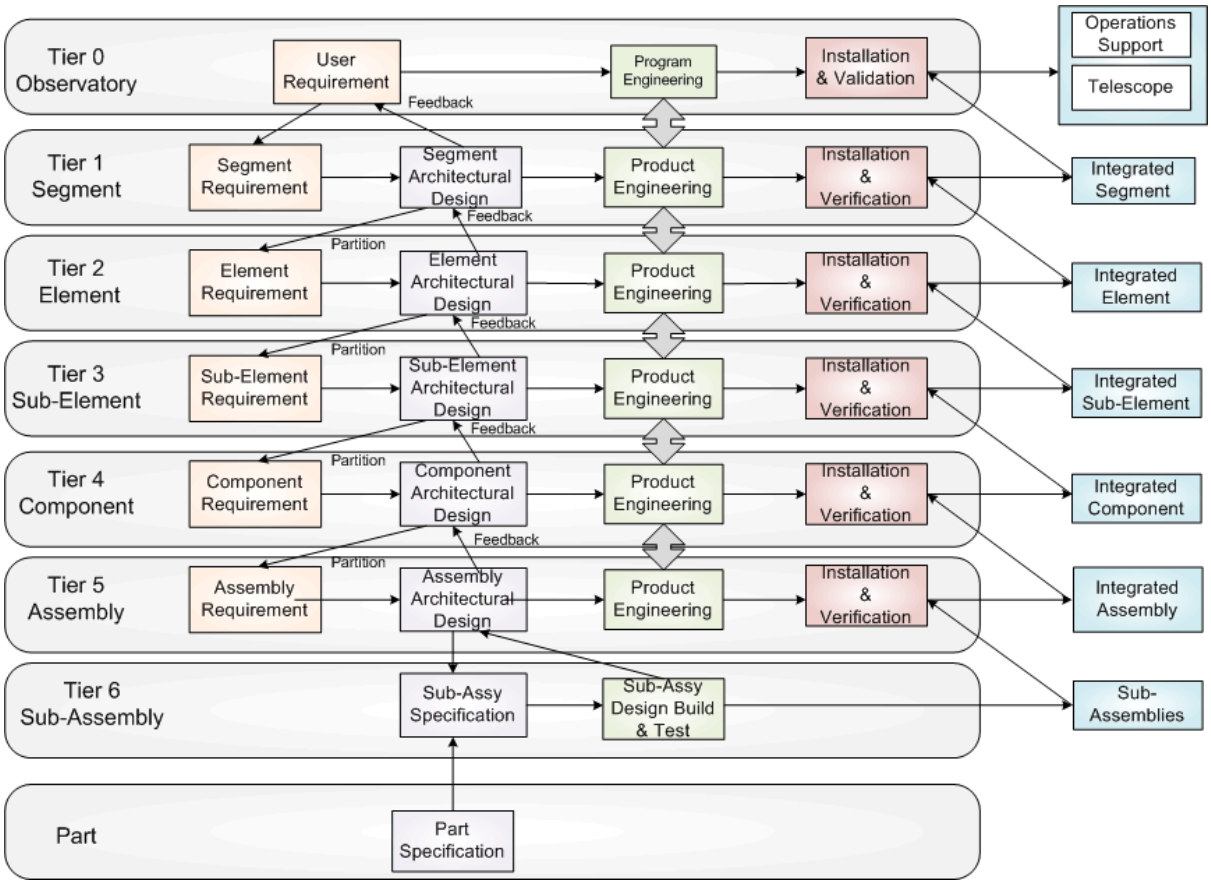

Figure 3 Requirements Hierarchy

Each tier in the hierarchy has its own set of requirements which are derived from the next hierarchical tier above. There is also a feedback path via the architectural design process to inform the requirements at the higher tier whether there are any issues. The flow-down and feedback is an on-going process iterating towards a stable and eventually base-lined requirement set.

The initial requirements for the concept phase of M&C system which will be operational from segment level downwards in the hierarchy is the scope of this document. It identifies the subset of concept phase system requirements that are applicable to M&C and presents additional requirements where there are gaps. This process forms part of an iterative feedback path to the system level. In the next phase these requirements will be refined so that they can be utilised by each of the lower level components in the hierarchy. M&C features are expected to manifest themselves at all levels either as part of the System M&C interface or local M&C.

3.2.1 Definition Phase

The aim of the next phase in the project is the definition of the requirements. The quality, design, development and other requirements will be developed in the next phase and the constraints identified. These will be presented at the M&C System Requirements Review.

In this phase requirements analysis and validation are undertaken in order to ensure that the complete set of requirements is understood and is present. Gaps will be identified and actions to address these shortcomings will be initiated. The result of these activities will be captured in the relevant Requirement Specifications to be reviewed at the conclusion of this phase.

This phase will be concluded by the domain System Requirements Review (SRR).

3.2.2 M&C System structure

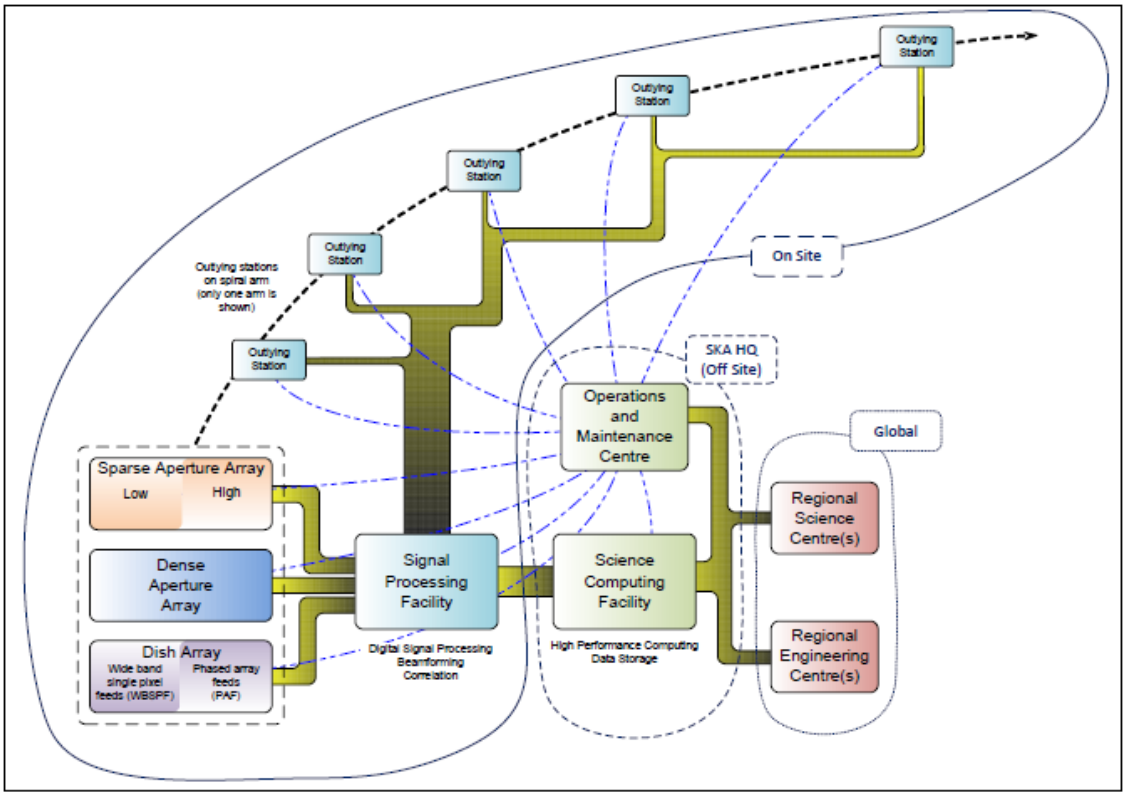

Figure 4. Scale free layout of SKA

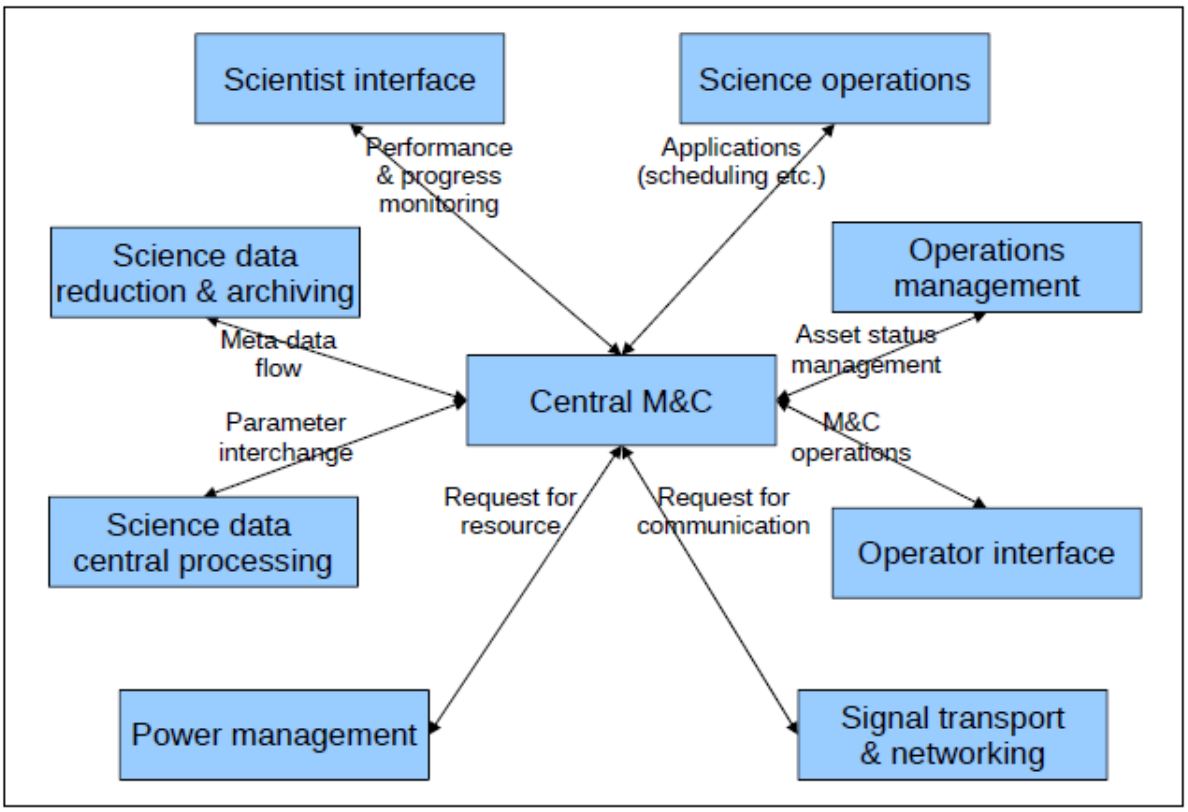

Figure 5 M&C interactions with other Elements

M&C has interactions with nearly every other Element, as shown in Figure 5.

The M&C system is central to the function and use of the SKA since its role includes the control and coordination of all the other elements and their parts, as well as facilitating and monitoring their operations. Although at the Element level it can be viewed as being at a level above from a control and coordination perspective.

M&C for SKA is structured into three logically hierarchical tiers as shown in Figure 6. SKA Components such as receptors, power equipment, signal transport equipment, beam-formers, cross correlator etc. have their own Local M&C systems that provide all the internal monitoring, control and coordination capabilities needed to ensure proper functioning of their Component. These M&C systems are typically developed as part of the Component, and include sensors and actuators to monitor and control the physical equipment and its environment. The functioning of all the Components in a region is monitored, controlled and coordinated by a Regional M&C system. The Local M&C of all the Components send their monitoring data, including alarms, errors and events, to the Regional M&C, and accept control and coordination commands from the Regional M&C. In turn, all the Regional M&C systems are monitored, controlled and coordinated by a Central M&C system. Operators and other users interact with Central M&C to direct the functioning of the instrument and manage its health status.

M&C in general will address the requirements of managing the instrument, managing the observation preparation and observation execution and creating the integrated data stream as output with science data and metadata incorporated into the stream. M&C will mandate a

consistent interface to all levels of M&C for communication, error reporting etc. These aspects will be elaborated upon in the design documents.

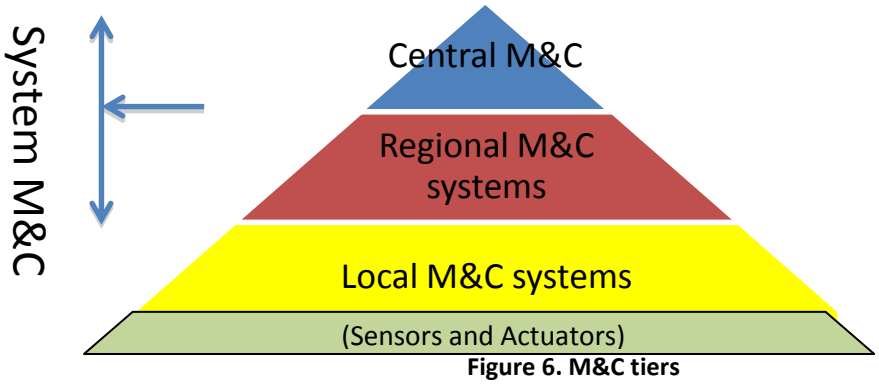

Figure 6. M&C tiers

3.2.3 Applicability to AD[1]

This section provides an Applicability Matrix showing the Applicability of AD[1] Requirements to the M&C Domain and whether the requirement has been analysed in the scope of the M&C CoDR.

Requirement ID	Requirement text	Applicability to M&C	In CoDR scope
SYS_REQ_1110	Electromagnetic frequency range. SKA1 shall be able to measure electromagnetic radiation in a frequency range from 70 MHz to 3 GHz.	No	No
SYS_REQ_1120	Instantaneous bandwidth. SKA1 shall have an instantaneous bandwidth, of: Fractional instantaneous bandwidth: 1 The SKA Phase 1 shall be designed so that the fractional instantaneous bandwidth is comparable to the observing frequency.	No	No
SYS_REQ_1130	Frequency band positioning. It shall be possible to position this band anywhere within the operating frequency band, with a positioning accuracy as specified in SYS_REQ_1970 and SYS_REQ_1980. The instantaneous observable Frequency band is a contiguous (TBC) band selected from the total frequency range.	Yes	Yes
SYS_REQ_1140	Band selection resolution. The resolution with which the 500 MHz and 1 GHz bands can be selected shall be TBD or less.	Yes	Yes
SYS_REQ_1150	Polarization frequency equality. It shall not be possible to select different digitized bands for the two polarizations of a single dish/antenna/array.	Yes	Yes
SYS_REQ_1160	Sub-band bandwidth. The sub band bandwidth after station level beam forming shall be less than TBD Hz.	No	No

SYS_REQ_1170	DSP signal processing capacity. The digital processing capacity shall be sufficient to process all sub-bands (Q: and beams, and polarizations, or should there be exchangeability).	No	No
SYS_REQ_1180	Beam sub-band and channel phase relations. The phase relations between the sub-bands and channels within a beam shall be known to such a precision that wider bands and corresponding time series can be reconstructed from sub-bands and/or channels.	No	No
SYS_REQ_1190	Spectral baseline. The SKA Phase 1 shall be designed so that the band pass does not show ripples or systematic fluctuations, on scales smaller than a frequency corresponding to about 300 km s^{-1}, that are larger than twice the thermal noise level after an integration of 1000 hr.	No	No
SYS_REQ_1210	Spectral resolution. SKA1 shall offer a spectral resolution in each polarization for science processing of: < 200 Hz in the band 70 to 240 MHz; 'The SKA Phase 1 shall provide a frequency resolution of at least 0.2 kHz.'	No	No
SYS_REQ_1211	Spectral resolution. SKA1 shall offer a spectral resolution in each polarization for science processing of: < 10kHz in the band 400MHz to 3 GHz	No	No
SYS_REQ_1212	Spectral resolution. SKA1 shall offer a spectral resolution in each polarization for science processing of: 100kHz in the band 70 to 240 MHz; 'This requirement follows directly from the radial resolution science requirement. For reference, assuming the concordance cosmology, at these redshifts, the co-moving length is given by ≈ 1.7 Mpc (ν/100 kHz). Therefore, to match the angular resolution a frequency resolution of about 100 kHz is required.'	No	No
SYS_REQ_1213	Spectral resolution. SKA1 shall offer a spectral resolution in each polarization for science processing of: 1 kHz in the band 70 to 240 MHz; 'In practice a more stringent requirement of 1 kHz in frequency resolution is required to identify and excise RFI, reduce bandwidth smearing, and calibrate ionospheric effects.	No	No
SYS_REQ_1220	Sub-band and channel phase relations. The signal processing performed on each sub-band shall leave the relative phases of sub bands and spectral channels intact or predictable.	No	No
SYS_REQ_1230	Spectral dynamic range. SKA1 shall have a spectral dynamic range of: ≥61 dB in the band 70MHz to 240 MHz	No	No
SYS_REQ_1231	Spectral dynamic range. SKA1 shall have a spectral dynamic range of: ≥43 dB in the band 200 MHz to 1.4 GHz	No	No

SYS_REQ_1310	Sensitivity (Aeff/Tsys). The SKA1 shall have a sensitivity of: 10^3 m^2 K^{-1} in the frequency range 70 MHz - 240 MHz	No	No
SYS_REQ_1311	Sensitivity (Aeff/Tsys). The SKA1 shall have a sensitivity of: 10^3 m^2 K^{-1} in the frequency range 400 MHz - 3 GHz	No	No
SYS_REQ_1312	Sensitivity (Aeff/Tsys). The SKA1 shall have a sensitivity of: 10^5 m^2 K^{-1} in the frequency range 800 MHz - 3 GHz	No	No
SYS_REQ_1410	Survey speed. The SKA1 survey speed requirement is: ~10^7 m^4 K^{-2} deg^2 for the frequency range 200MHz to 1.4 GHz	No	No
SYS_REQ_1411	Survey speed. The SKA1 survey speed requirement is: >10^7 m^4 K^{-2} deg^2	No	No
SYS_REQ_1420	The SKA Phase 1 shall be designed so that a major survey can be completed in 2 years of "on-sky" observation time.	No	No
SYS_REQ_1430	The SKA Phase 1 shall be designed so that a deep field can be completed in 1000 hr of integration time.	No	No
SYS_REQ_1510	Baseline. The SKA1 minimum baseline requirement is: 200 km for the range 70 to 240 MHz	No	No
SYS_REQ_1610	Main beam stability. The magnitude and phase variations of any SKA1 compound beam over a 12 hours period at any point of its half-power contour shall be less than 1% (TBC) relative to the beam peak.	Yes	No
SYS_REQ_1620	Temporal resolution. The SKA Phase 1 shall have an attainable time resolution of at least as short as 50 µs.	No	No
SYS_REQ_1621	Temporal resolution shall be 100 µs	No	No
SYS_REQ_1630	Spatial side-lobe stability. Spatial side lobes should be stable to within TBD.	Yes	No
SYS_REQ_1640	Beam former weight update rate. Changing the beam former weights shall be possible every 60 seconds (TBC) in the case of scheduled switching sequences.	Yes	No
SYS_REQ_1650	Beam former weight ad-hoc update response time. Changing the beam former weights shall be possible within 60 seconds in case of changes due to manual interaction or changes in schedule.	Yes	No
SYS_REQ_1660	Beam-switching downtime flagging. Observation data (specify: both uv(w)-data and tied array beams) acquired during a change of beam direction shall be flagged.	Yes	Yes
SYS_REQ_1670	The SKA shall be able to 'switch between observing frequencies within 10 minutes or less' (in the band 0.8–3 GHz)	Yes	Yes
SYS_REQ_1671	The SKA shall be able to provide 'near simultaneous access to multiple frequencies'	Yes	Yes

SYS_REQ_1710	Beam polarization stability. The polarization properties of the beams shall be stable enough to allow their calibration to better than 0.5% (TBC)	No	No
SYS_REQ_1720	External calibration measurements shall be necessary at a rate of no more than once per hour (TBC).	No	No
SYS_REQ_1730	Stokes parameters. SKA1 shall provide visibility data in all four Stokes parameters.	No	No
SYS_REQ_1740	Instrumental polarisation. The polarisation introduced by the instrument, after calibration, shall be less than 0.5% of the total intensity. (TBC)	Yes	No
SYS_REQ_1810	The SKA1 shall have limited (TBD) susceptibility to bursty/spiky RFI (for pulsars, transients)	No	No
SYS_REQ_1820	Transient RFI detection. The post station level processing shall detect and flag invalid data.	Yes	Yes
SYS_REQ_1910	These requirements imply a field of view greater than 5 degrees.	No	No
SYS_REQ_1920	Field of view imaging. It shall be possible to image the entire field of view	No	No
SYS_REQ_1940	Imaging dynamic range. SKA1 shall be able to provide an imaging dynamic range for continuum imaging (thermal noise imaging to classical (micro Jansky (Jy)) confusion limits) of at least: 35dB for the band 200MHz-1.4 GHz	No	No
SYS_REQ_1941	'studies of star formation at high redshift with a continuum deep field require a dynamic range of 74 dB in imaging'	No	No
SYS_REQ_1950	Dish beam absolute pointing accuracy. The pointing accuracy of the dish beams is: TBD	Yes	No
SYS_REQ_1960	AA beam absolute pointing accuracy. The pointing accuracy of the AA beams is: TBD	Yes	No
SYS_REQ_1970	Dish beam pointing estimation accuracy. The pointing estimation accuracy of the dish beams is: TBD	Yes	No
SYS_REQ_1980	AA beam pointing estimation accuracy. The pointing estimation accuracy of the AA beams is: TBD	Yes	No
SYS_REQ_2110	M&C. SKA1 shall provide a monitoring and control function.	Yes	Yes
SYS_REQ_2120	M&C purpose. The monitoring and control function shall ensure that all parts of the system work together coherently. All control functions, except certain local maintenance functions, are part of the M&C system.	Yes	Yes
SYS_REQ_2130	M&C failure detection. The monitoring and control function shall ensure that failures in hardware, software or signal transport are detected and reported.	Yes	Yes
SYS_REQ_2140	M&C autonomy. The monitoring and control function shall take autonomous action to ameliorate failures where possible and support a fail-safe	Yes	Yes

	philosophy.		
SYS_REQ_2150	M&C shall take autonomous action in safety critical situations such as system power failure, over-temperature, and storms (dish-stowing).	Yes	Yes
SYS_REQ_2160	M&C transparency. The monitoring and control function shall give user transparent and hierarchical access to the instruments functions and parameters.	Yes	Yes
SYS_REQ_2190	M&C remote operation. The monitoring and control function shall be designed to operate the instrument fully remotely.	Yes	Yes
SYS_REQ_2210	M&C performance monitoring. The monitoring and control function shall provide TBD performance monitoring data to users.	Yes	Yes
SYS_REQ_2220	M&C monitoring data. All SKA1 subsystems shall provide monitoring data to the monitoring and control function (for performance monitoring and closed-loop control functions)	Yes	Yes
SYS_REQ_2230	M&C logging. The monitoring and control function shall provide for a long-term logging sub-function with workflow support for the Operational Team and with sufficient information to relate system events to artefacts in the data.	Yes	Yes
SYS_REQ_2240	MM&C observation interrupts. It shall be possible to abort an observation if monitor parameters exceed user specified limits (including RFI mitigation performance indication parameters).	Yes	Yes
SYS_REQ_2250	M&C calibration information. Individual element calibration information shall be available to the measurement function.	Yes	Yes
SYS_REQ_2310	Control system. SKA1 shall have a control system that actively controls all system settings in the instrument.	Yes	Yes
SYS_REQ_2320	Control system autonomy. The control system shall be capable of autonomously calculating system settings in response to changes in instrument status, environment or measurement results.	Yes	Yes
SYS_REQ_2330	System settings activation. It shall be possible to activate the calculated system settings either automatically (autonomous control) or after explicit confirmation by the operator (manual control).	Yes	Yes
SYS_REQ_2340	System setting activation autonomy. It shall be possible to specify when settings should be activated automatically and when they need to be confirmed by the operator.	Yes	Yes
SYS_REQ_2350	Schedule update. It shall be possible to receive and accept updated schedules before the end-time of the currently active schedule has expired.	Yes	Yes
SYS_REQ_2410	Monitoring data consolidation. It shall be possible to consolidate monitoring information to produce high-level monitoring information from low-level	Yes	Yes

	monitoring information.		
SYS_REQ_2420	Subsystem-M&C action reports. Subsystems shall report completion of actions to M&C	Yes	Yes
SYS_REQ_2430	S&C summary reports. It shall be possible for all user roles (specification of these roles TBD) to produce summarized historical monitoring information.	Yes	Yes
SYS_REQ_2440	Control data augmentation. The results of control actions shall be verified with measurements made expressly for the purpose.	Yes	Yes
SYS_REQ_2441	If the normal measurement sequence does not provide for control verification in a timely fashion, such measurements shall be made out of sequence.	Yes	Yes
SYS_REQ_2450	Monitoring information consolidation. It shall be possible to consolidate monitoring information both on the physical instrument status and on designated logical concepts like observation, correlators.	Yes	Yes
SYS_REQ_2710	Synthesis imaging mode. SKA1 shall provide a synthesis imaging mode where compound beams are correlated to form visibilities.	Yes	Yes
SYS_REQ_2720	Visibilities. In synthesis imaging mode it shall be possible to form visibilities between all corresponding monochromatic compound beams (same frequency, same direction) from all dishes or all aperture arrays (stations). This means that the central processing function should be able to handle the full data stream from the dishes or aperture arrays in synthesis imaging mode.	Yes	Yes
SYS_REQ_2730	Tied array mode. SKA1 shall provide a tied array mode where the signals from all dishes are phased up, after real-time correction of instrumental effects, and transformed back into time series for pulsar processing.	Yes	Yes
SYS_REQ_2740	Fly's eye mode. SKA1 shall provide a fly's eye mode (TBC). In this mode the Autocorrelations of all single dishes / aperture (sub) arrays are recorded. Each dish / sub-array is tracking a different position on the sky.	Yes	Yes
SYS_REQ_2750	Aggregate mode. SKA1 shall provide an aggregate mode in which bandwidth is exchanged for spatial coverage in the correlators.	Yes	Yes
SYS_REQ_2760	Real-time calibration. SKA1 shall provide instrumental real-time calibration functions in all observational modes.	Yes	Yes
SYS_REQ_2770	Re-processing archive data. It shall be possible to re-process data retrieved from archive. To which extent this will be supported needs further discussion.	Yes	Yes
SYS_REQ_2810	Automated data products. SKA1 shall be able to produce final data products based on automated and interactive (manual) processing of acquired	Yes	Yes

	data.		
SYS_REQ_2820	Data product types. SKA1 shall produce recordable intermediate data products, for example pulsar voltage time series and RFI statistics.	Yes	Yes
SYS_REQ_3110	Up-time. SKA1 shall be aimed to be operated continuously (7 days per week 24 hours per day).	Yes	Yes
SYS_REQ_3130	Remote M&C from sites. It shall be possible for the operator to control and monitor the SKA1 instrument from the SKA station sites and core site.	Yes	Yes
SYS_REQ_3140	Physical access security. The system shall provide security to prevent unauthorized physical access to facilities and resources.	Yes	Yes
SYS_REQ_3150	Reconfiguration time. Reconfiguration of SKA1 from one observational mode to another shall not take longer than 5 minutes (TBC) provided all software applications are present at their designated location.	Yes	Yes
SYS_REQ_3160	Full remote control. It shall be possible to control all SKA1 functions from the operational centre, without requiring physical access to the instrument, including start-up and shut down.	Yes	Yes
SYS_REQ_3170	Start-up sequence. The start-up of SKA1 functions shall follow a pre-defined sequence taking not longer than: 10 minutes for a hot start (= restart)	Yes	Yes
SYS_REQ_3171	Start-up sequence. The start-up of SKA1 functions shall follow a pre-defined sequence taking no longer than: 24 hours for a cold start	Yes	Yes
SYS_REQ_3180	Start-up and shut-down individual antenna systems. It shall be possible to start-up or shutdown individual dishes or aperture arrays without disturbance [TBC] of routine operations.	Yes	Yes
SYS_REQ_3190	Shut-down sequence. The shutdown of SKA1 shall follow a pre-defined sequence taking no longer than TBD minutes. SKA1 shall also have an emergency shut-down for wind (stowing dishes), lightning, and electric power anomalies.	Yes	Yes
SYS_REQ_3210	Control over start-up and shutdown. Initialization of shut-down and start-up sequences shall be restricted to designated operators and engineers. To be defined: security requirements on different access levels (e.g. engineering mode).	Yes	Yes
SYS_REQ_3220	Start-up and shut-down dependencies. Any dependencies in the start-up and shutdown sequences shall be automatically verified (so they do not depend on operator intervention).	Yes	Yes
SYS_REQ_3230	Subsystem shut-down. The shutdown of pre-defined parts of the SKA1 system shall have no (TBC) impact on SKA1 operations after appropriate re-calibration performed automatically.	Yes	Yes
SYS_REQ_3240	Initial check-out. SKA1 shall be designed to enable	Yes	Yes

	an operational readiness check, including redundancies, prior to commencement of any SKA1 operations (initial check-out).		
SYS_REQ_3250	Operational readiness check. The operational readiness check shall not take longer to complete than 5 minutes.	Yes	Yes
SYS_REQ_3310	Personnel safety. As far as possible, no single failure in the SKA1 shall lead to personnel safety hazards.	Yes	Yes
SYS_REQ_3320	Failure propagation. Failures in one of the SKA1 subsystems shall not lead to failures in other subsystems.	Yes	Yes
SYS_REQ_3330	Operator command safety. No single operator command shall cause catastrophic, serious, or major consequences. The possible consequences are loss of life, injury, major equipment failure, loss of data, downtime, unscheduled maintenance requirements etc.	Yes	Yes
SYS_REQ_3340	Voltage transient's consequences. No voltage-transients or "cut-off" of electrical power shall lead to catastrophic or serious consequences. This includes voltage transients applied to the input of the receivers.	Yes	Yes
SYS_REQ_3350	Operator command absence. The absence of operator commands shall not cause catastrophic or serious consequences.	Yes	Yes
SYS_REQ_3360	Single-point failures. Single-point failures in the design shall be listed.	Yes	Yes
SYS_REQ_3370	Single-point failure justification. Each-single-point failure in the design shall be justified, and assessed against alternative design(s) where this single-point failure would not occur.	Yes	Yes
SYS_REQ_3380	Single-point failure watchdog. The correct functioning of each single-point-failure in the design shall be monitored by a watchdog function.	Yes	Yes
SYS_REQ_3410	Failing equipment. Failing equipment shall not provide data (TBC). Failing equipment shall indicate the problem if power is on, and the control function shall take appropriate measures.	Yes	Yes
SYS_REQ_3520	Status report availability time. The status report of the functioning of a subsystem shall be available in 5 seconds.	Yes	Yes
SYS_REQ_3530	Status report request. The status report of a subsystem shall reflect the functioning of the subsystem at or after the operator request has been submitted to the system.	Yes	Yes
SYS_REQ_3540	Status report scope. The status report shall display the status of a function, together with the system time the status was determined.	Yes	Yes
SYS_REQ_3610	System interrogation reply. Each dish or aperture array system shall have the capability to answer to	Yes	Yes

	an operator interrogation, in case of detected failures at the dish, which antenna chain has failed.		
SYS_REQ_3620	System autonomous and manual control modes. The system shall have the capability to be operated by an operator in an autonomous mode, and in a manual control mode.	Yes	Yes
SYS_REQ_3630	Autonomous malfunctioning actions. In the autonomous mode, all malfunctioning equipment and/or stations may be switched off autonomously, and a message with all details of this action shall be brought to the attention of the operator, and recorded in the systems log-file.	Yes	Yes
SYS_REQ_3640	Manual control switches on/off. In the manual control mode, the operator shall have the capability to switch on or off all equipment and/or stations.	Yes	Yes
SYS_REQ_3650	Operator actions logging. Operator actions shall be recorded in the systems log-file, in such a way that a complete picture of all correct functioning and/or all malfunctioning equipment, together with their operational and/or switch off statuses, can be achieved.	Yes	Yes
SYS_REQ_3660	Recovery actions. It shall be possible to take recovery actions without consequences for other parts of SKA1; the system shall minimize impact of recovery actions. The possible consequences can range from equipment damage and loss of data to unscheduled maintenance activity.	Yes	Yes
SYS_REQ_3670	Autonomous recovery. SKA1 shall be able to recover autonomously in case of failures that are classified as minor or negligible.	Yes	Yes
SYS_REQ_3680	Effect of disabled units. The SKA1 design shall ensure that disabled units do not corrupt the remaining system.	Yes	Yes
SYS_REQ_3710	Continuous operation period. SKA1 shall be designed for a continuous operational period of 6 month. After this time maintenance may be necessary, e.g. exchange/cleaning of air-conditioning filters and refurbishment of cryogenic systems.	Yes	Yes
SYS_REQ_3720	Minimum life time. SKA1 shall be designed for a minimum lifetime of TBD years, including initial installation, testing and commissioning period.	Yes	Yes
SYS_REQ_3730	Availability. The average availability of SKA1 during the operational period shall be better than 90% (TBC). Availability is defined here as being available for scheduled observations in at least one of the supported operational modes.	Yes	Yes
SYS_REQ_3740	Upgradeability SKA1 shall be upgradable.	Yes	Yes
SYS_REQ_3750	Life-time extension. Large scale maintenance and/or an upgrade shall give the possibility to reach a life time of 50 years (TBC)..	Yes	Yes

SYS_REQ_3810	Full fail rate. SKA1 shall be designed to fully fail less than two times per year (TBC), the number determined as average over its operational period.	No	No
SYS_REQ_3820	Repair period. The maximum period of repair once a failure of SKA1 has been established, shall be 1 (TBC) week. Here, a failure is defined as not being able to meet the scientific specifications due to (sub)system failure(s).	No	No
SYS_REQ_3830	Non-availability information. All users with scheduled measurements during the failure period shall be informed of the non-availability of the system	Yes	Yes
SYS_REQ_3840	Data loss due to power outage. All subsystems shall not lose more than 4 hours of acquired or processed measurement data (not yet permanently stored) as a result of an outage in the external power supply.	Yes	No
SYS_REQ_3850	Autonomous restart after power outage. All subsystems shall have the capability to restart autonomously and without failures, after an outage in external power supply.	Yes	Yes
SYS_REQ_3860	System availability after restart. All subsystems shall be available within 5 minutes (TBC) after restart. (Note – there may be subsystems such as cryo coolers that will probably not comply to the requirement and will need to be handled differently).	Yes	Yes
SYS_REQ_3870	Software/firmware reinstallation. All software/firmware in SKA1 shall allow its re-installation.	Yes	Yes
SYS_REQ_3880	Software/firmware upgrades. It shall be possible to replace all software/firmware configuration items in SKA1 through software upgrades, initiated by an engineer.	Yes	Yes
SYS_REQ_3890	Software code identification. Software configuration items shall provide unambiguous inputs to allow the maintenance of a configuration management database.	Yes	Yes
SYS_REQ_3910	Software code identification response time. The software identification shall be available to the operator within 10 seconds (TBC) after the request was made.	Yes	Yes
SYS_REQ_3920	Subsystem maintenance functions. All subsystems shall include functions that allow maintenance of hardware and software.	Yes	Yes
SYS_REQ_4110	Environmental rule compliancy. The SKA design shall be fully compliant to all environmental rules applicable to the SKA site.	Yes	Yes
SYS_REQ_4120	Lasting environmental effects. SKA shall be designed to have no lasting adverse environmental effects on	No	No

	the facility and site.		
SYS_REQ_5110	Climatic and environmental conditions. SKA shall be designed or protected against any deterioration leading to failure to meet the requirements specified herein caused by climatic and environmental conditions during its complete lifetime (both operating and non-operating).	Yes	Yes
SYS_REQ_5120	Compliancy with local environment. The design of SKA shall be appropriate (TBD) for operation in the natural environment for the geographical deployment location of the SKA.	Yes	Yes
SYS_REQ_5130	Transportation conditions. SKA equipment shall be designed for the induced transportation environment appropriate to the mode of transport being used (road, air, sea, etc.) between place of manufacturing and final installation on the SKA site (to be included: packaging requirements).	Yes	Yes
SYS_REQ_5210	Building climate conditioning. Buildings or parts of buildings containing central processing equipment and operator areas shall have a climatic conditioning system which can control the temperature within the range of 18 ºC to 23 ºC and the humidity within the range of 50 % to 70 % independent of weather conditions.	Yes	Yes
SYS_REQ_5220	Facilities and equipment intrusion. SKA equipment and operating facilities shall be adequately protected against intrusion by unauthorized persons or by “larger” wandering animals.	Yes	Yes
SYS_REQ_5230	Precipitation. SKA equipment shall be able to operate without degradation of the performance during any type of precipitation (to be specified).	Yes	Yes
SYS_REQ_5240	Pollution and contamination protection. SKA equipment shall be adequately protected against performance degradation caused by contaminating particles (dust, sand etc), polluted air or any precipitation.	Yes	Yes
SYS_REQ_5310	Humidity. SKA equipment located at the dishes or aperture arrays or outside the central processing and operating facilities shall be able to withstand moisture and humidity levels up to 100 % RH.	Yes	Yes
SYS_REQ_5320	Allowable air temperature range. SKA equipment located at the dishes or aperture arrays or outside the central processing and operating facilities shall be able to withstand (non-operating if necessary) an outside air temperature within the range of -15 ºC (TBC) to +60 ºC (TBC).	Yes	Yes
SYS_REQ_5330	Air temperature operation range. SKA equipment located at the dishes or aperture arrays or outside the central processing and operating facilities shall be able to operate within specification if the outside air temperature is within the range of -5 ºC (TBC) to	Yes	Yes

	+50 ºC (TBC).		
SYS_REQ_5340	Wind velocities. SKA equipment shall be able to survive wind velocities up to 160 km/hr (TBV), and shall operate within normal specification ranges for wind velocities up to 40 km/hr. (TBC).	Yes	Yes
SYS_REQ_5410	Damaging interference levels. SKA shall not be damaged by RFI signals less than TBD V/m.	Yes	Yes
SYS_REQ_5420	EM immunity. SKA shall not be susceptible to RFI signals, in-band or out-band, other than via the receptors.	Yes	Yes
SYS_REQ_5430	ADC clipping. The dynamic range of the ADC's in the SKA shall be such that no clipping will occur. Clipping occurs when the range of the input signal voltages to the ADC is larger than the ADC voltage range. The number of ADC bits shall therefore be sufficient to prevent clipping due to strong interfering signals such as airplane DME and satellite signals.	Yes	Yes
SYS_REQ_5610	EMC safety margin. The EMC safety margin, which is defined as the ratio between susceptibility threshold and the interference at any point within the system, shall be greater than TBD db.	Yes	No
SYS_REQ_5620	EMC compatibility marking. All "off-the-shelf" equipment applied within SKA shall possess as a minimum the host country EMC marking, including electrical and electronic supporting and infrastructural equipment.	Yes	No
SYS_REQ_5630	Grounding concept. A hybrid grounding concept as shown in figures TBD shall be used for EMC purposes. Ground loops involving DC, and low frequency AC, currents shall be avoided inside the system. Intentional currents through structure are not permitted. (to be elaborated)	No	No
SYS_REQ_5640	EMC design efforts. Maximum effort (to be detailed) shall be put into designing signal interfaces to withstand noisy environments and to minimize the generation of excessive noise.	No	No
SYS_REQ_2910	Self-generated RFI susceptibility. Interference due to self-generated RFI shall not degrade the performance of the instrument by greater than 1% by any measure (TBC).	Yes	No
SYS_REQ_5710	Lightning discharge susceptibility. The SKA shall be able to withstand the electromagnetic field impact defined in TBD during operation or in any other mode without any damage or characteristics degradation because of a lightning discharge.	No	No
SYS_REQ_5720	Lightning protection. SKA dedicated buildings and equipment located on sites shall be protected to minimize the effects of a direct lightning strike using certified methods (e.g. as described in NEN 1014).	No	No

SYS_REQ_5730	Lightning discharge flagging. Observation data taken during a lightning strike shall be flagged.	Yes	Yes
SYS_REQ_5810	Safety ground. Electrical safety ground shall be designed according to the regulations imposed by the local government.	No	No
SYS_REQ_5820	Corrosion protection. SKA equipment and buildings shall be protected against corrosion.	No	No
SYS_REQ_5830	Corrosion protection in air flows. SKA electronics and connectors in areas with a higher air flow (for cooling) or outdoor environment shall be additionally protected against corrosion.	No	No
SYS_REQ_5910	Earthquakes. SKA equipment and buildings shall be protected against earthquakes with a magnitude up to 3.8 (TBV) on the scale of Richter.	No	No
SYS_REQ_6110	Deployment locations. The SKA1 shall be installed at the SKA core site and at the SKA station sites.	Yes	Yes
SYS_REQ_6210	Feed Payload volume. The SKA1 front-end and cabling shall fit in the available feed boxes.	No	No
SYS_REQ_6220	Feed payload mass limit. The total mass of any feed payload, including the RF cables to the ground, shall not exceed: TBD.	No	No
SYS_REQ_7110	Materials, Parts and Processes list. Each subsystem supplier shall establish, collect, review and deliver the Materials, Parts and Processes lists including all the Materials, Parts and Processes intended for use in the SKA1 equipment by his suppliers and himself.	Yes	Yes
SYS_REQ_7111	Materials, Parts and Processes lists shall reflect the current design at the time of issue.	Yes	Yes
SYS_REQ_7130	Parts availability. The estimated availability of the Parts and products obtained from Materials and Processes used shall be compatible with the final system's life cycle (tests, storage, and mission).	Yes	Yes
SYS_REQ_7140	Material environmental rule compliance. All materials used in the SKA1 design shall be fully compliant to all environmental rules applicable to the SKA1 core and remote sites..	Yes	Yes
SYS_REQ_7150	Long-term environmental effects. Materials used in the SKA1 design shall not have any lasting effect on the site location.	Yes	Yes
SYS_REQ_7160	Maintenance free materials. Materials used for the parts subject to the outdoors environment shall be maintenance free. (TBC).	Yes	Yes
SYS_REQ_7210	Maintenance free materials. Materials used for the parts subject to the outdoors environment shall be maintenance free. (TBC).	Yes	Yes
SYS_REQ_7220	Marking method. Method of marking shall be compatible with the nature of the item and its use.	Yes	Yes
SYS_REQ_7230	Documentation marking. Identification numbers shall be marked on documentation and, where possible, on respective items.	Yes	Yes

SYS_REQ_7310	Mains supply. The SKA1 shall connect to the available power distribution at the SKA core and remote sites.	Yes	Yes
SYS_REQ_7320	Dish or AA power consumption. The power consumption of all equipment at any AA or dish station, including the motors driving the dishes, shall be less than TBD kVA.	Yes	Yes
SYS_REQ_7330	Observatory power consumption. The total power consumption of the SKA1 observatory shall be less than TBD kVA.	Yes	Yes
SYS_REQ_7410	Quality standard. SKA1 equipment and electronics shall be developed and produced according to the ISO9001 (TBC) quality standard.	No	No
SYS_REQ_7420	Field return rate. The field return rate of equipment shall be less than 0.5% (TBC) during installation and the first year full usage.	No	No
SYS_REQ_7510	General workmanship standards. General workmanship standards shall be applied as specified in the Product Assurance Plan (TBD) both for Software and Hardware production. These include ISO9001 (TBC).	Yes	Yes
SYS_REQ_7520	Scope of workmanship standards. SKA1 dedicated workmanship standards shall be specified in project dedicated documents	Yes	Yes
SYS_REQ_7521	Scope of workmanship standards. SKA1 dedicated workmanship standards shall and shall cover all phases of production, assembly and integration, testing, handling, and include clear requirements for acceptance/rejection criteria.	Yes	Yes
SYS_REQ_7610	Design margins. The SKA1 design shall possess design margins to cover all uncertainties in environment, analysis and properties of the materials and processes used.	Yes	Yes
SYS_REQ_7720	User-dependent accessibility. It shall be possible to specify on a per user basis which SKA1 facilities and resources (both hardware and software) may be accessed by the user.	Yes	Yes
SYS_REQ_7810	SKA1 equipment reliability. The reliability of SKA1 equipment to meet its performance requirements over a period of 10 years shall be greater than 99.4 % (TBC).	Yes	Yes
SYS_REQ_7820	Tools and test equipment. The SKA1 design shall require a minimum of special tools and test equipment to perform assembly, integration and repair and maintenance activities.	Yes	Yes
SYS_REQ_7830	Inaccessible hardware maintenance. Inaccessible hardware or structures shall require no maintenance during operation and should have built in test capability when applicable.	Yes	Yes
SYS_REQ_7840	Test and repair instructions. Test and repair instructions shall be written for fault detection and	Yes	Yes

	maintenance of the SKA1 equipment.		
SYS_REQ_7850	Maintenance team size. It should be possible to execute regular maintenance jobs with not more than two (2) people per job.	Yes	Yes
SYS_REQ_7860	Modular design. The SKA1 design (hardware and software) shall have a modular approach.	Yes	Yes
SYS_REQ_7870	System flexibility and expandability. The SKA1 design (hardware and software) shall provide flexibility and expandability to support anticipated areas of growth or changes in technology or mission. (e.g. in the field of but not limited to: network bandwidth, storage space, processing power)	Yes	Yes
SYS_REQ_7880	Self-test capability. The SKA1 design for both hardware and software shall provide self-test capabilities.	Yes	Yes
SYS_REQ_7890	Servicing point making. All servicing and test points shall be clearly marked using TBD labelling standards.	No	No
SYS_REQ_7910	Handling heavy equipment. SKA1 parts, test equipment or supporting equipment with mass exceeding 25 kg shall be provided with provisions for handling and transportation.	No	No
SYS_REQ_7920	Disassembly for transport. It shall be possible to disassemble SKA1 equipment for the reason of transportation or storage in its main parts.	No	No
SYS_REQ_7930	Long term storage. It shall be possible to store SKA1 equipment (spare parts) for 10 years without any degradation of its function or performance	No	No
SYS_REQ_7935	If special storage facilities are needed they shall be supplied as part of the spares procurement.	No	No
SYS_REQ_7940	Reusability. Reusability of SKA1 equipment shall be ensured through design and by refurbishment and maintenance where this has been demonstrated as being cost effective.	No	No
SYS_REQ_7950	Spare parts. SKA1 spare parts shall have a storage life consistent with availability and use during the full operational lifetime of the SKA1 equipment to which it applies.	No	No
SYS_REQ_7960	Support equipment life-time. SKA1 support equipment shall be designed to maintain SKA1 for 12 (TBC) years.	No	No
SYS_REQ_8110	Supply power. The power supplied to the SKA systems shall have the following characteristics (TBV): a) voltage 380 V +/- 10% b) 3 phases c) 50 Hz +/- 1 Hz	No	No
SYS_REQ_8130	Central facility UPS. The power source to the central facility shall have back-up provisions for controlled shut-down (TBV).	No	No

SYS_REQ_8140	Subsystem time standard. Each SKA AA or dish system shall maintain an internal time standard with an accuracy of TBD nanosecond.	Yes	Yes
SYS_REQ_8150	Central time standard. All SKA subsystems shall synchronize their internal time standards to the central timing standard with an accuracy of TBD nanosecond	Yes	Yes
SYS_REQ_8160	Limiting excessive currents. SKA equipment circuitry shall be protected against excessive currents by a current limiting device, which shall not itself produce excessive currents.	No	No
SYS_REQ_8170	Power surge protection. SKA sub-systems shall be protected against power transients and surges.	No	No
SYS_REQ_8180	Polarity mis-connection protection. SKA equipment circuitry shall be protected against the effects of inadvertent wrong polarity connections. (TBC)	No	No
SYS_REQ_8210	Data time-tagging. All dishes and aperture arrays shall time-tag received and processed data with the accuracy of their internal time standard.	Yes	Yes
SYS_REQ_9110	Test resources. SKA subsystems shall specify what special test resources they require in the operational phase.	No	No
SYS_REQ_9130	Preventive maintenance. Preventive maintenance of SKA1 hardware shall be performed in accordance with the maintenance program established for SKA.	Yes	Yes
SYS_REQ_10110	Dish/PAF interfaces. SKA1 Dishes shall be designed, built and verified such that they can accommodate Phased Array Feeds.	No	No
SYS_REQ_10120	Frequency Coverage. SKA1 Dishes shall be designed, built and verified such that they can meet AD1 optical requirements up to 10GHz.	No	No
SYS_REQ_10130	Polarization Purity. SKA1 feeds, receivers and digital processing subsystems shall be designed to provide the AD1 polarization purity requirement of 40dB.	No	No
SYS_REQ_10140	Imaging dynamic range. SKA1 elements shall be designed to provide an imaging dynamic range of 74 dB up to 10GHz	No	No
SYS_REQ_10150	Spectral dynamic range. SKA1 elements shall be designed to provide a spectral dynamic range of 67 dB.	No	No

4 General structure of requirements specification

The requirements are specified in the tables moving from the general to the specific. The tabular elements belong to sections and sub sections whose titles indicate the general category under which the requirement is classified such as Safety, Reliability etc. The specific entry in the table has a unique requirement ID and a Parent ID. The parent ID is a System level requirement. This model allows a hierarchical tabular structure with each high level M&C requirement being refined into further more specific requirement with a proper traceability link embedded in the table.

5 Allocated, Derived and Introduced Requirements

5.1 System Requirements

5.1.1 Functional

5.1.1.1 General

Ident	Requirement	Applicability	Parent	Verification
MC_REQ_0010	**Monitoring**. M&C shall provide a monitoring and control function for all of SKA_1 subsystems including itself.	Mandatory	SYS_REQ_2110	Analysis
MC_REQ_0020	**Heterogeneous evolution:** The M&C system shall be designed keeping in mind the spatio-temporal heterogeneity of the SKA_1 and shall accommodate and adapt to the evolutionary nature of the SKA leading to SKA Phase 2.	Mandatory	SYS_REQ_3740	Analysis

5.1.1.1.1 Initialisation and Termination

Ident	Requirement	Applicability	Parent	Verification
MC_REQ_0100	**Initialisation and termination.** M&C shall provide facilities to initialize and shutdown any or all of the lower order elements and the system itself in a synchronised and ordered manner.	Mandatory	SYS_REQ_3170	Analysis

5.1.1.1.1.1 Initialisation and termination details

Ident	Requirement	Applicability	Parent	Verification
MC_REQ_0110	**Start up sequence**. M&C shall ensure that SKA_1 follows a predefined sequence to enable consistent initialisation.	Mandatory	SYS_REQ_3170	Analysis
MC_REQ_0120	**Shutdown sequence.** M&C shall ensure that SKA follows a predefined sequence to enable consistent shutdown.	Mandatory	SYS_REQ_3190	Analysis
MC_REQ_0130	**Start up of Individual subsystems.** M&C shall enable start up of individual receivers or other subsystems (regional M&C, Local	Mandatory	SYS_REQ_3180 SYS_REQ_3210	Design

	M&C, Sensors and Actuators to the level of LRU) without disturbance to other operations in a consistent manner			
MC_REQ_0140	**Shutdown of subsystems.** M&C shall enable consistent shutdown of subsystems without impact on SKA operations after appropriate recalibration	Mandatory	SYS_REQ_3230	Design
MC_REQ_0150	**Initial check.** M&C shall perform an initial check of all subsystems including redundant ones prior to commencement of SKA operations	Mandatory	SYS_REQ_3240	Design
MC_REQ_0160	**Definition:** M&C shall provide a way to define the initial configuration statically as well dynamically change the configuration at runtime at the operator's behest.	Mandatory	SYS_REQ_1130 SYS_REQ_1140 SYS_REQ_1230 SYS_REQ_2710-50	Design
MC_REQ_0170	**Discovery:** M&C shall dynamically discover the initial configuration of the system and subsystems at start up, compare against the statically defined configurations and report any discrepancies.	Mandatory		Analysis
MC_REQ_0180	**Manual Override:** M&C shall provide an ability to interactively initialize the system including manual overrides**.**	Mandatory		Design
MC_REQ_0190	**Independence.** Each of the subsystems, both software and hardware shall initialize independently, as practicable as possible, and shall not block on the state of other subsystems that it may be connected to.	Mandatory		Design

5.1.1.1.2 Monitoring

Ident	Requirement	Applicability	Parent	Verification
MC_REQ_0200	**Monitoring**. M&C shall provide a monitoring function which shall permit all the subsystems including parts thereof to be monitored on demand or continuously	Mandatory	SYS_REQ_2110	

5.1.1.1.2.1 Details

Ident	Requirement	Applicability	Parent	Verification
MC_REQ_0210	**Science data augmentation.** The M&C shall provide data to annotate and augment the science data as required.	Mandatory	SYS_REQ_2160	Test

5.1.1.1.3 Control

Ident	Requirement	Applicability	Parent	Verification
MC_REQ_0300	**Control**. M&C shall provide a complete hierarchical control facility with an ability to control the smallest part that is amenable to control either directly or via proxies.	Mandatory	SYS_REQ_2110	
MC_REQ_0305	**Observation Interrupts.** M&C will provide facilities to interrupt a running observation and restart it or reschedule it as needed			

5.1.1.1.3.1 Autonomy

Ident	Requirement	Applicability	Parent	Verification
MC_REQ_0310	**Autonomy.** The hierarchical design of M&C shall not prevent autonomous or semi autonomous subsystems from functioning under the umbrella of System M&C or Local M&Cs.	Mandatory	SYS_REQ_2140 SYS_REQ_2150	Analysis
MC_REQ_0320	**Subsystem performance.** M&C shall permit the subsystems to act independently as required and communicate their state and decisions to the system M&C as needed.	Mandatory	SYS_REQ_2220	Test
MC_REQ_0330	**Definable actions.** Local M&C systems can choose between a set of defined actions in case of error states without consulting the System M&C	Mandatory		Test
MC_REQ_0340	**Automatic verification and operator intervention.** M&C shall try to automatically verify the results and responses to commands and in case of failures and multiple retries shall request for operator intervention.	Mandatory	SYS_REQ_2150	Test
MC_REQ_0350	**Recovery points.** M&C shall create recovery points for critical actions such as system upgrade to ensure rollback possibilities.	Mandatory	SYS_REQ_3660 SYS_REQ_3670	Design
MC_REQ_0360	**Automatically schedules maintenance.** M&C shall monitor the health of the subsystems and schedule maintenance as required.	Optional		Test
MC_REQ_0365	**Monitoring system performance parameters.** M&C shall provide hooks to monitor all the system parameters relevant to computation of current	Mandatory	SYS_REQ_2210	Test

	performance of the telescope components such as sensitivity, uptime and so on needed to ensure that the system is performing to the required specification.			

5.1.1.1.3.2 Scheduler

Ident	Requirement	Applicability	Parent	Verification
MC_REQ_0370	**Hierarchy**. M&C shall provide a hierarchy of schedulers with queues which can be programmatically and manually updated in order to provide maximum asynchronous operations capabilities.	Mandatory	SYS_REQ_2350	

5.1.1.1.3.3 Manual control

Ident	Requirement	Applicability	Parent	Verification
MC_REQ_0380	**Manual Control**. M&C shall provide complete hierarchical control facility with an ability to control at the LRU level either directly or via proxies, in a manual mode.	Mandatory	SYS_REQ_3640	Design

5.1.1.1.4 Performance

Ident	Requirement	Applicability	Parent	Verification
MC_REQ_0400	**Latency requirements.** M&C shall provide interfaces with proper response times as required by the subsystems, real time as well as non real time.	Mandatory	SYS_REQ_3610 SYS_REQ_3520 SYS_REQ_3170 SYS_REQ_3150	Test
MC_REQ_0410	**Maximum control latency:** Maximum latency of user commands being relayed to their target shall not exceed 500ms (TBC).	Mandatory	SYS_REQ_3530	Test
MC_REQ_0420	**Initialisation checks.** All initialisation checks shall complete with 10 mins	Mandatory	SYS_REQ_1310	Analysis
MC_REQ_0430	**Real time.** M&C shall not implement hard real time control. Only soft real time control in terms of advance issue of commands is supported. The hard real time control is implemented by subsystems themselves	Mandatory		
MC_REQ_0440	**Concurrency.** M&C system shall provide facilities for completely parallel/concurrent control of	Mandatory		

	different parts with interlocks or barriers defined for safety and synchronisation			
MC_REQ_0450	**Control transfer.** M&C shall enable the transfer of control between different control centres without out interrupting the current stream of activity.	Mandatory		

5.1.1.1.4.1 Profiling and interception

Ident	Requirement	Applicability	Parent	Verification
MC_REQ_0460	**Profiling and interception.** M&C shall provide the ability to profile the performance of the system to find hot spots as well as define an interception framework, which shall allow subsystems to provide hooks to the profiler/interceptor. This implies that all hardware and software functions of M&C can be traced and the time taken for execution of each individual task can be tracked.	Mandatory		

5.1.1.1.5 Configuration

MC_REQ_0500	**Self consistency check.** M&C shall provide a facility of a user initiated or automatic check of all the components, from the system M&C downwards in the hierarchy towards individual local M&C.	Mandatory	SYS_REQ_3240 SYS_REQ_3250	Analysis
MC_REQ_0510	**Information access.** M&C shall ensure that all available information at all levels of the system can be accessed.	Mandatory	SYS_REQ_2160 SYS_REQ_2420	Analysis
MC_REQ_0520	**Evolutionary design.** M&C shall be designed and built in a continuous model with different parts evolving independently yet able to participate in the whole, over the many years that is envisaged in its development and deployment	Mandatory		Analysis
MC_REQ_0530	**Partition into Subsystems.** M&C shall have a three level structure. System M&C , Regional M&C and Local M&C of the subsystems. The hierarchy of M&C shall mirror the hierarchy of subsystems.	Mandatory	SYS_REQ_2120 SYS_REQ_2160 SYS_REQ_3180	Analysis
MC_REQ_0540	**Time synchronization.** M&C shall provide capabilities to distribute the			Test

	synchronized time signal available at receptors to all other entities in the system as required, with a synchronization accuracy of TBD ms.			
MC_REQ_0550	**Reconfiguration.** M&C shall permit well bounded reconfiguration of the M&C system from System level downwards inclusive of partitioning, with efficient and consistent restoration and recovery paths.	Mandatory		Test

5.1.1.1.6 Safety

Ident	Requirement	Applicability	Parent	Verification
MC_REQ_0600	**Safe operating environment.** M&C shall ensure safety of all personnel, even in the presence of single failures. It shall also act proactively and autonomously to ensure protection of expensive equipment.	Mandatory	SYS_REQ_3310 SYS_REQ_3330 SYS_REQ_2150 SYS_REQ_3350	Test
MC_REQ_0610	**Weather and external environment monitoring.** M&C system shall ensure that the SKA shall operate safely or shutdown correctly under adverse weather conditions.	Mandatory		
MC_REQ_0620	**Manual Override.** The M&C system shall provide manual override facilities for every autonomous or automatic subsystem within its ambit	Mandatory	SYS_REQ_3640	Test
MC_REQ_0630	**Interruption**. M&C shall support automatic or operator induced cancellations on interruptions in the activity of the system as well as subsystems in bounded time in a safe manner.	Mandatory	SYS_REQ_2240	Test

5.1.1.1.7 Security

Ident	Requirement	Applicability	Parent	Verification
MC_REQ_0700	**Security.** M&C shall provide a monitored physical access security and video surveillance capability for the SKA as a whole.	Optional	SYS_REQ_3140	Test
MC_REQ_0710	**Logical security.** M&C shall provide a completely robust distributed authentication and role based		SYS_REQ_3140	Test

	authorization framework for access control to all parts of the system.			
MC_REQ_0720	**Cyber-security.** M&C shall address in tandem with STaN (Signal Transport and Networking) the issue of cybersecurity in all forms.	Mandatory	SYS_REQ_3140	Test

5.1.1.1.8 Reliability

Ident	Requirement	Applicability	Parent	Verification
MC_REQ_0800	**Detailed Error handling and reporting.** M&C shall provide pathways for detailed error reporting and handling at system, regional and local M&C levels with a progressive escalation model and the ability to coalesce and cascade the errors or faults.	Mandatory	SYS_REQ_2130	Demonstration
MC_REQ_0810	**Uptime and stability.** M&C shall perform stably with an uptime of 24 hours per day for the whole year with a minimum continuous period of six months	Mandatory	SYS_REQ_3110 SYS_REQ_3710	Test
MC_REQ_0820	**Backup and recovery.** M&C shall provide a framework to permit regular backup of the firmware and software components including configuration data. The system shall conform to the defined (TBD) recovery time and recovery point (TBD) objectives	Mandatory		
MC_REQ_0821	**Power outage.** M&C shall ensure that there is no (or bounded [last five minutes data lost]) data loss due to power outage and shall automatically restart after the power is restored (M&C being a control system with security and safety responsibilities requires a much more stringent data loss criterion compared to the SKA which is the controlled object whose data loss period is set to 4 hrs)	Mandatory	SYS_REQ_3840 SYS_REQ_3850	Design

5.1.1.1.8.1 Details

Ident	Requirement	Applicability	Parent	Verification
MC_REQ_0830	**Different failure modes**. M&C shall provide different failure modes in which errors can be propagated to handle cascaded and correlated	Mandatory		Demonstration

	error models			
MC_REQ_0840	**Different failure levels.** M&C shall define different levels to indicate degrees of failure	Mandatory		Demonstration
MC_REQ_0850	**Threshold levels.** M&C shall provide facilities to define threshold levels for measurable parameters and error handlers for overflow or underflow. These handlers will be supplementary to inbuilt error handling capabilities.	Mandatory		Demonstration

5.1.1.1.9 Logging

Ident	Requirement	Applicability	Parent	Verification
MC_REQ_0900	**Auditing and Logging.** M&C shall provide facilities for data collection and collect data related to audit and log information at all levels.	Mandatory	SYS_REQ_2230	Test
MC_REQ_0910	**Performance data.** M&C shall gather performance data from all subsystems and make them available continuously or on demand.	Mandatory	SYS_REQ_2210	Demonstration
MC_REQ_0920	**Timestamps.** M&C shall maintain timestamps for all logs and any data it collects in UTC.		SYS_REQ_8140 SYS_REQ_8150 SYS_REQ_8210	Test

5.1.1.1.9.1 Details

Ident	Requirement	Applicability	Parent	Verification
MC_REQ_0930	**Complete logs**. The M&C shall maintain logs and audit reports of all user commands, errors and alarms, and configuration changes to the system.	Mandatory		Test
MC_REQ_0940	**Normal log frequency.** The system log frequency under normal conditions shall be much lower than the frequency during error states and the log visualizer shall be able to coalesce the log entries as needed	Mandatory		Test
MC_REQ_0950	**Log on request.** The detailed log levels of various subsystems can be set up from the operator console and logging at different levels can be started on request.	Mandatory		Test
MC_REQ_0960	**Automatic increase in log frequency.** The frequency of logging shall be increased automatically with	Mandatory		Demonstration

	configurable parameters in case of error states etc.			
MC_REQ_0970	**Log viewing and management.** M&C shall contain a complete and complex log management and viewing subsystem capable of generating detailed reports	Mandatory	SYS_REQ_3730	Analysis

5.1.1.1.10 Design

Ident	Requirement	Applicability	Parent	Verification
MC_REQ_1000	**Design.** M&C shall have a modular and flexible design to support growth and evolution taking the spatio-temporal heterogeneity into account, including capabilities to handle variations in versions between different components.		SYS_REQ_7860 SYS_REQ_7870	Analysis
MC_REQ_1005	**Local M&C Interfaces.** M&C shall define a common set of interface and functional requirements to be met by all Local M&C systems, including Local M&C for off-the-shelf Components.			
MC_REQ_1010	**Standardised interfaces (direct and indirect) .** M&C shall interface with all the sensor and actuator subsystems via a standardised interfaces which shall implement additional layered control, monitoring, security and so on.	Mandatory		
MC_REQ_1020	**Versions.** M&C shall operate consistently in the presence of software version variations and shall always be backward compatible at the level of interoperability with the earlier versions of both protocols and command sets.	Mandatory		
MC_REQ_1021	**Language.** The primary language for M&C user interfaces, logging and documentation will be English.			

5.1.1.1.11 Integrity

Ident	Requirement	Applicability	Parent	Verification

MC_REQ_1100	**Atomicity and Persistence.** M&C shall support atomicity and persistence of configuration changes and ensure internal consistency of system configuration.	Mandatory	SYS_REQ_3330	Analysis
MC_REQ_1120	**Stable operating environment.** M&C at the system level, the regional level and the local M&C at the lower levels of the hierarchy shall function in tandem to ensure stable environment and operating conditions for all the elements and itself at all times.	Mandatory	SYS_REQ_2110 SYS_REQ_2120	Analysis
MC_REQ_1130	**Control data augmentation.** Control actions shall be performed in a verified manner in a sequential or out of sequence manner.	Mandatory	SYS_REQ_2440	Test
MC_REQ_1140	**Resource management.** M&C shall allocate resources to observations and other system operations as needed and avoid conflicts between concurrent operations that may be in progress in different parts of the system.	Mandatory		Test
MC_REQ_1150	**Fault isolation.** M&C shall act to detect and respond promptly to faults and provide containment to avoid propagation of faults to other parts of the system.	Mandatory	SYS_REQ_3320	Analysis
MC_REQ_1160	**Commands.** All operator commands shall be validated to ensure that they do not result in potential violations of safety and the system shall act proactively to maintain safety and stability in the absence of operator intervention or commands.	Mandatory	SYS_REQ_3350	Analysis
MC_REQ_1170	**Single point failure monitoring.** M&C shall monitor all critical or single point failure points in the system and shall use watchdogs and alerts to address failures therein.	Mandatory	SYS_REQ_3380	Analysis
MC_REQ_1180	**Incorrect data.** M&C shall ensure that failing or failed equipment shall never be able to inject its data into the data stream, either control or science.	Mandatory	SYS_REQ_3410	Analysis

5.1.1.1.12 User interfaces

Ident	Requirement	Applicability	Parent	Verification
MC_REQ_1200	**Remote operations.** M&C shall provide facilities that enable all control operations both at the system level and Component level to be performed from remote locations. .	Mandatory	SYS_REQ_2190	Demonstration
MC_REQ_1210	**Local and Remote Access.** M&C shall provide facilities for both local and remote access to its control and monitoring capabilities, subject to integrity constraints relating to avoidance of control conflicts.	Mandatory	SYS_REQ_2190 SYS_REQ_3130 SYS_REQ_3160 SYS_REQ_2160	Demonstration
MC_REQ_1220	**Local M&C Interfaces.** M&C shall provide interface specifications for Local M&Cs for control, monitoring and communication	Mandatory	SYS_REQ_2160	Test
MC_REQ_1230	**Remote Management of Components.** M&C shall provide facilities for engineers to be able to directly access custom Local M&C interfaces of Components from remote locations for troubleshooting and maintenance purposes.	Mandatory	SYS_REQ_2140 SYS_REQ_3130	Test
MC_REQ_1240	**Support for user interfaces.** M&C shall provide capabilities that enable the provision of monitoring, control, alarm handling, troubleshooting and system management interfaces for various classes of users, including operators, engineers and scientists. M&C shall avoid control conflicts from multiple concurrent users by design and ensure integrity of system control.	Optional		
MC_REQ_1250	**Applications support.** M&C shall provide interfaces to enable the development of applications and scripts to provide high-level control of instrument use, including applications for observation preparation, scheduling, execution, calibration and maintenance activities.	Mandatory		

5.1.1.1.12.1 Details

MC_REQ_1260	**Alarms and errors notification** M&C			Inspection

	shall make all the error conditions in the system available to operators and other users as appropriate.			
MC_REQ_1270	**Drill down capabilities.** M&C shall provide capabilities to facilitate drill down from high-level abstractions to the lowest level of data available within Components.			Inspection
MC_REQ_1280	**Configuration, status and maintenance information.** Users shall be able to obtain information about the current configuration and status of the instrument and all its Components, reasons for non-availability as applicable, as well future plans for maintenance activities and configuration changes that may affect the availability and capabilities of the instrument.		SYS_REQ_1200	Inspection
MC_REQ_1290	**Information abstraction.** M&C shall provide high-level abstractions of health, status, errors and alarms, performance parameters and other monitoring information that enable avoidance of information overload at user interfaces, while making complete detailed information about all parts and aspects the system available on demand to users through drilldown and query capabilities.			Demonstration
MC_REQ_1280	**Remote displays.** M&C shall provide facilities to pipe data to remote monitor only displays as well as interactive displays such as touch screens. The results displayed on these screens shall be configurable by the user in a standard way including display elements like fonts, colours, charts etc.			
MC_REQ_1300	**Reports.** The M&C shall provide capabilities to generate a variety of management reports including telescope utilization as well as observing time lost. Additional reports showing historical behaviour of the system such as data quality of the observations made shall be provided by the M&C.	Mandatory		

5.1.1.1.13 Environment

Ident	Requirement	Applicability	Parent	Verification
MC_REQ_1400	**Environment:** M&C shall measure environmental parameters from the	Mandatory		Analysis

	perspective of environmental conditions being adverse to observations as well as the perspective of SKA impacting the environment negatively.			

5.1.1.1.14 Archiving

Ident	Requirement	Applicability	Parent	Verification
MC_REQ_1500	**Storage and archiving.** M&C shall provide a logically separate facility for storage and archiving of all M&C related information in the system with full traceability to sources and their state at the time of generation of the information.	Mandatory	SYS_REQ_2450 SYS_REQ_2410 SYS_REQ_2430	Inspection

5.1.1.1.15 Documentation

Ident	Requirement	Applicability	Parent	Verification
MC_REQ_1600	**M&C Documentation.** M&C shall provide detailed design documentation and user documentation.	Mandatory		Analysis

5.1.1.1.16 Staging and Simulation

Ident	Requirement	Applicability	Parent	Verification
MC_REQ_1700	**Staging and simulation.** M&C shall provide staging and simulation capabilities either online or offline before execution of an action.	Optional		

5.1.1.1.17 Atmospheric modelling and Pointing models

Ident	Requirement	Applicability	Parent	Verification
MC_REQ_1800	**Pointing models.** M&C shall provide inputs based on real-time monitoring data to the signal processing and science data paths and accept provide control interfaces with which corrective actions can be implemented.	Mandatory		

5.1.1.1.18 Data transport and protocols

Ident	Requirement	Applicability	Parent	Verification
MC_REQ_1900	**Heterogeneity**. M&C should be able to communicate over a variety of data transport protocols in the physical	Mandatory		

	layer. IPv4/v6 is the preferred protocol of the data layer. Custom application layer format shall be defined by M&C.			

5.1.1.1.19 Inventory

Ident	Requirement	Applicability	Parent	Verification
MC_REQ_2000	**Inventory.** M&C shall maintain the configuration and inventory database for the complete SKA including the ability to track individual components and their status (dynamically acquired) and deployment. The inventory shall be maintained at least to the level of the LRUs defined as part of the System.	Mandatory		

5.2 M&C Sub Element Interface Requirements

5.2.1 General

M&C interfaces are broadly classified as External, namely those interfaces to entities outside the M&C Element, and Internal, between Sub-elements of M&C. Some of the External interface requirements, such as those stemming from interfaces to the environment, operations, monitoring and control functions (as opposed to fulfilling network functions for M&C), sustaining engineering and human actors, are found in their dedicated sections.

5.2.2 Interfaces

5.2.2.1 External

5.2.2.1.1 Physical design

Physical characteristics

Ident	Requirement	Applicability	Parent	Verification
MC_REQ_3000	The physical design of the SKA shall be designed to withstand adverse environmental conditions and M&C shall provide monitoring facilities for physical state of components where possible.			

Physical, electrical and data Interfaces

Ident	Requirement	Applicability	Parent	Verification
MC _REQ_3010	**Health checks**. M&C shall provide health monitoring facilities for the components to the level of LRU at physical, electrical and data integrity levels.			

Power requirements

Ident	Requirement	Applicability	Parent	Verification
MC _REQ_4000	**Power levels and quality**. M&C shall interface with the external power supply network and determine that adequate levels and quality of power is available for safe operation and execute safe shutdown or quiescing operations if mandated.			

5.2.2.1.2 Receivers

Ident	Requirement	Applicability	Parent	Verification
MC _REQ_5000	**Receivers.** M&C shall be designed to interface with and operate all kinds of receivers, present and future, which shall be part of the SKA.			

5.2.2.1.3 System software

Ident	Requirement	Applicability	Parent	Verification
MC _REQ_6000	The system software requirements are TBD			

5.2.2.1.4 Signal processing

Ident	Requirement	Applicability	Parent	Verification
MC _REQ_7000	**Signal processing.** M&C shall interface with signal processing software and hardware in a manner similar to other hardware and software components in the system, with real time interfaces if mandated.			

5.2.2.1.5 High performance computing

Ident	Requirement	Applicability	Parent	Verification
MC _REQ_8000	**High performance computing.** M&C shall interface with and monitor and control the nodes which are part of the high performance computing framework as well as use computing services provided by them for data analysis etc.			

5.2.2.1.6 Site infrastructure

Ident	Requirement	Applicability	Parent	Verification
MC _REQ_9000	**Site infrastructure.** M&C shall interface with site infrastructure components and monitor them for			

	reliability, failure, security and other failures which may compromise the system. M&C shall maintain a historical record of the behaviour of components.			

5.2.2.1.7 Power

Ident	Requirement	Applicability	Parent	Verification
MC _REQ_10000	**Power**. M&C shall interface with the power transmission and delivery network and control the power delivery to the subsystems.			

5.2.2.1.8 Cooling

Ident	Requirement	Applicability	Parent	Verification
MC _REQ_11000	**Cooling.** M&C shall monitor and control all the cooling related components in the SKA from receivers to the subsystems to the level of LRUs.			

5.2.2.1.9 Internal

Ident	Requirement	Applicability	Parent	Verification
MC _REQ_12000	**TBD**			

5.3 M&C Sub Element Operations Requirements

It is expected that these requirements shall be sourced primarily from [12], [5] & [6].

5.3.1 Modes

All the modes of observation and use as defined for the elements will be supported by M&C.

5.3.2 Observation

The M&C is designed to permit and facilitate all the existing modes of observation and be an open platform that allows the system to define additional modes as needed.

5.3.3 Monitor and Control

Each of the sub element shall provide specific set of interfaces and callbacks to the M&C to enable control and monitoring by the framework.

5.3.4 Maintenance & Diagnostics

M&C shall maintain diagnostic data for the sub systems to the level of the LRU

5.3.5 Modification

M&C is designed to permit and adapt to modifications of the sub systems in a continuous evolutionary mode and shall support all the different versions and variations of a given subsystem that does not fall under an obsolete classification.

5.3.6 Safety

M&C shall monitor the safe operations parameters for the subsystem and shall prevent the system from operating in an unsafe range.

5.3.7 Quality Assurance

The components of M&C as well as each of the elements/sub elements monitored and controlled by M&C is expected to pass strict quality measures with respect to performance, reliability and lifetime.

5.4 M&C Sub Element Design requirements

It is expected that these requirements will be sourced primarily from AD[1] (Extensibility), [6], [7] & [8].

5.4.1 Extensibility to SKA Phase 2

The M&C system is explicitly designed to evolve continuously and be easily adaptable to the wide variety of hardware and software components that will constitute SKA Phase 1. In addition it shall be extensible to the requirements of SKA Phase 2 components.

5.4.2 RFI Emissions

M&C will monitor the RFI In addition these parameters will be logged during the course of an observation and used to annotate/augment the science data.

5.4.3 Information Systems

Local M&C must conform to the Information/Object model which is defined by the M&C. They may possess custom interfaces and can register those custom interfaces with the M&C with adequate handling and display instructions for the data.

5.4.4 Electrical/Electromechanical

M&C will measure all the relevant electrical and electromechanical aspects of its subelements. If there are any measurable quality or performance level parameters related to electrical, electromechanical and mechanical behaviour of the sub elements or SKA elements, the M&C will measure and provide real time and historical data for the same. Faults and alarms may be raised. The consumers of this data will be the system maintenance office.

5.4.5 Mechanical

As above.

5.4.6 Thermal

Both real time and historical thermal behaviour of the components will be monitored and provided by the M&C both to operators and as part of the science data augmentation fields.

5.4.7 Sustainability

TBD

5.5 M&C Sub Element Development requirements

It is expected that these requirements will be sourced primarily from ADs [4] **Error! Reference source not ound.** [6] & [8].

5.5.1 Units of Measure

M&C will operate using a strict metric system. The user interfaces may permit Imperial units to be used but all of the internal data of M&C will be maintained in a metric system. Time will be conformant to ISO 8601 formats.

5.5.2 Modelling

The components that are not fully available during development will be modelled and simulated with respect to the interfaces and such simulators will be used to ensure a continuous development and commissioning methodology for the components.

5.5.3 Verification

The test benches for verifying the behaviour of the elements and sub-elements (hierarchically defined on the basis of top level requirements) will be stored and can be executed either automatically or interactively under M&C control for verification and diagnostics. The test benches will be provided by the component implementations.

5.5.4 Configuration Control

M&C shall utilise a process for configuration control that is defined in a SKA wide manner.

5.5.5 Product Assurance

TBW

5.6 M&C Sub Element Environmental requirements

These requirements will be sourced primarily from ADs [7] & [9]

5.6.1 Climatic & meteorological

M&C sub elements will define the environmental parameters for safe and successful operation and M&C will monitor and ensure that the conditions are met for safe operation. Under adverse conditions the subelements will automatically be shut down.

5.6.2 Geotechnical

M&C sub elements will define parameter ranges for effective operation during seismic activity and will be shutdown by the M&C under adverse conditions.

5.6.3 RFI Susceptibility

M&C will monitor the environmental RFI and thresholds for taking action based on the measurements.

5.6.4 Biological threats

M&C will ensure that the sub-elements are protected physically against biological threats and take shutdown action in case of intrusions or damage induced by these threats. SKA will take an active protection strategy against biological threats.

5.7 M&C Sub Element Human Factors requirements

These requirements will be sourced primarily from ADs [12], [5], [6], [10] & [11].

5.7.1 HMI

M&C will provide man machine interfaces to all Sub Elements at the level of LRU and will enable custom interfaces to be launched in order to facilitate access and diagnostics at a finer level of detail, in terms of the internal constituents of the sub elements.

5.7.2 Training

M&C will provide the documentation and the training on the use and operation of the sub elements of M&C.

5.7.3 Safety

M&C will ensure that the sub elements operate under safe ranges of operational parameters and conditions.

5.7.4 Security

M&C will provide an integrated security framework, which will be used by the sub elements including itself.

5.8 M&C Sub Element Statutory/Regulatory requirements

M&C shall conform to all applicable regulatory requirements. The specific requirements are TBD.

5.8.1 Consents

TBW

5.8.2 Governance

TBW

5.8.3 Employment

M&C will maintain a database of employees, permanent and temporary and allocate access credentials so that proper security related access control and auditing could be implemented in the SKA. The database will also provide data for compliance confirmation.

5.8.4 Health & Safety

M&C will provide automatic and manually operable safety locks and monitor and trigger them as necessary to ensure complete safe operation of the SKA. The emissions and effluents from the system will be measured and monitored to ensure health and safety of all the personnel and ecosystems in which the SKA is embedded.

5.8.5 Security

M&C will share the security framework of the SKA. In addition M&C may define M&C specific roles in the role based access model and use them to define access to M&C components. A periodic audit of the M&C components will be performed from the security to perspective to ensure that the software and hardware components are not compromised.

M&C will maintain physical and logical security of the SKA. Periodic security audits will be executed as a part of the normal maintenance processes of SKA and M&C will schedule and facilitate the process. Individual security alerts generated by the systems will be part of the general alert system of M&C.

5.8.6 Land use

M&C shall maintain detailed inventory for the land allocation and use as well and at any point of time be able to provide a complete geographically detailed and drill down map of the SKA with quantitative measurements. M&C shall also provide views to look at the SKA functionality and resource use from a geographic point of view.

5.8.7 Energy use

M&C shall have a backup power source based on local storage of energy or local generation of energy to maintain itself in the event of disruptions in the primary energy supply. This backup power source will be monitored and controlled by the M&C as a M&C Element.

5.8.8 Waste management

The M&C System will maintain an inventory and database of resources used and disposed off including energy (heating and cooling) of all its units and centres and over time aid in defining an optimal waste management policy. The policy may be generalised to include all of the SKA components.