REQUIREMENTS DOCUMENT FOR

SKA DISH ARRAY

Document number WP2-020.030.020-RS-001
Revision ..... B
Author ..... N.Roddis
Date 2011-06-16
Status ..... Draft

Name	Designation	Affiliation	Date	Signature
Additional Authors				
Submitted by:				
Accepted by:				
Approved by:				

DOCUMENT HISTORY

Revision	Date Of Issue	Engineering Change Number	Comments
A	-	-	
B			

DOCUMENT SOFTWARE

	Package	Version	Filename
Wordprocessor	MsWord	Word 2007	
Block diagrams			
Other			

ORGANISATION DETAILS

Name	SKA Program Development Office
Physical/Postal Address	Jodrell Bank Centre for Astrophysics Alan Turing Building The University of Manchester Oxford Road Manchester, UK M13 9PL
Fax.	+44 (0)161 275 4049
Website	www.skatelescope.org

TABLE OF CONTENTS

1 INTRODUCTION 7
1.1 Purpose of the document 7
2 REFERENCES 7
3 DISH ARRAY CONTEXT AND HIERARCHY 9
3.1 Dish Array context 9
3.2 Dish Array hierarchy 12
3.2.1 Dish sub system 12
3.2.2 Single pixel feeds sub system 13
3.2.2.1 Feed payloads 13
3.2.2.2 Single pixel feed receiver 13
3.2.3 Phased Array Feed Sub system 13
4 DISH ARRAY FUNCTIONAL AND PERFORMANCE REQUIREMENTS 14
4.1 Requirements derivation 14
4.2 Spectral Characteristics 14
4.2.1 Operating frequency 14
4.2.2 Instantaneous bandwidth 14
4.2.3 Spectral flatness 15
4.2.4 Spectral dynamic range 15
4.3 SKA_1 sensitivity and survey requirements 16
4.3.1 Sensitivity 16
4.3.2 Survey speed 16
4.3.3 Survey 'on-sky' time 16
4.3.4 Deep field integration time 16
4.4 Temporal characteristics 17
4.4.1 Main beam stability 17
4.4.2 Spatial sidelobe stability 17
4.4.3 Frequency switching agility 17
4.5 Polarisation characteristics 17
4.6 Imaging characteristics 18
4.6.1 Imaging dynamic range 18
4.6.2 Pointing accuracy 19
4.6.3 Pointing estimation accuracy 19
4.7 Monitoring and Control (M&C) Function 19
4.7.1 Top-level M&C requirements 19
4.8 Observational modes 21
5 DISH ARRAY OPERATIONAL REQUIREMENTS 21
5.1 General 21

5.2 Routine operations 22
5.3 Start up and shut down 22
5.4 Failure management 24
5.4.1 General 24
5.4.2 Detection and reporting 26
5.4.3 Diagnosis and recovery 27
5.5 Lifetime 28
5.6 Maintenance 30
5.7 Disposal phase 32
5.8 Environmental requirements 32
5.8.1 General 32
5.8.2 Site and infrastructure 33
5.8.3 Contamination and precipitation 33
5.8.4 Weather related requirements 34
5.9 EMC and radio frequency interference 35
5.10 Lightning 37
5.11 Grounding 37
5.12 Corrosion 38
5.13 Earthquakes 38
5.14 Feed payload size and mass 38
6 QUALITY ASSURANCE 39
6.1 Qualification testing 39
6.2 Verification methods 40

LIST OF FIGURES

Figure 1: Dish Array Context Diagram 9
Figure 2: Dish Array hierarchy 12

LIST OF TABLES

No table of figures entries found.

LIST OF ABBREVIATIONS

AIP……Advanced Instrumentation Program
CoDR ..... Conceptual Design Review
DRM..... Design Reference Mission
FoV ..... Field of View
LNA ..... Low Noise Amplifier
OMT……Ortho-mode transducer
OTPF..... Observing Time Performance Factor
PAF ..... Phased Array Feed
PrepSKA ..... Preparatory Phase for the SKA
RFI ..... Radio Frequency Interference
rms ..... root mean square
SEFD..... System Equivalent Flux Density
SKA..... Square Kilometre Array
SPDO..... SKA Program Development Office
SSFoM ..... Survey Speed Figure of Merit
TBD..... To be decided
wrt ..... with respect to

1 Introduction

This document is a first draft requirement specification for the SKA Dish Array, considering both Phase 1 and Phase 2 of the project. Requirements for the Dish Array flow down from the SKA System Requirements Specification [1], which currently addresses the Phase 1 requirements. However, as the dishes are high value, long lifetime items they must be designed, as far as possible, to meet the requirements of SKA Phase 2 insofar as they are known or can be predicted.

This document is part of a series generated in support of the Dish Array CoDR which includes the following:

- Design Concept Descriptions
- Dish Array Requirements
- Dish Array Costs
- Dish Array Risk Register
- Dish Array Strategy to Proceed to the Next Phase

The focus of this requirements document is providing traceable Element and Sub-system level requirements and their associated attributes.

1.1 Purpose of the document

The aim is to capture all requirements that will determine the design of the Dish Array and its component sub systems, to classify them in terms of their importance, to record the sources of all requirements, and to identify the means by which the Dish Array designs will be verified against the requirements.

Over the course of the project the requirements, and hence this document, will evolve.

2 References

[1] SKA Phase 1 System Requirements Specification, SPDO doc. no. WP2-005.030.000-SRS-002

[2] The Square Kilometre Array Design Reference Mission, SPDO doc. no. PHASE1-DRM-V1.3 (DRAFT)

[3] The Square Kilometre Array Design Reference Mission: SKA-mid and SKA-lo, SKA Science Working Group v 1.0

[4] SKA1: High Level System Description, SPDO doc. no. WP2-005.030.010-TD-002

[5] A Concept Design for SKA Phase 1 (SKA1), SKA Memo 125

[6] Project Execution Plan Pre-construction Phase for the Square Kilometre Array (SKA), SPDO Doc. no. MGT-001.005.005-MP-001

3 Dish Array context and hierarchy

3.1 Dish Array context

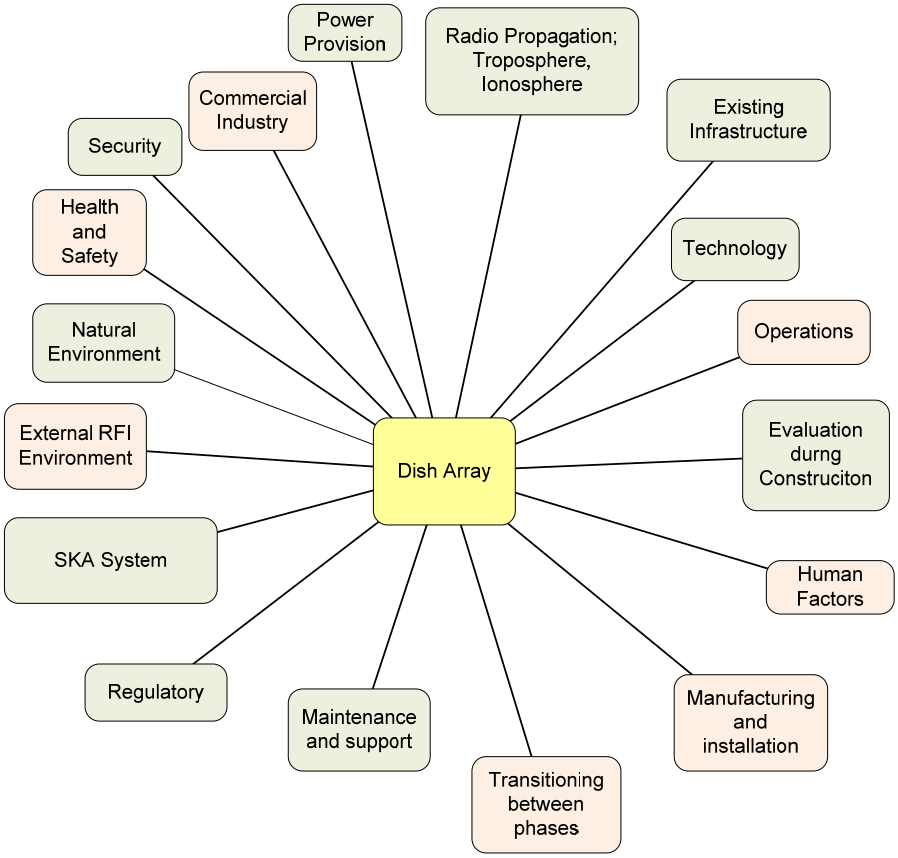

Figure 1: Dish Array Context Diagram

Figure 1 is a first order Dish Array context diagram, which contains a mix of both technical and non-technical influences. The diagram illustrates the large number of influences that must be considered in the system design. These will spawn the development of Dish Array requirements, both functional and non-functional, some of which already appear in this document. Although it may not yet be complete, other elements of the context will be identified in the next phase of the project.

1. *Radio propagation; troposphere, ionosphere:* In SKA phase 1 the dishes will cover the frequency range 450 MHz to 3 GHz, and in phase 2 this will be extended up to 10 GHz, and possibly down to 300 MHz. Propagation of radio astronomy signals towards the lower end of these bands is affected significantly by the ionosphere, particularly during sunspot maximum periods, and calibration methods will be needed to deal with these effects. Troposphere?

2. *Existing infrastructure:* existing infrastructure may be present as the result of precursor telescope construction. The SKA is likely to require significant upgrade to this infrastructure, including where it affects the implementation of the Dish Array.

3. *Technology:* The SKA will only meet its design objectives within cost constraints if highly power efficient and reliable technologies are employed. In the case of the Dish Array it will be essential to develop new technology that can deliver the necessary longevity in the prevailing environmental conditions, with minimal maintenance.

4. *Operations:* When designing the Dish Array it will be vital to take into account the operations plan for the SKA, for example in determining the functionality of the monitor and control sub system.

5. *Evaluation during construction:* The imaging dynamic range requirement on the SKA Dish Array will put some demands on the dish performance that can only be fully tested once an array of dishes has been implemented. Performance of the dishes in the array will need to be continually evaluated as the array expands, and as more experience is gained in operating the dishes in the local environment.

6. *Human factors*: The SKA will be deployed and operated by humans. Which aspects of the system's operations will be human operated – and which will be automated – may change over time to optimise operating costs, *flexibility* and reliability of operations. Much of the maintenance will have to be done in remote locations, for which personnel recruitment may be difficult. Thus it will be essential to consider human factors in designing the Dish Array, with particular attention going to the design for manufacture and installation, and to the maintenance of the array.

7. *Manufacturing and installation:* Dish Arrays make up a significant fraction of the cost of the SKA and their manufacture and installation will need to be optimised in order to deliver a cost effective system.

8. *Transitioning between phases:* To deliver science results during construction, careful attention will have to be paid to commissioning aspects while transitioning equipment and software from pre-production to in-production states. In addition, the major phases of the SKA project may have different expected outcomes from the funding providers' perspectives, so these will also have to be taken into account. When the Dish Array is deployed for Phase 1 of the SKA it will be important to consider the future deployment of Phase 2.

9. *Maintenance and support:* Maintenance and support represent significant – perhaps the most significant – aspects of the total life cycle costs for the SKA. The remoteness of the site adds complication and cost to maintenance. So attention must be paid to optimising these cost aspects for the Dish Array. This includes exploring options that might have higher initial capital costs to deliver lower costs of maintenance and support.

10. *Regulatory:* The dish arrays will have to be designed, installed, maintained, operated and ultimately decommissioned in accordance with all regulations that apply to the SKA site.

11. *SKA System:* Requirements for the Dish Array flow down from the SKA System requirements [1].

12. *External RFI environment:* One of the most important factors of the SKA's environment is the Radio Frequency Interference (RFI) that it will have to deal with. The Dish Array design process will have to take RFI – including self-generated RFI – into consideration from the start.

13. *Natural environment:* Along with RFI considerations, the Dish Array design will have to take into account the potentially harsh desert and semi-desert environment of the two candidate sites. In addition, the Dish Array's impact on those environments must be considered – for example, waste from construction, operations and equipment retirement will have to be dealt with according to the regulations in force in the host country, in line with any requirements from the funding agencies, and in an environmentally responsible manner.

14. *Health and safety:* Associated with all aspects of human interaction with the SKA equipment are health and safety considerations. These will also have to be dealt with according to the regulations in force in the host country and in line with any requirements from the funding agencies, and most likely the SKA itself will have to develop specific policies in regards to staff health and safety. As the dishes are large, heavy structures there are potentially many hazards associated with their manufacture, installation, operation and maintenance.

15. *Security:* The Dish Array will be constructed using valuable resources and equipment and will comprise valuable but highly specialised equipment and infrastructure. So security of tangible equipment will have to be a high priority during construction and operations. This is especially the case for the remote locations of the core sites – and the potentially even more remote station sites.

16. *Commercial industry:* Industry will play a crucial role in the delivery and through-life support of the Dish Array technologies and infrastructure. The scale of the SKA, and the need to produce components, requires industry engagement on a scale unprecedented in radio astronomy. The involvement of organisations with experience and expertise in delivering demanding technological specifications within a production cost envelope will be essential.

17. *Power provision: S*upply of power to all components of the SKA will be complicated and expensive. Power and its management must be considered a first order design issue for the Dish Array, and this is a crucial interface with the rest of the SKA System. Design of the Dish Array should aim to minimise power consumption, but not at the expense of system sensitivity or reliability.

3.2 Dish Array hierarchy

Figure 2 shows the Dish Array hierarchy, where the Dish Array is an Element within the SKA System. There are three sub systems that make up the Dish Array: the dish itself, plus a number of single pixel feeds on each dish, and potentially a PAF on some of the dishes. Currently the baseline for SKA Phase 1 calls for each dish to be equipped with octave band single pixel feeds to cover the frequency range 0.45 to 3 GHz [5].

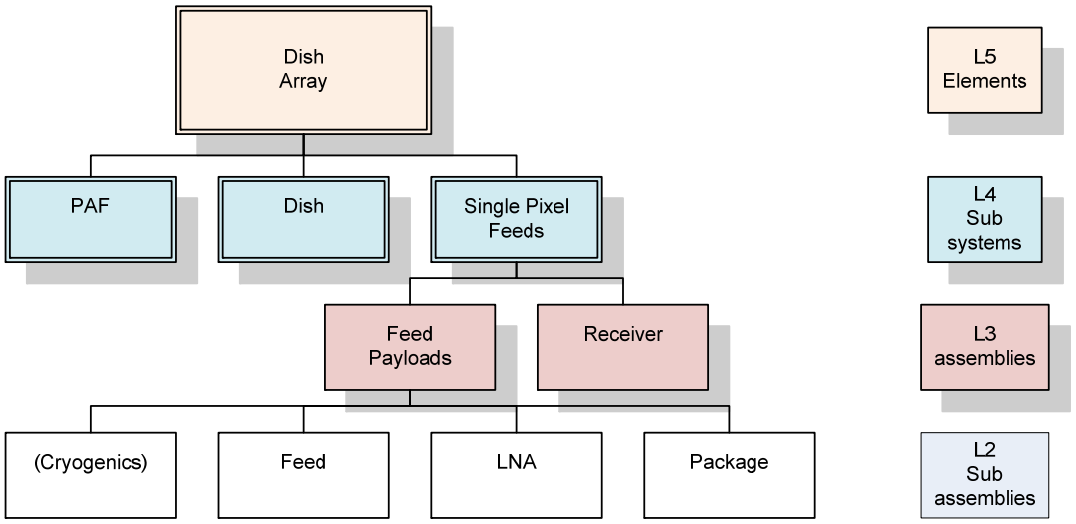

Figure 2: Dish Array hierarchy

3.2.1 Dish sub system

The dish sub system comprises the following assemblies and sub assemblies.

- Foundations
- Reflector(s) and mount structure
- Feed indexer for single pixel feeds
- PAF mount
- Dish drives and control system (including software)
- Other monitor and control hardware and software
- Power conditioning and distribution
- Safety hardware and software
- Security hardware and software
- Temperature regulation hardware and software

3.2.2 Single pixel feeds sub system

Each dish will house a single pixel feeds sub system. The number of feeds and types of feed that are deployed on the dishes will change over time. For example, the suite of feeds required for SKA Phase 2 will be different to that required for Phase 1. Each single pixel feeds sub system will comprise one or more feed payloads, a receiver assembly and interconnecting cables/fibres.

3.2.2.1 Feed payloads

SKA dishes will utilise a variety of feed payloads. Their performance is critical to obtaining the required sensitivity over the required frequency range. Feed payloads for SKA Phase 1 are expected to cover nominally octave bands, for example 0.45 to 0.9 GHz. Phase 2 of SKA may see the deployment of wide band feed payloads, covering a 4 to 1 frequency range or greater, if these are successfully developed in the AIP [6]. A feed payload will comprise the following.

- Feed
- Polarizer/OMT
- LNAs
- Cryogenic cooling (optionally)
- Dewar or other housing
- Power supply
- Monitor and control hardware (and possibly software)

3.2.2.2 Single pixel feed receiver

A single pixel feed receiver will select the dual-polarized outputs from one of the feed payloads; these will be amplified and possibly frequency converted, then digitised and optically modulated for distribution via the optical fibre signal transport network.

3.2.3 Phased Array Feed Sub system

Development of phased array feed (PAF) sub systems for the SKA is part of the Advanced Instrumentation Program (AIP). The purpose of the AIP is to develop technology to optimise the science return from Phase 2 of the SKA, although PAFs may also be deployed as modular subsystems on the Phase 1 dishes to enhance the science impact of SKA Phase 1 [6].

4 Dish Array functional and performance requirements

4.1 Requirements derivation

As far as possible the Dish Array functional and performance requirements derive from the SKA System Requirements Specification [1]. Any additional requirements that are determined to be necessary specifically for the Dish Array may later be referred back to the System requirements Specification as part of a review process.

4.2 Spectral Characteristics

This section refers to the part of the spectrum to be observed with SKA_1.

4.2.1 Operating frequency

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0010	**Electromagnetic frequency range.** The SKA1 Dish Array shall be able to detect and process electromagnetic radiation in a frequency range from 450 MHz to 3 GHz.	Mandatory	SYS_REQ_1110	Test

4.2.2 Instantaneous bandwidth

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0020	**Fractional instantaneous bandwidth:** The SKA Phase 1 Dish Array shall be designed such that the fractional instantaneous bandwidth is comparable to the observing frequency.	Mandatory	SYS_REQ_1120	Test

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0030	**Frequency band positioning.** It shall be possible to position the receiving 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. .	Mandatory	SYS_REQ_1130	Test

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0040	**Band selection resolution.** The resolution with which the 500 MHz and 1 GHz bands can be selected shall be TBD or less.	Mandatory	SYS_REQ_1140	Test

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0050	**Polarization frequency equality**. It shall not be possible to select different digitized bands for the two polarizations of the Dish Array.	Mandatory	SYS_REQ_1150	Demo

4.2.3 Spectral flatness

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0060	**Passband flatness.** All pass bands in the Phase 1 Dish Array shall be flat to TBD.	Mandatory	SYS_REQ_1190	Test

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0070	**Passband stability.** All pass bands in the Phase 1 Dish Array shall be stable to within TBD over a period of 1000 hours.	Mandatory	SYS_REQ_1190	Test

4.2.4 Spectral dynamic range

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0080	**Spectral dynamic range**. The performance of the Phase 1 Dish Array shall be consistent with a system spectral dynamic range of ≥43 dB in the band 450 MHz to 1.4 GHz.	Mandatory	SYS_REQ_1230	Test

4.3 SKA_1 sensitivity and survey requirements

4.3.1 Sensitivity

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0090	**Sensitivity (Aeff/Tsys)**. The Phase 1 Dish Array shall have a sensitivity of 10^3 m^2 K^{-1} in the frequency range 450 MHz - 3 GHz.	Mandatory	SYS_REQ_1310	Test

4.3.2 Survey speed

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0100	**Survey speed.** The Phase 1 Dish Array shall permit a survey speed figure of merit (SSFoM) of at least $10^7 m^2 K^{-2} deg^2$ over the frequency range 450 MHz to 1.4 GHz**.**	Mandatory	SYS_REQ_1410	Test

4.3.3 Survey 'on-sky' time

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0110	**Survey duration.** The design of the Phase 1 Dish Array shall be compatible with the System Requirement that a major survey can be completed in 2 years of "on-sky" observation time.	Mandatory	SYS_REQ_1420	Analysis

4.3.4 Deep field integration time

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0120	**Deep field.** The design of the Phase 1 Dish Array shall be compatible with the System Requirement that a deep field can be completed in 1000 hr of integration time.	Mandatory	SYS_REQ_1430	Analysis

4.4 Temporal characteristics

4.4.1 Main beam stability

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0130	**Main beam stability**. The magnitude and phase variations of any Phase 1 Dish Array 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.	Mandatory	SYS_REQ_1610	Test

4.4.2 Spatial sidelobe stability

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0140	**Sidelobe stability.** Sidelobes generated by dishes in the Phase 1 Dish Array shall be stable to TBD.	Mandatory	SYS_REQ_1630	Test

4.4.3 Frequency switching agility

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0150	**Frequency agility.** The Phase 1 Dish Array shall be able to change to any frequency within its specified operating range within TBD minutes.	Mandatory	SYS_REQ_1670	Test

4.5 Polarisation characteristics

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0160	**Beam polarisation stability.** The polarization properties of the beams produced by the Phase 1 Dish Array shall be stable enough to allow their calibration to better than 0.5% (TBC)	Mandatory	SYS_REQ_1710	Test

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0170	**External calibration** measurements of the Phase 1 Dish Array shall be necessary at a rate of no more than once per hour (TBC).	Mandatory	SYS_REQ_1720	Analysis

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0180	**Polarisation.** The Phase 1 Dish Array shall simultaneously provide outputs corresponding to nominally orthogonally polarised received signals.	Mandatory	SYS_REQ_1730	Test

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0190	**Instrumental polarisation**. Performance of the Dish Array shall be compatible with the System Requirement that the polarisation introduced by the instrument, after calibration, shall be less than 0.5% of the total intensity. (TBC).	Mandatory	SYS_REQ_1740	Test

4.6 Imaging characteristics

4.6.1 Imaging dynamic range

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0200	**Imaging dynamic range**. Performance of the Phase 1 Dish Array shall be compatible with the System Requirement that 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 74 dB at 1.4 GHz.	Mandatory	SYS_REQ_1940	Analysis & Test

4.6.2 Pointing accuracy

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0210	**Dish beam absolute pointing accuracy**. The required pointing accuracy of the Phase 1 Dish Array beams is: TBD.	Mandatory	SYS_REQ_1950	Test

4.6.3 Pointing estimation accuracy

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0220	**Dish beam pointing estimation accuracy**. The required pointing estimation accuracy of the Phase 1 Dish Array beams is: TBD.	Mandatory	SYS_REQ_1970	Test

4.7 Monitoring and Control (M&C) Function

4.7.1 Top-level M&C requirements

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0230	**M&C.** The SKA Phase 1 Dish Arrays shall provide a monitoring and control function that is compatible with SKA system requirements.	Mandatory	SYS_REQ_2110	Demo

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0240	**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.	Mandatory	SYS_REQ_2120	Demo

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0250	**M&C failure detection**. The monitoring and control function shall ensure that failures in hardware, software or signal transport are detected and reported.	Mandatory	SYS_REQ_2130	Demo

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0260	**M&C autonomy**. The monitoring and control function shall take autonomous action to ameliorate failures where possible and support a fail-safe philosophy.	Mandatory	SYS_REQ_2140	Demo

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0270	**M&C and safety**. M&C shall take autonomous action in safety critical situations such as system power failure, over-temperature, and storms (dish-stowing).	Mandatory	SYS_REQ_2150	Demo

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0280	**M&C transparency**. The monitoring and control function shall give user transparent and hierarchical access to the instruments functions and parameters.	Mandatory	SYS_REQ_2160	Demo

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0290	**M&C remote operation**. The monitoring and control function shall be designed such that the Dish Array can be operated fully remotely.	Mandatory	SYS_REQ_2190	Demo

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0300	**M&C performance monitoring**. The monitoring and control function shall provide TBD performance monitoring data to users.	Mandatory	SYS_REQ_2210	Demo

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0310	**M&C monitoring data**. All Phase 1 Dish Array subsystems shall provide monitoring data to the monitoring and control function (for performance monitoring and closed-loop control functions).	Mandatory	SYS_REQ_2220	Demo

4.8 Observational modes

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0320	**Real-time calibration.** Design of the Phase 1 Dish Array shall be compatible with the requirement that SKA1 shall provide instrumental real-time calibration functions in all observational modes.	Mandatory	SYS_REQ_2760	Analysis

5 Dish Array operational requirements

5.1 General

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0330	**Up-time**. The Phase 1 Dish Array shall be aimed to be operated continuously (7 days per week 24 hours per day).	Desirable	SYS_REQ_3110	Analysis

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0340	**Remote M&C from sites**. It shall be possible for the operator to control and monitor the Phase 1 Dish Array from the SKA station sites and core site.	Mandatory	SYS_REQ_3130	Demo

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0350	**Physical access security**. The Phase 1 Dish Array shall provide security to prevent unauthorized physical access to facilities and resources.	Mandatory	SYS_REQ_3140	Demo

5.2 Routine operations

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0360	**Reconfiguration time**. Design of the Phase 1 Dish Array shall be compatible with the System Requirement that 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.	Mandatory	SYS_REQ_3150	Demo

5.3 Start up and shut down

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0370	**Full remote control**. It shall be possible to control all Phase 1 Dish Array functions from the operational centre, without requiring physical access to the instrument, including start-up and shut down.	Mandatory	SYS_REQ_3160	Demo

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0380	**Start-up sequence**. Design of the Phase 1 Dish Array shall be compatible with the System Requirement that the start-up of SKA1 functions shall follow a pre-defined sequence taking not longer than: 10 minutes for a hot start (=restart) 24 hours for a cold start	Mandatory	SYS_REQ_3170	Demo

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0390	**Start-up and shut-down individual antenna systems**. It shall be possible to start-up or shutdown individual dishes in the Phase 1 Dish Array without disturbance [TBC] of routine operations.	Mandatory	SYS_REQ_3180	Demo

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0400	**Shut-down sequence**. Design of the Phase 1 Dish Array shall be compatible with the System Requirement that the shutdown of SKA1 shall follow a pre-defined sequence taking not longer than TBD minutes. SKA1 shall also have an emergency shut-down for wind (stowing dishes), lightning, and electric power anomalies.	Mandatory	SYS_REQ_3190	Demo

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0410	**Subsystem shut-down**. The shutdown of pre-defined parts of the Phase 1 Dish Array shall have no (TBC) impact on SKA1 operations after appropriate re-calibration performed automatically.	Mandatory	SYS_REQ_3230	Demo

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0420	**Initial check-out**. Design of the Phase 1 Dish Array shall be compatible with the System Requirement that SKA1 shall be designed to enable an operational readiness check, including redundancies, prior to commencement of any SKA1 operations (initial check-out).	Mandatory	SYS_REQ_3240	Demo

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0430	**Operational readiness check**. The operational readiness check for the Phase 1 Dish Array shall not take longer to complete than TBD minutes.	Mandatory	SYS_REQ_3250	Demo

5.4 Failure management

5.4.1 General

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0440	**Personnel safety**. As far as possible, no single failure in the Phase 1 Dish Array shall lead to personnel safety hazards.	Desirable	SYS_REQ_3310	Analysis

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0450	**Failure propagation**. Failures in one of the Phase 1 Dish Array subsystems shall not lead to failures in other subsystems.	Desirable	SYS_REQ_3320	Analysis

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0460	**Operator command safety.** The Phase 1 Dish Array control system shall be designed such that no single operator command shall cause catastrophic, serious, or major consequences.	Mandatory	SYS_REQ_3330	Analysis

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0470	**Voltage transients consequences**. No voltage-transients or "cut off" of electrical power shall lead to catastrophic or serious consequences for the Phase 1 Dish Array. This includes voltage transients applied to the input of the receivers.	Desirable	SYS_REQ_3340	Test

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0480	**Operator command absence**. The absence of operator commands shall not cause catastrophic or serious consequences for the Phase 1 Dish Array.	Mandatory	SYS_REQ_3350	Demo

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0490	**Single-point failures**. Single-point failures in the design shall be listed.	Mandatory	SYS_REQ_3360	Analysis

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0500	**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.	Mandatory	SYS_REQ_3370	Analysis

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0510	**Single-point failure watchdog**. The correct functioning of each single-point-failure in the design shall be monitored by a watchdog function.	Mandatory	SYS_REQ_3380	Analysis

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0520	**Failing equipment**. Design of the Phase 1 Dish Array shall be compatible with the System Requirement that 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.	Mandatory	SYS_REQ_3410	Analysis

5.4.2 Detection and reporting

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0530	**Status report availability time**. The status report of the functioning of a subsystem in the Dish Array shall be available in 5 seconds.	Mandatory	SYS_REQ_3520	Demo

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0540	**Status report request**. The status report of a subsystem shall reflect the functioning of the subsystem in the Dish Array at or after the operator request has been submitted to the system.	Mandatory	SYS_REQ_3530	Demo

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0550	**Status report scope.** Design of the Phase 1 Dish Array shall be compatible with the System Requirement that the status report shall display the status of a function, together with the system time the status was determined.	Mandatory	SYS_REQ_3540	Demo

5.4.3 Diagnosis and recovery

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0560	**System interrogation reply**. Each dish in the Phase 1 Dish Array shall have the capability to answer to an operator interrogation, in case of detected failures at the dish, which antenna chain has failed.	Mandatory	SYS_REQ_3610	Demo

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0570	**System autonomous and manual control modes.** Design of the Phase 1 Dish Array shall be compatible with the System Requirement that the system shall have the capability to be operated by an operator in an autonomous mode, and in a manual control mode.	Mandatory	SYS_REQ_3620	Demo

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0580	**Recovery actions**. It shall be possible to take recovery actions without consequences for other parts of SKA1; design of the Phase 1 Dish Array shall be compatible with the System Requirement that the system shall minimize impact of recovery actions.	Mandatory	SYS_REQ_3660	Analysis

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0590	**Autonomous recovery**. Design of the Phase 1 Dish Array shall be compatible with the System Requirement that SKA1 shall be able to recover autonomously in case of failures that are classified as minor or negligible.	Mandatory	SYS_REQ_3670	Demo

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0600	**Effect of disabled units**. The Phase 1 Dish Array design shall ensure that disabled units do not corrupt the remaining system.	Mandatory	SYS_REQ_3680	Analysis

5.5 Lifetime

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0610	**Continuous operation period**. The Phase 1 Dish Array shall be designed for a continuous operational period of at least 12 months, without the need for planned maintenance.	Mandatory	SYS_REQ_3710	Analysis & Test

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0620	**Minimum life time.** The Phase 1 Dish Array shall be designed for a minimum life time of 30 years, including initial installation, testing and commissioning period.	Desirable	SYS_REQ_3720	Analysis

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0630	**Availability.** The average availability of the Phase 1 Dish Array 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.	Desirable	SYS_REQ_3730	Analysis

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0640	**Upgradeability.** The Phase 1 Dish Array shall be upgradable. Upgrades may include addition and replacement of single pixel payloads and receivers as well as the addition of phased array feeds.	Mandatory	SYS_REQ_3740	Analysis

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0650	**Life-time extension**. Large scale maintenance and/or an upgrade shall give the possibility to reach a life time of 50 years (TBC).	Mandatory	SYS_REQ_3750	Analysis

5.6 Maintenance

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0660	**Full fail rate.** Design of the Phase 1 Dish Array shall be compatible with the System Requirement that the SKA1 shall be designed to fully fail less than two times per year (TBC), the number determined as average over its operational period.		SYS_REQ_3810	Analysis

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0670	**Repair period**. The design of the Phase 1 Dish Array will be such that repairs can be carried out in the shortest possible time with minimal manpower and tools. Wherever possible repairs will consist of the replacement of line replaceable units (LRUs).		SYS_REQ_3820	Analysis

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0680	**Autonomous restart after power outage**. All subsystems shall have the capability to restart autonomously and without failures, after an outage in external power supply.		SYS_REQ_3850	Demo

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0690	**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).		SYS_REQ_3860	Demo

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0700	**Software/firmware reinstallation**. All software/firmware in the Phase 1 Dish Array shall allow its re-installation.		SYS_REQ_3870	Demo

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0710	**Software/firmware upgrades**. It shall be possible to replace all software/firmware configuration items in the Phase 1 Dish Array through software upgrades, initiated by an engineer.		SYS_REQ_3880	Demo

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0720	**Software code identification.** Software configuration items shall provide unambiguous inputs to allow the maintenance of a configuration management database.		SYS_REQ_3890	Demo

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0730	**Software code identification response time**. The software identification shall be available to the operator within 10 seconds (TBC) after the request was made.		SYS_REQ_3910	Demo

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0740	**Subsystem maintenance functions.** All subsystems shall include functions that allow maintenance of hardware and software.		SYS_REQ_3920	Demo

5.7 Disposal phase

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0750	**Environmental rule compliancy.** The Phase 1 Dish Array design shall be fully compliant to all environmental rules applicable to the SKA site.		SYS_REQ_4110	Analysis

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0760	**Lasting environmental effects.** The Phase 1 Dish Array shall be designed to have no lasting adverse environmental effects on the facility and site.		SYS_REQ_4210	Analysis

5.8 Environmental requirements

5.8.1 General

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0770	**Meteorological and environmental conditions**. The Phase 1 Dish Array shall be designed or protected against any deterioration leading to failure to meet the requirements specified herein caused by meteorological and environmental conditions during its complete lifetime (both operating and non-operating).		SYS_REQ_5110	Analysis & Test

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0780	**Compliance with local environment**. The design of the Phase 1 Dish Array shall be appropriate (TBD) for operation in the natural environment for the geographical deployment location of the SKA1.		SYS_REQ_5120	Analysis

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0790	**Transportation conditions**. Phase 1 Dish Array 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).		SYS_REQ_5130	Analysis

5.8.2 Site and infrastructure

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0800	**Facilities and equipment intrusion**. Phase 1 Dish Array equipment and operating facilities shall be adequately protected against intrusion by unauthorized persons or by larger wandering animals		SYS_REQ_5220	Demo

5.8.3 Contamination and precipitation

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0810	**Precipitation**. Phase 1 Dish Array equipment shall be able to operate		SYS_REQ_5230	Test

	without degradation of the performance, other than increase in system noise temperature, during any type of precipitation (to be specified).			

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0820	**Pollution and contamination protection**. Phase 1 Dish Array equipment shall be adequately protected against performance degradation caused by contaminating particles (dust, sand etc), polluted air or any precipitation.		SYS_REQ_5240	Test

5.8.4 Weather related requirements

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0830	**Humidity**. Phase 1 Dish Array equipment shall be able to withstand moisture and humidity levels up to 100 % RH.		SYS_REQ_5310	Test

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0840	**Allowable air temperature range**. Phase 1 Dish Array equipment shall be able to withstand (non-operating if necessary) an outside air temperature within the range of - 15 ºC (TBC) to +60 ºC (TBC).		SYS_REQ_5320	Test

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0850	**Air temperature operation range.** Phase 1 Dish Array equipment shall be able to operate within specification if the outside air temperature is within the range of -5 ºC (TBC) to +50 ºC (TBC).		SYS_REQ_5330	Test

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0860	**Wind velocities**. The Phase 1 Dish Array shall be able to survive wind velocities up to 160 km/hr (TBC) from any direction, and shall operate within normal specification ranges for wind velocities up to 40 km/hr (TBC) from any direction.		SYS_REQ_5340	Analysis & Test

5.9 EMC and radio frequency interference

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0870	**Damaging interference levels**. The Phase 1 Dish Array shall not be damaged by RFI signals less than TBD V/m.		SYS_REQ_5410	Test

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0880	**EM immunity.** The Phase 1 Dish Array shall not be susceptible to RFI signals, in band or out of band, other than via the antenna feeds.		SYS_REQ_5420	Test

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0890	**ADC clipping**. The dynamic range of the ADC's in the Phase 1 Dish Array shall be such that no clipping will occur. The number of ADC bits shall be sufficient to prevent clipping due to strong interfering signals such as aircraft Distance Measuring Equipment (DME) and satellite signals.		SYS_REQ_5430	Test

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0900	**EMC safety margin.** The EMC safety margin, which is defined as the ratio between susceptibility threshold and the interference at any point within the Dish Array, shall be greater than TBD dB.		SYS_REQ_5610	Analysis & Test

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0910	**EMC compatibility marking.** All "off-the-shelf" equipment applied within the Phase 1 Dish Array shall posses as a minimum the host country EMC marking, including electrical and electronic supporting and infrastructural equipment.		SYS_REQ_5620	Demo

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0920	**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)		SYS_REQ_5630	Analysis

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0930	**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.		SYS_REQ_5640	Analysis & Test

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0940	**Self-generated RFI susceptibility**. Interference due to self generated RFI produced by the Dish Array shall not degrade the performance of the SKA Phase 1 instrument by greater than 1% by any measure (TBC).		SYS_REQ_2910	Test

5.10 Lightning

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0950	**Lightning discharge susceptibility.** The Phase 1 Dish Array 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.		SYS_REQ_5710 SYS_REQ_5720	Analysis

5.11 Grounding

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0960	**Safety ground**. The Phase 1 electrical safety ground shall be designed according to the regulations imposed by the local government.		SYS_REQ_5810	Analysis

5.12 Corrosion

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0970	**Corrosion protection**. The Phase 1 Dish Array shall be protected against corrosion.		SYS_REQ_5820 SYS_REQ_5830	Analysis

5.13 Earthquakes

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0980	**Earthquakes.** The Phase 1 Dish Array shall be protected against earthquakes with a magnitude up to Richter 3.8 (TBC).		SYS_REQ_5910	Analysis

5.14 Feed payload size and mass

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_0990	**Feed Payload volume.** The SKA Feed Payloads, SPF Receivers and associated Signal Transport hardware shall fit into the space provided on the Phase 1 Dish Array dishes.		SYS_REQ_6210	Analysis & Test

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_1000	**Feed Payload and SPF Receiver mass limit.** The total mass of all Feed Payloads, SPF Receiver and associated Signal Transport hardware mounted on a dish in the Phase 1 Dish Array shall not exceed TBD kg, including associated cabling.		SYS_REQ_6220	Analysis & Test

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_1010	**PAF size.** Any PAF mounted on a dish in the Phase 1 Dish Array shall fit within the volume envelope TBD. This includes associated Signal Transport hardware.		TBD	Analysis & Test

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_1020	**PAF mass**. Any PAF mounted on a dish in the Phase 1 Dish Array shall have mass not greater than 200 kg (TBC). This includes associated Signal Transport hardware.		TBD	Analysis & Test

Ident	Requirement	Applicability	Parent	Verification
DA_REQ_1020	**Dish Array power consumption.** The power consumption of the Phase 1 Dish Array shall be less than TBD kVA.		SYS_REQ_7320	Analysis

6 Quality Assurance

This section will describe the formal tests/verifications of System requirements specified in the body of this specification.

6.1 Qualification testing

Tests shall mainly be performed to verify that the SKA1 Dish Array complies to the performance requirements specified in this specification.

An incremental qualification approach shall be adopted starting at material level and culminating at SKA1 Dish Array in a Test & Qualification (T&Q) program. For existing products (COTS) proof of qualification, including the specification, method of testing and results, will be utilised. No requalification of these products will be performed (TBC: there may be need for additional EMC qualification in certain instances). However, wherever interfaces have been modified/added, regression testing will be performed to confirm the integrity of the interface against its original interface control specification.

The tests to be performed on the various subsystems of the SKA1 Dish Array will be described here. These will include aspects such Factory Acceptance Tests and Site Acceptance Tests (stand alone and integrated).

6.2 Verification methods

The requirements specified in this document shall be verified by one or more of the following methods:

- Inspection
  - Verification shall be by visual examination, comparison with engineering data and simple measurement without the use of precision measuring equipment.
- Test
  - Verification shall be by analysis or review of test data recorded using special measurement equipment and procedures.
- Demonstration
  - Verification shall be by application of go/no go criteria without the use of elaborate measurement equipment.
- Analysis
  - Verification shall be by analysis or review of calculated or simulated data.