SKA PHASE 1 SCIENCE (LEVEL 0) REQUIREMENTS SPECIFICATION

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Name	Designation	Affiliation	Date	Signature
Owned by:				
T.Cornwell	SKA Architect	SKA Office	2014.06.06	
Approved by:				
A.McPherson	Head of Project	SKA Office	2014.06.06	
Released by:				
P.Diamond	SKA Director General	SKA Office	2014.06.06	

Name	Designation	Affiliation	Date
Authored by:			
R. Braun	SKA Science Director	SKA Office	2014.06.06
T.Cornwell	Head of Computing	SKA Office	2014.06.06

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ORGANISATION DETAILS

Name	SKA Organisation
Registered Address	Jodrell Bank Centre for Astrophysics Room 3.116 Alan Turing Building The University of Manchester Oxford Road Manchester, UK M13 9PL Registered in England & Wales Company Number: 07881918
Fax.	+44 (0)161 275 4049
Website	www.skatelescope.org

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LIST OF ABBREVIATIONS

AA. ..... Aperture Array
AGN…….Active Galactic Nucleii
AIP ..... Advanced Instrumentation Programme
CoDR ..... Conceptual Design Review
ConOps..... Concept of Operations
DAA..... Dense Aperture Array
dB..... Decibel
DRM..... Design Reference Mission
EoR..... Epoch of Reionisation
EX ..... Example
FLOPS ..... Floating Point Operations per second
FoV ..... Field of View
Hr ..... hour
Hz..... Hertz
IXR……Intrinsic cross polarisation ratio
K..... Kelvin
Km..... kilometre
LNA..... Low Noise Amplifier
M ..... metre
PAF ..... Phased Array Feed
RFI ..... Radio Frequency Interference
RfP ..... Request for Proposals
S..... second
SDP..... Science Data Processor
SEFD ..... System Equivalent Flux Density
SETI……..Search For Extraterrestrial Intelligence
SKA..... Square Kilometre Array
SSEC ..... SKA Science and Engineering Committee
SSFoM ..... Survey Speed Figure of Merit
STD..... Standard
T..... Temperature
TBC..... To be confirmed
TBJ..... To be determined
TBJ..... To be justified
WBSPF ..... Wide Band Single Pixel Feed

1 Observatory

1.1 L0 Requirements

1.1.1 Introduction

The Science case for the SKA has been developed over the course of the past two decades and has most recently been summarised in a collected format[6] While many of the applications enunciated at that time are still of relevance, there have also been a host of new developments and discoveries that have changed our view of the cosmos.

Two aspects of the complete SKA Science Case were selected as a focus for the initial deployment of the SKA[4], namely

1. Understanding the history and role of neutral Hydrogen in the Universe from the dark ages to the present-day, and
2. Detecting and timing binary pulsars and spin-stable millisecond pulsars in order to test theories of gravity (including General Relativity and quantum gravity), to discover gravitational waves from cosmological sources, and to determine the equation of state of nuclear matter.

The SKA Organisation Members defined the scope of SKA Phase 1 to consist of three components that make maximum reuse of infrastructure at the MeerKAT site in South Africa and at the Australian SKA Pathfinder site:

1. SKA1-Low: a low frequency aperture array,
2. SKA1-Mid: a mid-frequency dish array
3. SKA1-Survey a mid-frequency survey array

The SKA Board also recommended the preparation of a Baseline Design[1] that represents a specific technical implementation of SKA1. The Baseline Design (BD) was written in the context of the SKA Members' decisions noted above, while striving to match the scientific capabilities embodied in the SKA1 Design Reference Mission. The Baseline Design has led to a set of System (Level 1) Requirements[3].

Between March 2013 and January 2014 there have been a series of eight Science Assessment Workshops, one for each of the current Science Working Groups that coordinate community science engagement with the SKA. The workshops have provided the opportunity for a critical review of the science capabilities of the SKA1 Baseline Design in relation to their areas of science expertise and produced two outcomes:

1. A list of the most compelling science drivers that are achievable with the current design

2. A list of potential changes to the design that might be considered to enhance the science performance.

Workshop summaries that present these outcomes are available at the meeting website [7].

1.1.2 References

1.1.2.1 Applicable documents

In the event of conflict between the contents of the applicable documents and this SKA1 Level 0 Requirement Specification document, the applicable documents shall take precedence

[1]SKA1 System Baseline Design SKA-TEL-SKO-DD-001 Rev 1
[2]Concept of Operations for the SKA Observatory SKA.TEL.SE.OPS-SKO-COO-001-0-A
[3]SKA Phase 1 System (Level 1) Requirements Specification, SKA-OFF.SE.ARCC-SKO-SRS-001_3

1.1.2.2 Reference documents

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

[4] SKA Memo 125: '*Concept Design for SKA Phase 1 (SKA$_1$)*', M.A. Garrett, J.M. Cordes, D. De Boer, J.L. Jonas, S. Rawlings, and R. T. Schilizzi (SSEC SKA Phase 1 Sub-committee), 30 May 2010.
[5] SKA Memo 130: '*SKA Phase 1: Preliminary System Description*', P.E. Dewdney et al, dated November 2010.
[6] Science with the Square Kilometre Array, edited by Carilli and Rawlings (2004).
[7] SKA SWG meeting reports https://indico.skatelescope.org/categoryDisplay.py?categId=1 .
[8] SKA-SCI-USE-001-G_Science_use_cases.

1.1.3 Purpose of the document

This document serves as a vehicle to communicate the scientific goals of the SKA Phase 1 Observatory in the form of formal requirements. The requirements are derived from the key reference documents [4,6], supported by the recent Science Assessment Workshops [7], and are written to be consistent with the Level 1 (System) requirements, which are in turn a reflection of the Baseline Design. Unlike the normal process, then, the Baseline Design document is the foundational document for SKA requirements. This approach was recommended by the November 2012 SKA Systems Engineering Review.

It is anticipated that a re-baselining process will be undertaken in the third quarter of 2014, leading to

SKA Board approval of a new Baseline Design with associated Level 0 Science Requirements in the first quarter of 2015. At that point, the updated Level 0 Requirements will become the foundation document for SKA requirements as depicted in Figure 1.

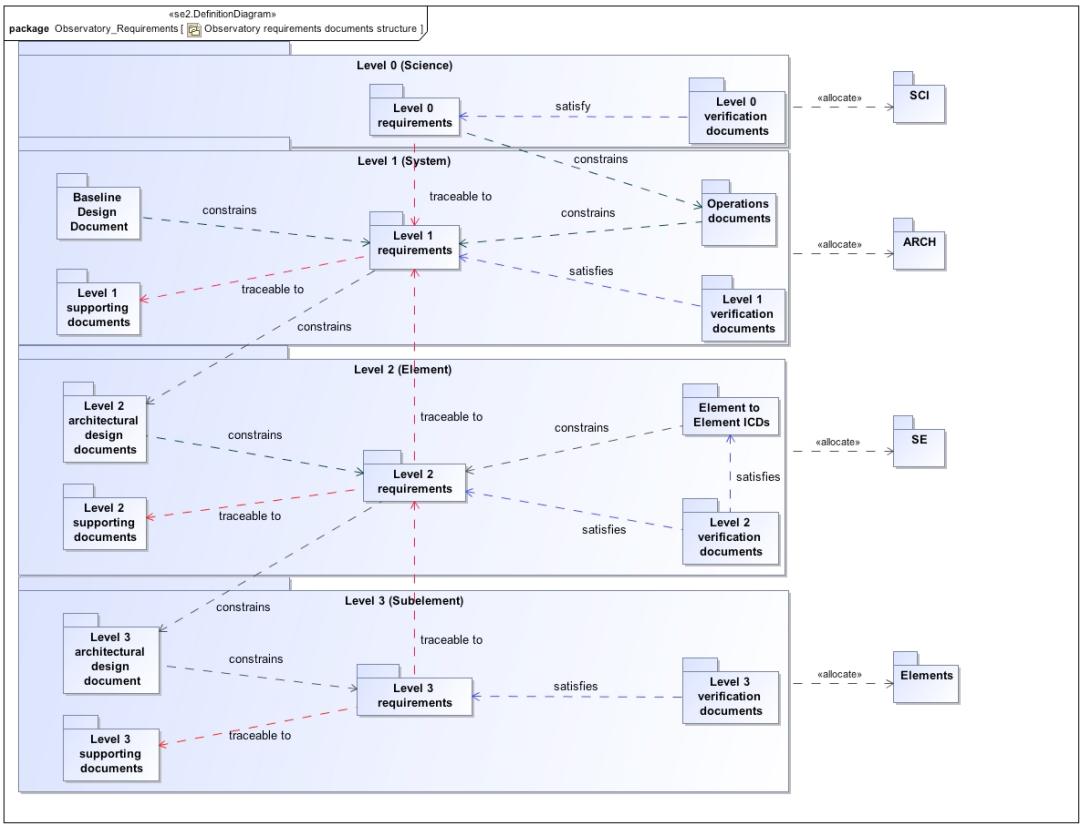

Figure 1 Phase 1 Level 0 Requirements Specification Context

1.1.3.1 Parent requirements

Parent Requirements: The Parent Requirement field denotes the source of information providing justification. The allowed values or types of value are:

- "Root": No further justification is considered to be necessary. Common in this root document.
- "Established Precedent": There is a known precedent such as an existing computing centre at a given location.
- Other requirement: Another requirement acts as justification.
- Baselined SKA document: for example ConOps or Baseline design.
- SKA document in preparation
- Publically available document with established naming conventions such as standard, academic papers.

Within this definition, we will provide a parent requirement for all requirements.

1.1.3.2 Verb convention

"Shall" is used whenever a statement expresses a convention that is binding. The verbs "should" and "may" express non-mandatory provisions. "Will" is used to express a declaration of purpose on the part of the design activity.

1.1.3.3 Definitions

All quoted sensitivities are intended to represent RMS thermal noise values that are to be achieved despite the presence of other factors such as residual calibration errors.

All quoted observing times are intended to be interpreted as net effective observing times. For example, one year of observation should be taken to imply 8760 hours of net integration time with the relevant SKA1 facility.

Image fidelity is defined as the maximum relative error in accurate recovery of an arbitrary known test image.

Dynamic range is defined as the ratio of peak to RMS residual power in an area of 10 by 10 beam areas centred on the brightest source.

A standard definition of nominal continuum bandwidth, of $\Delta\nu/\nu=0.3$, is adopted throughout. This is deemed as the maximal fractional bandwidth over which a broad-band flux density measurement is still meaningful, given the large variation in spectral energy distributions of anticipated target populations. It is distinct from the frequency range over which such measurements might be required.

The intrinsic cross-polarisation ratio (IXR) is adopted as the figure-of-merit for specifying the pre-calibration attributes of the polarization quality of the system. As documented in Carozzi and Woan, IEEE Trans. Antennas Propag, 2009, this measure defines an upper limit to the quality of post-calibration polarisation purity.

1.1.3.4 Priorities

The following priority levels are used:

- Essential: Essential that this requirement be met i.e. the minimum
- Useful: Adds significant capability beyond Essential
- Interesting: Much more capable than Essential

The “Essential” priority level is reserved for requirements that shall be met by the current Baseline Design. Other priority levels are applied to requirements that may be within or may be beyond the scope of the current Baseline Design, for example in the context of future ECPs.

The priority level is encapsulated in column 3 of the tables below. To emphasize, items with priority level 'Essential' are met by the current Baseline Design; those with other priority levels will be considered as part of future changes, upgrades or expansion.

1.1.3.5 Verification

Several standardised methods of requirement verification are defined below. For the purposes of verifying the requirements specified in this document our approach is to adopt the **Analysis** method for all those requirements that relate to post-calibration performance following significant integration times. A reference model will be used to extrapolate measured quantities appropriately.

Demonstration (D): Operation of the system, subsystem or a part of the system that relies on observable, functional operation, not requiring use of instrumentation, special test equipment or subsequent analysis

Test (T): Operation of the system, subsystem or a part of the system using instrumentation or other special test equipment to collect data for later analysis.

Analysis (A): Processing of accumulated data obtained from other qualification methods. Examples are reduction interpolation or extrapolation of test results. Since many of the requirements are for long integrations such as 1000h, actual testing is not plausible.

Inspection (I): Visual examination of system components, documentation, etc.

Special Verification Methods: Special verification methods for the system or subsystem, for example, special tools, techniques, procedures, facilities, acceptance limits, use of standard samples, preproduction or periodic production samples, pilot models or pilot lots.

Our approach is to adopt the **Analysis** method for all those requirements that relate to post-calibration performance following significant integration times. A reference model will be used to extrapolate measured quantities appropriately.

1.1.4 Memo 125 top science goals

Memo 125[4] identified the two following equal priority top science goals:

1.1.4.1 Neutral hydrogen from the Dark Ages to the present-day

- Understanding the history and role of neutral hydrogen in the Universe from the Dark Ages to the present-day

1.1.4.1.1 SKA1 will detect and image the Epoch of Reionization at redshifts of 6 to 13

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-1	SKA1 shall achieve a Stokes-I brightness sensitivity of 1 mK RMS over 1 MHz and with polarisation purity of at least 0.1% on 5 arcmin angular scales at 100 – 200 MHz over a field size of 25 deg^2 within 1000 hours of integration.	Essential	SKA1 will detect individual 21cm fluctuations during the Epoch of Reionisation (z = 6 – 13) and characterise the fluctuation spectra .	Root

1.1.4.1.2 SKA1 will detect the Cosmic Dawn at redshifts larger than 13

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-2	SKA1 shall achieve a Stokes-I brightness sensitivity of 1 mK RMS over 1 MHz and with polarisation purity of at least 0.1% on 1 degree angular scales at 50 -100 MHz over a field size up to 100 deg^2 (at 50MHz) within 1000 hours of integration.	Essential	SKA1 will characterise the 21cm fluctuation spectrum during the Cosmic Dawn (z>13).	Root

1.1.4.1.3 SKA1 will survey neutral hydrogen from galaxies at median redshift of 0.2

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-7	SKA1 shall achieve a Stokes-I sensitivity of 0.17 mJy RMS at 0.8 – 1.4 GHz (HI ΔV=30 km/s) with 2 – 5 arcsec angular resolution over 30,000 deg^2 within two years on-sky	Essential	SKA1 will detect neutral hydrogen emission from more than 5×10^6 galaxies at a median red-shift, <z> = 0.2.	Root

	integration.			

1.1.4.1.4 SKA1 will survey neutral hydrogen absorption systems at median redshift of 2

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-5	SKA1 shall achieve a Stokes-I sensitivity of 0.6 mJy RMS at 450MHz – 900 MHz (HI ΔV=3 km/s) with 2 arcsec angular resolution over 30,000 deg^2 within two years on-sky integration.	Useful	SKA1 will detect ~ 1000 deep neutral hydrogen absorption systems with a median red-shift, <z> = 2 by probing the sightlines to at least 10^6 continuum sources brighter than 1.5 mJy and at z > 2.	Root

1.1.4.2 Detecting and timing pulsars to test gravity

- Detecting and timing binary pulsars and spin-stable millisecond pulsars in order to test theories of gravity.

1.1.4.2.1 SKA1 will survey the Galaxy for pulsars in the time domain at intermediate frequencies

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-3	SKA1 shall achieve a pulse-averaged flux density sensitivity of 4 microJy at 1.4 GHz (and the scaled equivalent (assuming a spectral index = -1.6) at any other frequency within the observing frequency range of 0.35 to 3 GHz) with a bandwidth of 300MHz and a time resolution of 50microsec over 30,000 deg^2 within two years of integration. The optimum observing frequency is matched to the dispersion measure of each sky location.	Essential	SKA1 will discover the pulsar population of our own Galaxy (down to a scaled brightness of 4uJy). This will permit discovery of the rare systems that allow the strongest possible constraints to be placed on theories of gravity.	Root

1.1.4.2.2 SKA1 will survey the Galaxy for pulsars in the time domain at all deployed frequencies

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-48	SKA1 shall achieve a pulse-averaged flux density sensitivity of 4 microJy at 1.4 GHz (and the scaled equivalent (assuming a spectral index = -1.6) at any other frequency within the entire observing frequency range of SKA1) with a bandwidth of 300MHz and a time resolution of 50microsec, over 30,000 deg^2 within two years of integration. The optimum observing frequency is matched to the dispersion measure of each sky location.	Useful	SKA1 will discover the pulsar population of our own Galaxy (down to a scaled brightness of 4uJy). This will permit discovery of the rare systems that allow the strongest possible constraints to be placed on theories of gravity.	

1.1.4.2.3 SKA1 will conduct precision pulsar timing observations

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-4	SKA1 shall conduct precision pulsar timing observations spanning 0.45 – 3 GHz to an instrumental accuracy of 10 ns (rms) relative to a time standard that is stable over 10 years.	Essential	This will permit detection of gravitational radiation through a series of regular (weekly to bi-weekly) multi-frequency timing observations of about 100 – 200 millisecond pulsars.	Root

1.1.4.2.4 SKA1 will survey the Galaxy for pulsar candidates in the image domain

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-9	SKA1 shall achieve Stokes-I sensitivity of 2 μJy RMS at 1 – 1.7 GHz ($\Delta\nu/\nu$=0.3) with 2 arcsec resolution over 30,000 deg^2 within two years on-sky integration.	Essential	SKA1 will survey the Galaxy for unresolved pulsar candidates in the image domain to enable efficient pulsed emission searches.	Root

1.1.5 Other science goals (alphabetical order)

1.1.5.1 Astrobiology and the Cradle of Life

1.1.5.1.1 SKA1 will map grain growth in proto-planetary disks

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-16	SKA1 shall achieve Stokes-I sensitivity of 60 nJy at 12 GHz (Δν/ν=0.3) at 0.04 arcsec resolution over 10 arcmin^2 within 1000 hours of integration.	Useful	SKA1 will allow mapping of the growth of grains through the cm-sized regime both inside and outside the snow-line in clusters of proto-planetary disks at a distance of 100 pc.	Root

1.1.5.1.2 SKA1 will detect exo-planets

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-18	SKA1 shall achieve Stokes-V sensitivity of 150 μJy at 50 MHz (Δν/ν=0.3) over 5 deg^2 within 1 minute of integration.	Useful	planets with periods longer than one hour and with a minimum cadence of one observation per day.	Root

1.1.5.1.3 SKA1 will detect pre-biotic molecules

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-19	SKA1 shall achieve Stokes-I sensitivity of 35 μJy at 8 - 13 GHz (velocity resolution of 0.4 km/s) with 3 arcsec resolution for a single pointing within 500 hours of integration.	Useful	SKA1 will detect pre-biotic molecules with abundances relative to H of order 10^-11 in pre-stellar cores at a distance of 100 pc.	Root

1.1.5.1.4 SKA1-Low will provide the spigots to facilitate high time resolution processing

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-	SKA1-Low shall provide a	Essential	This will enable SETI	Root

42	data spigot across the 50 MHz to 350 MHz range that enables access to the time series voltage data for one dual polarisation tied array beam within the primary beam that provides the maximum available RF bandwidth for processing by external teams while either targeted or other commensal imaging observations are taking place.		surveys of nearby stars for radio emission from exo-planets, study of the Fast Radio Burst population and discovery of other rapid transient phenomena.	

1.1.5.1.5 SKA1-Mid and SKA1-Survey will provide spigots to facilitate high time resolution processing

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-46	SKA1-Mid and SKA1-Survey shall provide data spigots across the equipped frequency range that enables access to the time series voltage data for four dual polarisation beams within the primary beam that each provide the maximum available RF bandwidth for processing by external teams while either targeted or other commensal imaging observations are taking place.	Essential	This will enable SETI surveys of nearby stars for radio emission from exo-planets, study of the Fast Radio Burst population and discovery of other rapid transient phenomena.	Root

1.1.5.2 Cosmic Magnetism

1.1.5.2.1 SKA1 will measure an all sky grid of Faraday rotation measures

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-10	SKA1 shall achieve Stokes-Q and -U sensitivity of 2 μJy RMS at 1 – 1.7 GHz	Essential	SKA1 will measure an all-sky grid of Faraday rotation measures with a	Root

	(Δν/ν=0.3) with 2 arcsec resolution and polarisation purity of at least 0.1% over 30,000 deg^2 within two years on-sky integration.		density of several hundred sources per square degree, allowing estimation of galactic, intergalactic, and high-redshift galaxy magnetic fields.	

1.1.5.2.2 SKA1 will image faint magnetic field structures at 1 - 2 GHz

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-11	SKA1 shall achieve Stokes-Q and -U sensitivity of 100 nJy RMS at 0.9 – 1.8 GHz (Δν/ν=0.3) at 0.5 arcsec resolution and polarisation purity of at least 0.1% over 10 deg^2 within two years of integration.	Essential	SKA1 will measure the magnetic field structure and its relation to gas flows in a large number of galaxies, AGNs and intergalactic filaments.	Root

1.1.5.2.3 SKA1 will image faint magnetic field structures at 2 - 3 GHz

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-12	SKA1 shall achieve Stokes-Q and -U sensitivity of 100 nJy RMS at 1.6 – 3 GHz (Δν/ν=0.3) at 0.5 arcsec resolution and polarisation purity of at least 0.1% over 3 deg^2 within 1.5 years of integration.	Essential	SKA1 will measure the magnetic field structure and its relation to gas flows in a large number of galaxies, AGNs, galaxy clusters and intergalactic filaments.	Root

1.1.5.3 Cosmology

1.1.5.3.1 SKA1 will place constraints on primordial fluctuations

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-13	SKA1 shall achieve Stokes-I sensitivity of 2 μJy RMS at 1 – 1.7 GHz (Δν/ν=0.3) with 2 arcsec resolution over 30,000 deg^2 within two years on-sky	Essential	SKA1 will provide a sufficient source detections to permit sensitive constraints to be placed on the non-Gaussianity of primordial	Root

	integration.		fluctuations using the Integrated Sachs Wolfe effect.	

1.1.5.3.2 SKA1 will measure weak gravitational lensing

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-14	SKA1 shall achieve Stokes-I sensitivity of 1 μJy RMS at 1.4 – 1.7 GHz (Δν/ν=0.3) with at least 0.7 arcsec resolution with residual systematic PSF shape errors of less than 35dB over 5,000 deg^2 within two years on-sky integration.	Essential	This will provide sufficient high accuracy source shape measurements to permit significant constraints to be placed on the Dark Energy equation of state using weak gravitational lensing.	Root

1.1.5.3.3 SKA1 will measure Baryon Acoustic Oscillations

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-15	SKA1 shall achieve Stokes-I sensitivity of 0.07 mJy RMS at 0.8 – 1.4 GHz (HI ΔV=30 km/s) with 2 – 5 arcsec angular resolution over 5,000 deg^2 within two years on-sky integration.	Essential	SKA1 shall measure red-shift resolved Baryon Acoustic Oscillations from the neutral hydrogen emission from more than 10^7 galaxies at a median red-shift, <z> = 0.3, and with more than 10^5 galaxies at a median red-shift, <z> = 1.	Root

1.1.5.4 Galaxy Evolution

1.1.5.4.1 SKA1 will detect actively star forming galaxies to redshift 3

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-35	SKA1 shall achieve Stokes-I sensitivity of 2 μJy RMS at 1 – 1.7 GHz (Δν/ν=0.3) with 2 arcsec resolution over 30,000 deg^2 within two years on-sky integration.	Essential	SKA1 will detect actively star-forming galaxies (L_IR = 10^12 L_Sun) out to at least z = 3.	Root

1.1.5.4.2 SKA1 will detect diffuse radio halos in galaxy clusters

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-26	SKA1 shall achieve Stokes-I sensitivity of 20 μJy with 10 arcsec resolution over 0.1 - 0.3 GHz (Δν/ν=0.3) over 30,000 deg^2 within two years of integration.	Essential	SKA1 will detect diffuse radio halos in galaxy clusters of masses M < 3-5 10^14 M_Sun up to z=0.5.	Root

1.1.5.4.3 SKA1 will measure galaxy morphology

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-8	SKA1 shall achieve Stokes-I sensitivity of 100 nJy RMS at 0.9 – 1.8 GHz (Δν/ν=0.3) with 0.5 arcsec resolution over 10 deg^2 within two years on-sky integration.	Useful	SKA1 will study morphology of galaxies at a sufficient brightness sensitivity of about 0.1K rms for galaxy evolution studies at z > 1, deep fields and lensing clusters.	Root

1.1.5.4.4 SKA1 will detect thermal emission from star forming galaxies

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-27	SKA1 shall achieve Stokes-I sensitivity of 45 nJy with 0.1 – 1 arcsec resolution over 8 – 13 GHz (Δν/ν=0.3) for a single pointing within 1000 hours of integration.	Useful	SKA1 will detect thermal emission from star-forming galaxies and allow the study of star-formation driven processes at z>1.	Root

1.1.5.4.5 SKA1 will observe AGN

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-36	SKA1 shall achieve Stokes-I sensitivity of 2 μJy RMS at 1 – 1.7 GHz (Δν/ν=0.3) with 2 arcsec resolution over 30,000 deg^2 within two years on-sky	Essential	SKA1 will observe moderate luminosity active galactic nuclei (P_1.4GHz = 10^24 W/Hz) to at least z = 5.	Root

	integration.			

1.1.5.4.6 SKA1 will image HI cloud complexes

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-6	SKA1 shall achieve Stokes-I brightness sensitivity of 5 K RMS at 1.3 – 1.43 GHz (HI ΔV=2 km/s) with 2 arcsec resolution over 0.4 deg^2 within 1000 hours of integration.	Essential	SKA1 will resolve and detect individual cloud complexes (500 pc and 2 km/s) in galaxies out to 50 Mpc distance.	Root

1.1.5.5 Radio transients

1.1.5.5.1 SKA1 will detect and localise transient sources

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-20	SKA1-Low, SKA1-Mid, and SKA1-Survey shall be capable of imaging every correlator integration to detect and localise transient sources, with a latency of less than 10 seconds after data is available at correlator.	Useful	This will increase the rate of transients detection, and the chances of finding the most rare events. Rapid dissemination of the brightest alerts will maximise the global scientific return via multi-wavelength follow up.	Root

1.1.5.5.2 SKA1-Mid and SKA1-Survey will be capable of reacting to external triggers

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-24	SKA1-Mid, and SKA1-Survey shall be capable of rapid reconfiguration of their observing mode in no more than 10 seconds in response to internal or externally generated, pre-	Essential	For the dish arrays this would correspond to reconfiguring the observing mode and begin slewing to the requested look direction.	Root

	defined triggers.			

1.1.5.5.3 SKA1-Low will be capable of reacting to external triggers

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-47	SKA1-Low shall be capable of rapid reconfiguration of observing mode in no more than 3 seconds in response to internal or externally generated, pre-defined triggers.	Essential	For SKA1-LOW this would correspond to pointing the arrays in the new direction	Root

1.1.6 Technical capabilities

General technical requirements have emerged from the Science Assessment Workshops described in the Introduction above and documented in the Workshop summaries [7] as well as from the Use Cases [8] that consider the methodology to achieve specific science outcomes.

1.1.6.1 SKA1 will allow wide-field surveys

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-22	SKA1 shall undertake wide-field surveys of the sky while dominated by thermal noise that declines as the square root of accumulated bandwidth ($\Delta\nu/\nu=0.5$ to $\Delta\nu/\nu=10^{-6}$) and observing time (up to 1000 hours).	Essential		SKA1-SCI-5, SKA1-SCI-7, SKA1-SCI-9, SKA1-SCI-26, SKA-SCI-10, SKA1-SCI-12, SKA1-SCI-13, SKA1-SCI-14, SKA1-SCI-15

1.1.6.2 SKA1 will allow tracking observations

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-31	SKA1 shall undertake tracking observations while dominated by thermal noise that declines as the square root of accumulated bandwidth ($\Delta\nu/\nu=0.5$ to	Essential		SKA1-SCI-1, SKA1-SCI-2, SKA1-SCI-27, SKA1-SCI-16, SKA1-SCI-20

	Δv/v=10^-6) and observing time (up to 1000 hours).			

1.1.6.3 SKA1-Low will image at high dynamic range

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-39	SKA1-Low shall attain dynamic range of 50dB where the noise level is measured no closer than 10 synthesized beams to the brightest source in the field.	Essential		SKA1-SCI-1, SKA1-SCI-2

1.1.6.4 SKA1-Mid will image at high dynamic range

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-40	SKA1-Mid shall attain dynamic range of 60dB where the noise level is measured no closer than 10 synthesized beams to the brightest source in the field.	Essential		Root

1.1.6.5 SKA1-Survey will image at high dynamic range

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-41	SKA1-Survey shall attain dynamic range of 60dB where the noise level is measured no closer than 10 synthesized beams to the brightest source in the field.	Essential		Root

1.1.6.6 SKA1 will image with high spectral dynamic range

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-30	SKA1 shall possess relative calibration accuracy of adjacent frequency intervals of better than 40 dB for	Essential		Root

	Δv/v=10^-2 to Δv/v=10^-5.			

1.1.6.7 SKA1 will image with very high spectral dynamic range

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-44	SKA1 shall possess relative calibration accuracy of adjacent frequency intervals of better than 50 dB for Δv/v=10^-2 to Δv/v=10^-5.	Useful		Root

1.1.6.8 SKA1 will image with high relative calibration accuracy across the sky

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-37	SKA1-Low, SKA1-Mid, SKA1-Survey shall provide a relative calibration precision for different source directions on the sky of better than 20 dB for source separations in the range of 1 arcmin to 180 deg.	Essential		Root

1.1.6.9 SKA1 will image with very high relative calibration accuracy across the sky

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-33	SKA1-Low, SKA1-Mid, SKA1-Survey shall provide a relative calibration precision for different source directions on the sky of better than 35 dB for source separations in the range of 1 arcmin to 180 deg.	Useful		Root

1.1.6.10 SKA1 will image with high polarisation purity

ID	Requirement	Priority	Rationale	Parent

				Requirement
SKA1-SCI-34	SKA1-Low, SKA1-Mid, SKA1-Survey shall provide an intrinsic cross polarisation ratio (IXR) of at least 30 dB on-axis and 30 dB down to the half power point of the dish or station beam.	Essential		SKA-SCI-1, SKA-SCI-2, SKA-SCI-10, SKA-SCI-11, SKA-SCI-12

1.1.6.11 SKA1 will image with very high polarisation purity

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-38	SKA1-Low, SKA1-Mid, SKA1-Survey shall an provide intrinsic cross polarisation ratio of at least 40 dB on-axis and 40 dB down to the half power point of the dish or station beam.	Interesting		SKA-SCI-1, SKA-SCI-2, SKA-SCI-10, SKA-SCI-11, SKA-SCI-12

1.1.6.12 SKA1 will allow non-imaging observations

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-32	SKA1-Mid shall be capable of non-imaging observations, using the beamformed time series.	Essential		SKA1-SCI-3, SKA1-SCI-4, SKA-SCI-42

1.1.6.13 SKA1 will provide a sub-array capability

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-29	All SKA1 telescopes shall be capable of operating with one to four sub-arrays, in which the collecting area is split and allocated to separate, concurrent observing programmes.	Essential	All those applications that require more simultaneous field of view than instantaneous sensitivity benefit from sub-array operation; these include many types of transient phenomena and phase-referenced VLBI.	Root

1.1.6.14 SKA1 will provide an extensive sub-array capability

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-53	All SKA1 telescopes shall be capable of operating with one to sixteen sub-arrays, in which the collecting area is split and allocated to separate, concurrent observing programmes.	Useful	All those applications that require more simultaneous field of view than instantaneous sensitivity benefit from sub-array operation; these include many types of transient phenomena and phase-referenced VLBI.	

1.1.6.15 SKA1 will allow VLBI with tied-array beams

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-28	SKA1-Mid and SKA1-Survey shall support VLBI with four tied-array beams distributed over one or more sub-arrays.	Essential	This will enable high resolution imaging in conjunction with other, simultaneously recorded, VLBI data.	Root

1.1.6.16 SKA1 will mitigate the effects of RFI

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-43	SKA1 shall be designed to mitigate the effects of RFI at all subsystems according to an RFI/EMC mitigation plan.	Essential	Science based on redshifted Neutral Hydrogen is dependent on accurate and efficient RFI mitigation.	Root

1.1.6.17 SKA1 will permit commensal imaging data products

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-50	SKA1 shall be designed to allow multiple categories of imaging data products to be generated from the same data stream when not constrained by the available computing capacity.	Essential	Multiply the scientific productivity of the facilities by simultaneously providing data products for broad-band continuum, polarimetric continuum,	Root

			red-shifted spectral lines and slowly varying radio transients.	

1.1.6.18 SKA1 will provide high image fidelity

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-51	SKA1 shall provide an image fidelity of better than 20dB.	Essential		SKA1-SCI-9, SKA1-SCI-14, SKA1-SCI-8, SKA1-SCI-27, SKA1-SCI-36

1.1.6.19 SKA1 will image with high astrometric accuracy

ID	Requirement	Priority	Rationale	Parent Requirement
SKA1-SCI-52	SKA1 shall provide connected interferometric imaging over the entire range of deployed frequency coverage with an astrometric accuracy relative to the adopted reference frame of better than one tenth of the point spread function full width at half maximum.	Essential		SKA1-SCI-7, SKA1-SCI-5, SKA1-SCI-9, SKA1-SCI-16, SKA1-SCI-19, SKA1-SCI-10, SKA1-SCI-13, SKA1-SCI-14, SKA1-SCI-15, SKA1-SCI-35, SKA1-SCI-8, SKA1-SCI-36, SKA1-SCI-6, SKA1-SCI-20