A year in the life of the SKA telescopes: overview and main outcomes

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1 Introduction

1.1 Purpose of the Document

The construction and commissioning of the Square Kilometre Array (SKA) telescopes are proceeding at pace, with the first phase of Science Verification expected in 2027. To provide crucial input for operations planning as we head towards telescope operations, the Science Operations team undertook a significant piece of work to simulate a "year in the life of the SKA telescopes". This work provides a fairly detailed representation of what a "standard" year in operations might look like, drawing heavily on the increasingly sophisticated SKA science plans within the astronomy community and the increasingly detailed understanding of the SKA telescopes. The year in the life has allowed us to build confidence in the system that is being delivered for science, and the processes in place to allow users to access the full potential of the SKA. Chief amongst the outcomes is the first real understanding of the distribution of telescope mode usage, commensality potential, Science Data Processor loading, the distribution of Observatory Data Product types delivered to the SKA Regional Centres Network (SRCNet) and the overall data rates. The content presented in this document draws heavily on the material collated from this internal year in the life analysis.

In this document, we summarise the year in the life analysis in a compressed form that we hope will provide the community with an accessible resource that provides some guidance on how we might expect the SKA telescopes to function. It provides the SKA user community with the technical capabilities of the SKA telescopes at AA* during steady-state cycle operations, along with the science data processing workflows and their output data products. It also summarises the anticipated interaction between the telescope users, the SKA Observatory, and the SRCNet during the proposal submission, project execution, and data analysis phases. The SKA Observatory is compiling a scientific timeline describing the evolving capabilities of the SKA telescopes as we build towards steady-state cycle operations, which can be found on the Observatory's scientific timeline webpage.

1.2 Scope of the Document

The SKAO remains committed to delivering the design baseline (512 SKA-Low stations and 197 Mid dishes), but since funding to meet this goal has not yet been fully secured, we are planning to begin Operations with an intermediate array, called AA*. The AA* array will comprise 307 SKA-Low stations and 144 SKA-Mid dishes [AD1], providing the community with two hugely powerful telescopes already capable of transforming our understanding of the Universe. For the purposes of the year in the life analysis we have employed the AA* array, but note that, with some scaling, it has also provided a valuable resource for understanding how a year in the life with the baseline design telescopes might differ, mostly in complexity of data product creation and data product size.

Here, we further consider what steady-state cycle operations (anticipated around cycle 4) might look like and note that there will be a ramp-up in telescope capabilities, starting with science verification and continuing into the early observing cycles. The expected capabilities available during this intervening period are presented in the Observatory's scientific timeline webpage.

The biggest influences on the year in the life of the SKA are the capabilities of the telescopes, operational model and the overall science programme. For the latter, we have drawn on the wealth of community resources including the updated SKA Science Cases [RD1]; the results of the SKA Regional Centre Steering Committee (SRCSC) Working Group 6 TP1 SWG questionnaire; the Jumping Jive VLBI science use cases [RD2]; discussions with members of the SWGs; the previously defined High Priority Science Objectives (HPSOs) [RD3]; and SKA science cases, established following the 2014 community meeting, and subsequent SKA Science Book [RD4]. While we placed significant emphasis on making sure we had a representative scientific programme, we understand that the process has been very different to how it will be decided once the Observatory is operational. The derived scientific program does not imply any preference for some science cases over others; rather, it represents our best attempt at a representative program that falls within the reasonable natural variation we might expect from cycle to cycle.

We encourage feedback from the SKA users' community, ideally directly addressed to members of the Science Operations team at sciops@skao.int.

2 Capabilities of the SKA telescopes

2.1 The SKA-Low and SKA-Mid arrays

In the AA* milestone, the SKA-Low telescope consists of 307 Low-Frequency Aperture Array (LFAA) stations. Each SKA-Low station comprises 256 dual-polarisation log-periodic antennas, sensitive to radio frequencies (RF) in the 50 - 350 MHz range. The stations are arranged in a three-armed spiral pattern with a dense core, resulting in a maximum baseline length of ~74 km.

In the AA* milestone, the SKA-Mid telescope consists of 144 dishes comprising 80 15-m SKA dishes (including 14 MeerKAT+ dishes) and 64 13.5-m MeerKAT dishes. Figure 1 shows the array layouts of both telescopes at the AA* milestone. The SKA-Mid dishes are sensitive to radio frequencies in the 0.35 - 15.4 GHz range. This broad frequency range incorporates four different receivers (bands 1, 2, 5a, and 5b), whose individual bandwidths are listed in Table 1. Note that bands 5a and 5b receiver backends are available only on the 80 15-m SKA dishes.

The SKA-Mid dishes are arranged in a three-armed spiral pattern with a dense core, resulting in a maximum baseline length of ~108 km. The longest baseline is provided by a single dish (SKA008, represented as a red square in Figure 1), without which the maximum baseline length is ~36 km. In the short term, the implementation of SKA008 primarily serves as a means for testing long-baseline capabilities to be fully implemented when SKA-Mid is extended to the design baseline. In the intervening period, even for long-track observations, the inclusion of SKA008 produces an elliptic PSF with large sidelobes. For this reason, we anticipate that much of the science program will be carried out without SKA008.

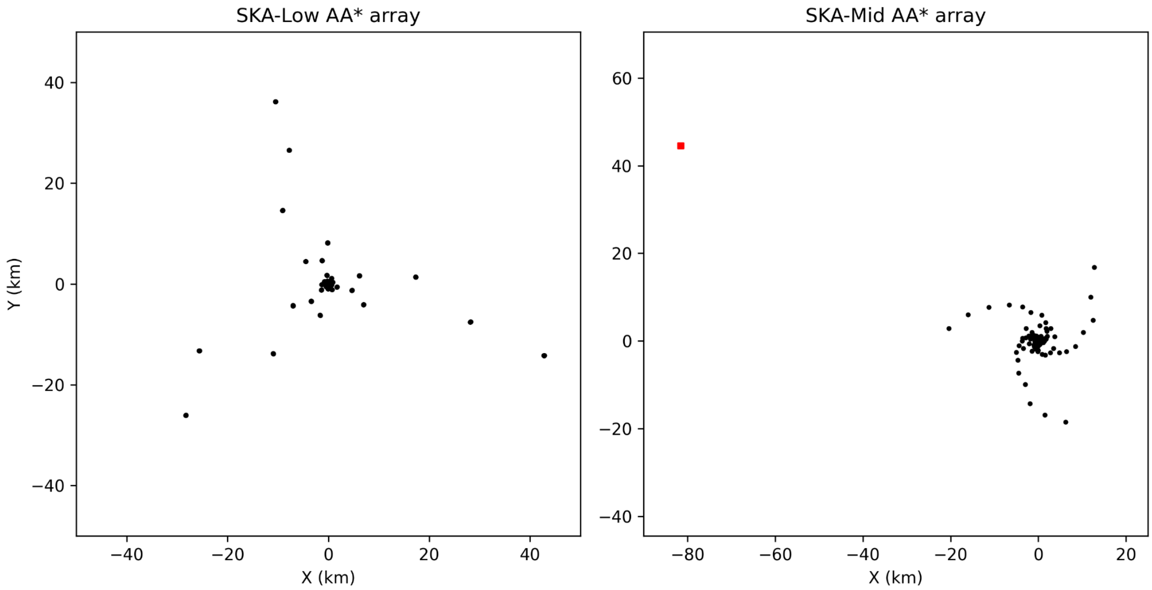


Figure 1: Array layout of the SKA-Low and SKA-Mid telescopes in AA* array assembly.

While many SKA projects will require the enormous sensitivity and imaging quality of the full AA* arrays, some projects may be able to meet their scientific goals with a smaller array. To meet these needs, while maximising scientific efficiency, the SKA telescopes can form up to 16 concurrent subarrays for both scientific and engineering/maintenance purposes. The SKA Observatory will maintain a library of scientifically motivated subarray templates, which can be selected at the proposal submission stage. A detailed discussion on the subarray usage and the subarray templates library can be found in the SKA subarray templates memo [AD2].

In the case of SKA-Low, the digital station beamforming employed by the telescope allows for more complex and flexible digital signal processing. Each SKA-Low station can create up to 48 station beams, provided the maximum bandwidth per station beam is limited to 300 MHz, and if more than one station beam is configured, the sum of the bandwidths of all the station beams produced by each SKA-Low station does not exceed 300 MHz.

Furthermore, the 256 antennas in each SKA-Low station can be grouped and beamformed separately to create substations. Utilising substations allows astronomers to access a larger field of view and shorter baseline lengths (as compared to correlating with full stations). Note that observing using substations requires sacrificing the instantaneous bandwidth since the full 300 MHz is unavailable with substations. This is because the number of baselines in the subarray increases tremendously with the inclusion of substations, resulting in a data rate that cannot be supported. Detailed discussions on the restrictions imposed by substation usage are presented in the SKA-Low substation templates memo [AD3]. In AA*, the SKA-Low telescope can support up to 1440 substations.

The RF signal from each SKA-Low station beam and each SKA-Mid dish is preprocessed (amplified, digitised, and coarse channelised) at their respective telescope sites before they are transported to the Central Signal Processor facilities for fine channelisation, correlation and beamforming, and post processing.

2.2 Observing modes

The SKA-Low and SKA-Mid telescopes can operate in one, or up to all (subject to available resources), of the following observing modes simultaneously:

- Continuum
- Zoom/spectral line
- Pulsar search
- Pulsar timing
- Detected filterbank (dynamic spectrum)
- Flow-through
- Transient buffer capture
- VLBI

These eight observing modes are made possible by three subsystems that form the Central Signal Processor (CSP) shown in Figure 2: Correlator Beam Former (CBF), Pulsar Search Subsystem (PSS) and Pulsar Timing Subsystem (PST). The outputs of these subsystems are passed to the Science Data Processor (SDP), which runs observing mode-specific real-time and batch processing workflows to generate the Observatory Data Products (ODPs). The ODPs will then be delivered to the science users via the SKA Regional Centre Network (SRCNet). The relationships between these subsystems and the eight observing modes are described below.

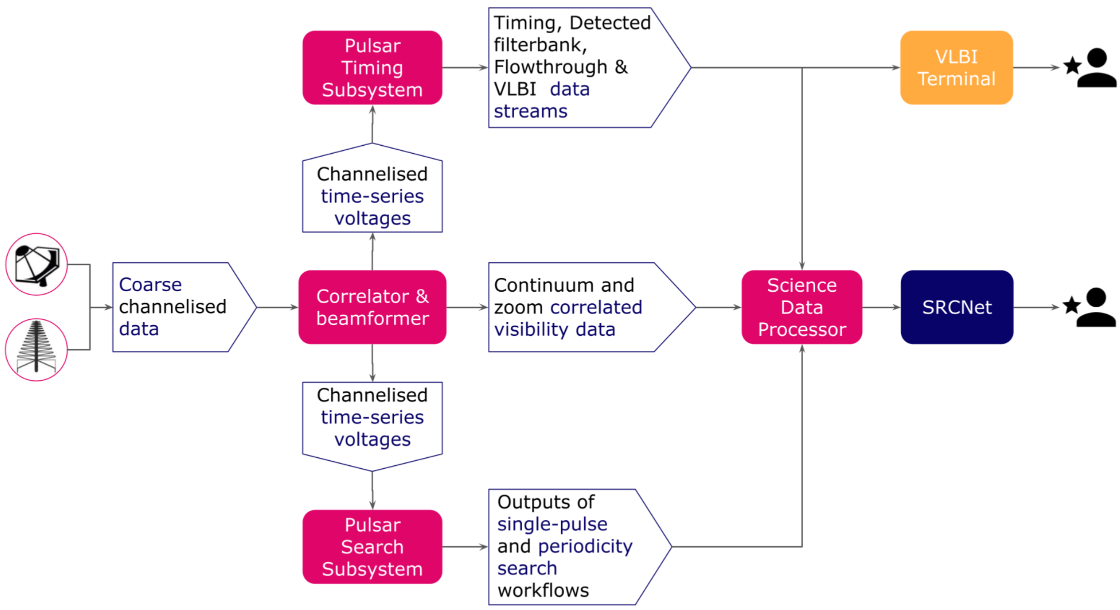


Figure 2: Schematic layout of the various subsystems available on the SKA-Low and SKA-Mid telescopes.

The **continuum** and **zoom/spectral line** correlation modes are facilitated by the CBF subsystem, which correlates signals from the individual dishes/station beams in a given subarray to produce visibility data. This includes both auto- and cross-correlations for all four Stokes parameters. The bandwidth and channelisation for the two telescopes in continuum and zoom correlation modes are listed in Table 1 below. Note that the continuum bandwidth for SKA-Mid is different in each of the four receiver bands. In the zoom/spectral line mode, on both telescopes, multiple spectral windows can be configured, and each spectral window can be independently configured to use any of the channelisation schemes mentioned in Table 1 below. For both telescopes, the number of channels per zoom window can be arbitrarily tuned, provided that the configuration is within the limits imposed by available resources on the CBF, the SDP, and the network infrastructure.

The **pulsar search** mode is facilitated by the CBF and PSS subsystems. For this mode, channelised time-series data from the tied-array beams formed by the CBF are processed in the PSS, and any detected pulsar (through periodicity searches) or fast transient (through single-pulse searches) candidates are forwarded to the SDP. For SKA-Low, the time and frequency resolutions of the PSS data stream are 69 μs and 14.5 kHz, respectively, and the maximum bandwidth is 118.5 MHz. In the case of SKA-Mid, the time and frequency resolutions are 65μs and 107.5 kHz, respectively, and the maximum bandwidth is 300 MHz. When performing periodicity searches, scans are configurable between 180 and 1800 seconds, for all beams in a subarray, in fixed multiples of the sampling interval. Moreover, for both telescopes, tied-array beamforming is restricted to the inner 20 km of the array.

In AA*, the SKA-Low and SKA-Mid telescopes can create up to 8 and 16 PST beams, respectively. With SKA-Low, the maximum allowed bandwidth per PST beam is 300 MHz. With SKA-Mid, the maximum allowed bandwidth per PST beam is limited to 2.5 GHz or the width of the observing band, whichever is smaller. On both telescopes, each PST beam can be independently configured to record data in one of the three observing modes: **pulsar timing**, **detected filterbank**, and **flow-through**. The time and frequency resolutions of the PST data streams produced by the CBF are 207 μs and 3.6 kHz, respectively, for Low and 16.3 μs and 53.8 kHz, respectively, for Mid. Note that a given PST tied-array beam cannot record more than one type of data; i.e., the same PST beam cannot simultaneously record, for example, pulsar timing (folded-pulse data) and detected filterbank data.

When the PST is configured to process a beam in **pulsar timing** mode, the output product is a series of integrated pulse profiles (IPPs). IPPs are frequency- and pulsar phase-resolved averages of polarised flux for a given pulsar. IPPs generated by the PST are used in the SDP to generate time-of-arrival measurements (ToAs). Observations are configurable between 10 seconds and 300 minutes.

The **detected filterbank** mode converts the channelised time-series voltages from the tied-array PST beam into time- and frequency-resolved spectra with configurable time (between 100 ns and 10 s) and frequency (between 2 Hz and 10 MHz) resolutions. The following signal processing may be applied in this mode: re-channelisation, formation of Stokes parameters, bit-width resampling, time averaging, de-dispersion to a provided dispersion measure, and RFI identification and excision.

The **flow-through** mode transmits the channelised time-series voltages from the tied-array PST beam to SDP with minimal signal processing. The user can request bit-width resampling and channel selection on flow-through data. The flow-through data are routed to the SRCNet (via SDP) for further processing.

The **transient buffer capture** mode consists of a buffer continuously recording a certain bandwidth of raw voltage data, in dual polarisation, corresponding to all Mid antennas and Low station beam data to capture transient events. The characteristics of the buffer (e.g., bandwidth and size) depend on the upstream configuration of the telescope. The maximum bandwidth that can be buffered is limited to 150 MHz with SKA-Low and 400 MHz with

SKA-Mid. The default bit depth for both telescopes is 2 bits. With SKA-Low, the buffer is 900 seconds long and can be triggered to dump 510 seconds of data for the default bandwidth and bit depth. With SKA-Mid, the buffer is 60 seconds long and can be triggered to dump 22 seconds of data for the default bandwidth and bit depth. Reducing the bandwidth allows users to dump longer time windows and with higher bit depths. The buffer can be dumped when an alert is received, either internally from the telescope (e.g., following the detection of a single pulse) or externally from multi-wavelength and/or multi-messenger triggers.

VLBI mode provides independent steerable tied-array dual polarisation beams. The VLBI observing mode is enabled by the PST subsystem, and to be compatible with data from other telescopes participating in the VLBI experiment, the voltage data from the PST beams are re-channelised, averaged in time, polarisation-corrected, and RFI masked, before being exported in the standard VLBI format (VLBI Data Interchange Format; VDIF) for correlation at an external facility. In the AA* configuration, SKA-Low can form up to four VLBI beams, each with a maximum bandwidth of 64 MHz. Wider bandwidth of up to 256 MHz can be achieved by configuring all four VLBI beams to the same pointing centre. SKA-Mid can form four VLBI beams, each with a maximum bandwidth of 2500 MHz.

Table 1: Anticipated capabilities of SKA-Low and SKA-Mid in the AA* configuration.

	Low	**Mid**
Number of dishes/stations	307	144 (including 64 13.5-m MeerKAT antennas)
Max. effective baseline	74 km	36 km (108 km with SKA008)
Frequency range	50 - 350 MHz	Band 1: 350–1050 MHz Band 2: 950–1760 MHz Band 5a: 4.6–8.5 GHz (80 antennas) Band 5b: 8.3–15.4 GHz (80 antennas)
Continuum channelisation	5.4 kHz	13.4 kHz
Standard integration time	0.85 s	0.125 s
Max. continuum bandwidth	300 MHz	Band 1, 2, 5a: full BW Band 5b: 2 x 2.5 GHz
Station beams	48	—
Zoom modes	**Freq res (Hz)**	**Freq res (kHz)**
	14.1	0.21
	28.2	0.42

	Low	Mid
	56.4	0.84
	113	1.68
	226	3.36
	452	6.72
	904	13.44
	1808	
PSS	250 beams 118-MHz BW	1125 beams 300 MHz BW
PST	8 beams 300-MHz BW	16 beams up to 2.5 GHz BW
Subarray	Max 16	Max 16
Substations	Max 1440	N/A
Transient buffer size	Max 900 s	Max 60 s
VLBI	4 beams 64 MHz BW per VLBI beam	4 beams[1] up to 2.5 GHz BW per VLBI beam

2.3 Telescope tracking modes

The SKA telescopes will support four tracking modes:

1. **Sidereal tracking:** when a target is continually observed as it moves at the sidereal speed (the apparent rate at which the celestial sky rotates).
2. **Non-sidereal tracking:** when a target is continually observed at a speed different from the sidereal rate (e.g. objects in our Solar System, non-astrophysical objects).
3. **Wide-area scanning:** also referred to as on-the-fly mapping, for Mid, when a large area of the sky is observed at a speed faster than the sidereal rate, with multiple parallel scans (raster scanning), in a given coordinate system (right ascension - declination, altitude-elevation, Galactic). These observations are typically done for shallow integrations, and used for cases where the overheads to produce a large map with other observing modes will be significantly higher.
4. **Drift scanning:** when the observation is fixed relative to the Earth, i.e. at a fixed azimuth and elevation, and the sky moves at the sidereal rate across the field of

[1] While the requirement remains at 4 beams, it might be possible to implement a maximum of 16 VLBI beams in a single subarray.

view. This mode would include zenith drift scans, which could be utilised by some of the science fields.

For SKA-Mid, these modes (except drift scanning) require the physical movement of the dishes, whilst for SKA-Low, these modes require appropriate beamforming. For both telescopes, PSS and PST tied-array beamforming is possible only with sidereal tracking.

2.4 SDP workflows and Observatory Data Products

The real-time and batch processing workflows executing on the SDP will generate the ODPs associated with each observing mode. It is the responsibility of the SKA Observatory to provide the standard calibration schema for each observation. It is therefore not necessary for the proposal team to specify their calibration strategy, and the execution time required for any calibration observations will be attributed to an Observatory calibration project rather than the science project. If the project team determines that bespoke calibration is required, the time for calibration will be chargeable to the project. Since the Observatory will endeavour to provide the appropriate calibration, this should be a relatively rare occurrence.

Note that VLBI data streams are not processed on the SDP, but instead, they are forwarded to an external correlation facility via the VLBI terminal (see Figure 2).

The SKAO will provide users with science data products, called ODPs, which are generated on the SDP according to the parameters and pipelines specified in the proposal. ODPs are classified into two categories:

1. Observation-Level Data Products (OLDPs): data products generated with SDP using the data from (typically) a single observing session.
2. Project-Level Data Products (PLDPs): data products generated by combining several related OLDPs.

After ODP generation and rigorous Quality Assessment (QA), the ODPs will be exported to the SRCNet, where the users can interact with them. Within the SRCNet, users may create *Advanced Data Products (ADPs),* generated through rigorous analysis and/or modelling using the ODPs.

In Table 2 below, we list the different ODPs grouped by the corresponding observing modes. More information about these ODPs and their data lifecycle management plan can be found in [AD4]. Note that the ODPs corresponding to the wide-area scanning mode and auto-correlation data are not list in Table 2. Their precise definition and procedure to generate them are currently under investigation and more information about these ODPs can be found in [AD4].

Table 2: Description of Observatory Data Products (ODPs).

ODP type	Description
Correlated observations (continuum and zoom/spectral line)	

Table 2: Description of Observatory Data Products (ODPs).

ODP type	Description
Images/spectral cubes	Inverted and deconvolved image or spectral line cube along with the model, PSF, and residual images. Spectral line cubes can be generated after optional continuum subtraction, where the individual channels are deconvolved and imaged separately.
Calibrated visibilities	Visibility data with appropriate time and frequency averaging[2].
uv grids[3]	Calibrated visibility data gridded (with associated weights per uv cell) at the user-requested spatial and frequency resolution. One grid per facet is generated if direction-dependent calibration has been applied to the data.
Local Sky Model (LSM) catalogue	Catalogue of a subset of the Global Sky Model (GSM) containing the sources relevant for the data being processed. These are the sources in the FOV, as well as, potentially, strong sources outside of the current FOV.
Imaging transient source catalogue	Time-ordered catalogue of candidate transient objects pertaining to each detection alert from the real-time, fast imaging pipeline.
PSS	
Sieved pulsar and transient candidates	In pulsar acceleration search mode: an Optimised Candidate Lists & Data (OCLD), i.e. a list of parameters containing period, acceleration, signal-to-noise and dispersion measure of each of the detected candidates; and a single cube per candidate, representing the total intensity (Stokes I) of the signal for the folded and de-dispersed pulsar profiles (without information on polarization). In single pulse search: a Single Pulse Optimised Candidate Lists & Data (SPOCLD), i.e. a list of parameters containing time of occurrence, signal-to-noise, dispersion measure and pulse width; and full polarisation (Stokes IQUV) filterbank data (at a configurable frequency and time resolution) covering the pulse duration.

[2] A null calibration table with zero averaging could be applied to allow access to raw visibilities in exceptional circumstances.

[3] The main driver for generating uv grids is to enable PLDP generation. The Observatory is exploring other approaches to PLDP generation, including Sidereal Visibility Averaging (see [AD5]).

Table 2: Description of Observatory Data Products (ODPs).

ODP type	Description
PST	
Pulsar timing solutions	include the original input data (folded pulsar profiles that the SDP receives, before the PST pipelines on the SDP perform further RFI excision, calibration and averaging) as well as averaged versions of these data products (either averaged in polarisation, frequency, or time) in PSRFITS format; time of arrival (ToAs); residuals from the current best-fit timing model for the pulsar and updated ephemerides (timing models).
Detected filterbank archives	High time- and frequency-resolution, full Stokes polarisation filterbank data, with configurable frequency and time resolutions, requantised to efficient bit depth (1, 2, 4, 8, 16 or 32 bits/sample).
Flow-through archive	Archive of the input tied-array beam signal from the beam former. Raw, dual-polarisation beamformed voltages requantised to appropriate bit depth (1, 2, 4, 8, 16 or 32 bits/sample), with some simple RFI mitigation; and a portion of the frequency band in one or both polarisations selected for archiving in PSRDADA format.
Other observing modes	
Transient buffer data	Complex dual-polarisation voltage data from each SKA-Mid dish or SKA-Low station beam (after station beamforming) that is part of the subarray.
Science alerts catalogue	Catalogue of International Virtual Observatory Alliance (IVOA) formatted science alerts, produced and communicated by the SDP. This catalogue provides a searchable and retrievable record of past alerts.
Science product catalogue	A database relating to all science data products processed by the SDP. It includes associated scientific metadata that can be queried and searched, and includes all information so that the result of a query can lead to the delivery of data.

2.5 Commensal observations with the SKA telescopes

As discussed in section 2.2, the flexible Central Signal Processors and the ability to create multiple subarrays (and station beams on SKA-Low) enable the SKA telescopes to observe in multiple modes commensally. On both telescopes, the ability to execute multiple observing modes is limited only by the compute resources available on the various subsystems in the CSP, the compute and storage space available on the SDP, and the capacity of the network infrastructure between the various subsystems. During steady-state cycle operations, we anticipate two primary drivers for commensal observations with the SKA telescopes: proposal-driven and observatory-identified commensality.

Proposal-driven commensality is where the science goal of a proposal requires observations in multiple modes to occur concurrently. For example, a proposing team might want to concurrently observe a given target at two different Mid bands, each with different subarrays, or a proposer might be interested in searching for a transient using the PSS tied array beams while also recording continuum visibility data for transient localisation and/or characterisation. To aid the SKA users' community, we have built a prototype setup validation tool (https://setup-validator.skao.int/) which allows the users to determine if a given observational setup can be executed on the SKA telescopes.

Observatory-identified commensality is the case where the observatory might decide to execute two observations concurrently to increase the observing efficiency of the telescope. For example, three proposals might each want to perform continuum, HI spectral line, and transient search observations towards the Large Magellanic Cloud. Depending on the compute and storage resource availability of the telescopes, the observatory might decide to execute these observations in parallel. This observatory-identified commensality will be worked out during the observations planning and scheduling phase of an observing cycle and should be invisible to the user community.

It is not the responsibility of the proposers to work out commensality between different proposals.

3 User interaction with the Observatory and SRCNet

This section provides a brief overview of how a user might interact with the SKA Observatory and the SRC network to carry out their science program. The information presented is largely derived from the "Observatory Establishment and Delivery Plan" [AD6] and updated to reflect the current operational concept. It should be noted that we are still several years from cycle operations, and so it is natural to expect that the operational model will evolve in the coming years. When such changes take place, the SKA users' community will be kept informed as appropriate.

Like other major observatories, the science program of the SKA Observatory will be driven by observing cycles. The technical capabilities of the telescopes in each observing cycle will be defined in the Call for Proposals. SKA users will submit their proposal through the Proposal Handling Tool (PHT), which is currently in an early development phase. To assist the user community in planning their observations, the Observatory will maintain a suite of user tools like the sensitivity calculator, the setup validation tool, the subarray and the substation templates libraries.

As defined in the Access Rules and Regulations of the SKA Observatory [AD7], the SKAO define three project categories:

- Key Science Projects (KSPs): projects that require significant observing time and resources over more than one observing cycle[4].
- Principal Investigator (PI) projects: projects that require small to moderate allocations of telescope time, typically over one or a limited number of cycles within an overall time request threshold.
- Director-General's Discretionary Time (DDT): time allocated by the Director-General outside the normal allocation process, generally at short notice, when an unforeseen, unexpected or significant event has occurred requiring telescope time before the next cycle.

These project types can be further categorised according to four additional attributes:

- Target of Opportunity (ToO; a pre-planned rapid response observation following an expected trigger),
- Long-Term Projects (LTP; projects requiring more than one cycle to complete, but require significantly less resources than a KSP),
- Joint SKA Projects (JSP; projects that require both Mid and Low to complete science goals, contemporaneously or not),
- Coordinated Projects (CP; projects that require coordination with an external facility or facilities, including but not limited to Very Long Baseline Interferometry (VLBI)).

Once the SKA Science Archive has grown and matured, a further proposal type will be added to these definitions to allow for archival projects within the SRCNet. Although by definition these proposals won't require telescope time, they are likely to require significant SRCNet resources and therefore need to be considered alongside the other proposal types.

After the proposal review and time allocation process[5], the Observatory will execute the science program for each cycle using a flexible/dynamic scheduling approach. Once observations are successfully executed, the appropriate ODPs will be generated on the SDP based on the pipeline specifications in the proposals, followed by a rigorous quality assessment. There will be no direct access for users to the SDP. Access to all ODPs will be via the SRCNet. SKAO recognises that there will sometimes be a need to observe a small fraction (i.e., a few hours to a few percent of the project depending on the individual requirements) of a large project and deliver the derived data products together with the calibrated visibility data to the SRC Network for consideration by the project PIs. Based on these data, the PIs may wish to test and fine-tune the selected SDP pipelines (which will be accessible within the SRC Network) and ultimately amend the requested SDP workflow for the full project. Following this process, it is expected that the remainder of the project will be processed by the SDP without further interaction with the project PIs. This is a mutually beneficial process to ensure that the completed project satisfies the science goals.

Each ODP will be subject to a proprietary period wherein access to that ODP will be limited to the PI and Co-Is of the originating project. The proprietary period will be specified in the Access Rules & Regulations [AD7], but is currently assumed to be one year from the date that the PI is informed the ODPs are available. Following the expiration of the

[4] The threshold between KSPs and PI projects will be published in each call for proposals.

[5] Details of the proposal review and the time allocation process will be provided in a separate document.

proprietary period, the ODPs will be publicly available. The SKA Director-General will have the discretion to alter the proprietary period for any ODP on a case-by-case basis.

To provide appropriate user support during the different phases of the observing cycle (from proposal planning to data access), the Observatory and the SRCNet will operate a common helpdesk, providing a single point of contact to the user community.

4 A simulated year in the life

To inform various aspects of operations planning and to provide crucial input for the ongoing development of SKA systems, we undertook a year-in-the-life analysis of the SKA telescopes, which attempted to simulate what a year (characterised by an observing cycle during steady-state operations) would look like during steady-state operations. This effort allowed us to understand the anticipated telescope- and observing-mode usage, commensality between projects, sizes and distribution of ODP requests, SDP loads and data delivery rates to the SRCNet. Some of the user tools, like the subarray and substation template libraries [AD2, AD3], were developed as part of this work. The value associated with the conversations held across the Observatory to align visions, plans and understanding was significant.

In a real observing cycle, the SKA science programme will be based on the scientific ranking of proposals submitted by the community, technical feasibility, resource availability and Member-share accounting. A distributed peer review and an independent Time Allocation Committee (TAC) are expected to be an integral part of the process, assessing the scientific impact and working with SKAO to determine the technical feasibility (see [AD7] for more information).

The year in the life analysis requires a representative list of projects to test the end-to-end systems. In advance of submitted proposals and a TAC process, we developed a science program for the simulated year that covers the breadth of projects we expect on the SKA telescopes, but in no way indicates any scientific preferences or anticipated time allocation per science area. In generating the simulated science program, we have ensured that all the key science drivers for the SKA telescopes, observing modes, subarray and substation templates, telescope tracking modes, observing bands, and ODP types are represented.

To generate this simulated science program, we have drawn from the following sources: the updated SKA Science Cases [RD1]; the results of the SKA Regional Centre Steering Committee (SRCSC) Working Group 6 TP1 SWG questionnaire; the Jumping Jive VLBI science use cases [RD2]; discussions with members of the SWGs; the previously defined High Priority Science Objectives (HPSOs) [RD3]; and SKA science cases, established following the 2014 community meeting, and subsequent SKA Science Book [RD4]. Some of the science cases presented in these documents relate to the AA4 configuration and needed to be updated to fit within the AA* capabilities. To supplement these community plans, we also consulted a number of (mostly recent) studies in the literature, drawing on the success of the SKA precursor instruments to help formulate the project lists.

In this simulated year, we assumed that 7884 and 7709 wall clock hours (actual available time, i.e. not incorporating commensality) are available for science with SKA-Low and SKA-Mid, respectively, where “available for science” means at least one subarray is executing an observation (either observing a calibrator or a target). These are based on the assumption that the telescopes will be available for science observations for 90% and 88% of the available hours, respectively. The anticipated availability of the telescopes is described in the OEDP [AD6]. We also assumed that 65% of the observing time in the simulated year is allocated for KSPs, and the remaining 35% is allocated for PI projects.

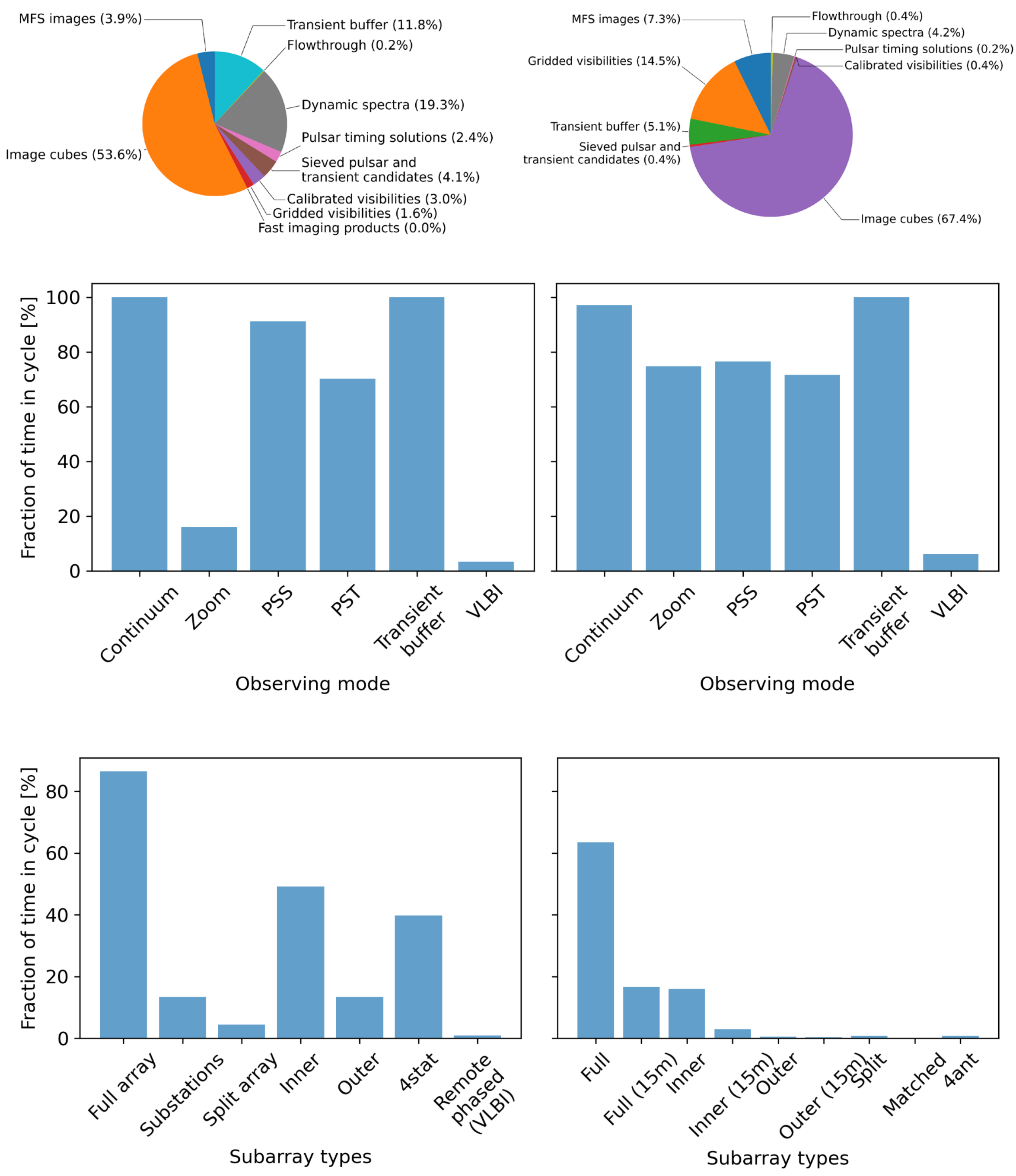
For each project in the simulated science program, we worked out the precise observing setup, pipeline and ODP specifications to verify that the project, as defined, can be executed on the SKA telescopes. We also worked out the possible combinations of commensality between different projects, taking into account the compute resource requirements on the various subsystems and the limits of the network infrastructure.

A few outcomes of the year in the life analysis that might be of interest to the SKA user community are listed below:

- The ODP data volume in the simulated year is ~130 PB and ~170 PB for the SKA-Low and SKA-Mid telescopes, respectively. Accounting for maintenance and network overhead, this corresponds to an average data rate of ~48 Gbps and ~70 Gbps between the SDP and the SRCNet. The **first row** in Figure 3 below shows the contribution of each ODP type to this total data volume. Note that we have not assumed any compression in estimating the data sizes. Nor have we used baseline-dependent averaging for visibility data.
- The **second row** in Figure 3 shows the fraction of time in the simulated year when the SKA telescopes are configured to operate in a given mode. The figure shows that there is sufficient capacity in the signal processors of both telescopes to execute imaging and tied-array beamformed observations in parallel.
- Allowing for all combinations of commensal observing modes, in the simulated year, the Low and the Mid telescopes can execute ~2.7x and ~4.5x the number of wall clock hours available in a cycle. We note that we have derived, in some respects, an idealised science programme and that the possibilities for commensality (within the resources available) are highly dependent on the requests of individual projects in a cycle. We therefore expect the opportunities for commensality to fluctuate, but our simulated science programme suggests that both telescopes can execute at least twice the wall clock hours in a steady-state cycle.
- The **third row** in Figure 3 below shows the distribution of the subarray templates used in the simulated year. While the full AA* subarrays are the most commonly used subarray type, the other classes of subarray templates are well-represented in the simulated science program.

Figure 3: Representative plots from the year in the life analysis for the SKA-Low (left column) and SKA-Mid (right column) telescopes.

SKA-Low **SKA-Mid**



A References

A.1 Applicable Documents

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

[AD1] SKAO staged delivery, array assemblies and layouts (SKAO-TEL-0002299 revision 04)

[AD2] SKA Low and Mid subarray templates (SKAO-TEL-0002380 revision 02)

[AD3] SKA-Low substation templates (SKAO-TEL-0002390 revision 01)

[AD4] SKAO Science Data Products: A Summary (SKA-TEL-SKO-0001818 revision 02)

[AD5] Unlocking ultra-deep wide-field imaging with sidereal visibility averaging, de Jong et al (2025), Astronomy & Astrophysics, Vol. 694, A98

[AD6] Observatory Establishment & Delivery Plan (SKA-TEL-SKO-0001722 revision 01)

[AD7] Access Rules and Regulations of the SKA Observatory (SKAO-GOV-0000127 revision 01)

A.2 Reference Documents

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

[RD1] SKA1 Scientific Use Cases (SKA-TEL-SKO-0000015 revision 04)

[RD2] "D10.3 Portfolio of SKA-VLBI science cases" https://jumping.jive.eu/vlbi-ska.html

[RD3] SKA1 Science Priority Outcomes (SKA-TEL-SKO-0000122)

[RD4] Advancing Astrophysics with the Square Kilometre Array https://pos.sissa.it/215/

LIST OF ABBREVIATIONS

AD	Applicable Document
ADP	Advanced Data Products
CBF	Correlator Beam Former
CP	Coordinated Project
CSP	Central Signal Processor
DDT	Director-General's Discretionary Time
Gbps	Gigabits per second
GSM	Global Sky Model
HPSO	High Priority Science Objectives
IPP	Integrated Pulse Profile
JSP	Joint SKA Projects
KSP	Key Science Projects
LFAA	Low-Frequency Aperture Array
LSM	Local Sky Model
LTP	Long-Term Projects
OCLD	Optimised Candidate Lists & Data
ODP	Observatory Data Product
OLDP	Observation-Level Data Products
PB	Petabyte
PHT	Proposal Handling Tool
PI	Principal Investigator
PLDP	Project-Level Data Products
PSS	Pulsar Search Subsystem
PST	Pulsar Timing Subsystem
QA	Quality Assessment
RD	Reference Document
RF	Radio Frequency
SDP	Science Data Processor
SKA	Square Kilometre Array
SKAO	SKA Observatory
SPOCLD	Single Pulse Optimised Candidate Lists & Data
SRCNet	SKA Regional Centre Network
SRCSC	Science Regional Centre Steering Committee

TAC	Time Allocation Committee
ToA	Time of Arrival
ToO	Target of Opportunity
VDIF	VLBI Data Interchange Format
VLBI	Very Long Baseline Interferometry

DOCUMENT HISTORY

Revision	**Date Of Issue**	**Engineering Change Number**	**Comments**
01	2025-06-13		Initial version

DOCUMENT SOFTWARE

	Package	**Version**	**Filename**
Word processor	MS Word	Office 365	SKAO-TEL-0002665-01_YITL_OverviewAndMainOutcomes
Block diagrams			
Other			

ORGANISATION DETAILS

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