SCIENCE AND OPERATIONS PLANNING

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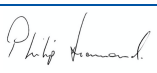
Phil Diamond	Director General	SKAO		
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LIST OF ABBREVIATIONS

AN .....Another

EX.....Example

SKA .....Square Kilometre Array

SKAO .....SKA Organisation

1 Introduction

1.1 Purpose of the Document

The purpose of this document is to define some key milestones that relate to preparation for, and ultimately scientific utilisation of the SKA1 telescopes.

The document is intended to initiate a discussion on the science planning milestones and will be developed in further detail following input from the various stakeholders.

1.2 Scope of the Document

Several distinct categories of preparation and scientific utilisation are briefly outlined. For each category, related activities are identified and the time durations estimated to undertake them. The prerequisites for their successful implementation are noted, together with an estimate of when these prerequisites might be met within the current roll-out schedule of the SKA1 telescopes.

2 References

2.1 Applicable Documents

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

[AD1] None

2.2 Reference Documents

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

[RD1] SKA-TEL-AIV-4410001_5, “Roll-out Plan for SKA1-Low”.
[RD2] SKA-TEL-AIV-4430001_D, “Integration and Verification Plan for SKA1-Low”
[RD3] SKA-TEL-AIV-2410001_5, “Roll-out Plan for SKA1-Mid”.
[RD4] SKA-TEL-AIV-2430001_D, “Integration and Verification Plan for SKA1-Mid”

3 Major Science Milestones

In this section, we will consider the preparatory activities and each of the major streams of scientific observation that are foreseen for the Observatory. What is envisaged is a sequence of four phases of scientific observing, each of which has more stringent requirements. The four envisaged categories are:

- Science Verification
- Shared Risk PI Observations
- PI Observations
- Key Science Project Observations

A description of each of these categories, together with the prerequisites for their scheduling is given in the following sub-sections. The prerequisites are closely tied to the construction and commissioning schedules. To provide some context we provide an overview of the key Assembly, Integration and Verification (AIV) Milestones and what they entail in Table 1 (taken from RD1 – RD4). The Array Assembly events in the table correspond to the predicted times when installation and stand-alone testing of the components has been completed on site. The availability dates are referenced to the date on which first construction contracts are awarded, C0, and are in units of months. The dates are taken from the current SKA1 integrated construction schedule. The date for construction contracts to be awarded is currently anticipated to be, C0 = 28/03/2020.

Table 1. Key Events Associated with Assembly, Integration & Verification.

Assembly, Integration & Verification Event	Low Stations	Date for Low	Mid Dishes SKA+MK	Date for Mid
AA1	18	C0+35	8 + 0	C0+34
AA2	64	C0+47	64 + 0	C0+44
AA3	256	C0+58	120 + 8	C0+58
AA4	512	C0+70	133+64	C0+67

3.1 Preparatory Activities

There are three main components to the current engagement strategy with the scientific user community:

1. A regular sequence of Science Meetings, both very broad ones and more narrowly focused ones.
2. A regular sequence of Key Science Project Workshops.
3. Data and Calibration Challenges.

For the Science Meetings, we seek to develop new themes and highlight synergies that bring the SKA to the attention of an ever-wider community. We will be discussing with their management the increasing use of the Precursor facilities on the SKA sites, as they now begin their own equivalent of Key Science Projects (KSPs) in the coming 12 months (in the case of ASKAP and MeerKAT). Large surveys with precursors and pathfinders allow for testing the concepts behind KSP surveys and improving the readiness to utilise the greatly enhanced capabilities that the SKA will offer. In previous years, we've been able to capitalise on such connections with LOFAR and MWA in the same way. We anticipate that the SKAO will organise a major Science Meeting every 24 months. Participation in other

relevant events that are organised both internationally and nationally will continue to occur at the rate of about two per month. The first major SKA Science meeting in this sequence took place in 2014.

For the KSP Workshops, we are currently envisaging an 18-month interval between these events, based on feed-back from previous participants. As time progresses we foresee the workshops evolving from the current stage of preliminary coordinating discussions to much more focused activities involving aspiring proto-survey teams. The first KSP Workshop took place in 2015.

A third preparatory activity is only now starting to be organised. This involves issuing "big data" or calibration challenges based on simulated SKA data or, in the short term, large databases from existing observatories, to stimulate algorithm and pipeline development to increase preparedness for the SKA KSP era. New challenges would be announced as available, but targeted for release on one to two year intervals.

Table 2. Key Events Associated with Preparation.

Preparation Event	Interval (months)	Start Date	Final Date
Major Science Meetings	24	06/2014	-
KSP Workshops	18	08/2015	KSP Kick-off
Data / Calibration Challenges	12 - 24	06/2018	KSP Kick-off

3.2 Science Commissioning

As soon as the first SKA1 dish or station is available on the respective sites some aspects of scientific commissioning will begin. These activities will ramp up as more components become available, together with the capabilities for telescope control, data acquisition and processing. These activities will be very intermittent in nature at the outset and will be matched to the availability of components and capabilities. As roll-out proceeds, more complex observing modes will be commissioned. This activity will continue until all observing modes have been fully commissioned. This is currently anticipated to be some 36 months following availability of AA4. The first SKA1 production dish is anticipated to be available on the SKA1-Mid site on 18/11/2021. This would mark the beginning of Science commissioning.

3.3 Science Verification

Once a sufficiently capable array of dishes or stations has been deployed and undergone engineering verification in the field, it will be desirable to engage as widely as possible with the SKA science community by inviting suggestions for suitable targets for science commissioning observations. In each "Call for Suggestions" that is made, the priority areas for impending commissioning activities would be outlined. All data acquired in this mode would be publicly released as soon as possible to enable informal community participation in the commissioning process, as well as delivering the first SKA science results. This would be in addition to any more formal arrangement for community involvement with SKAO commissioning.

The requirement for scheduling science verification observations (which we will term Milestone SM1) is that engineering verification of the dishes or stations has been completed successfully, including the availability of suitable correlator and Science Data Processor support for astronomical observations. The key events associated with initiation of such observing are summarised in Table 3.

It is currently foreseen that the first scheduled observations in this mode might be undertaken about 9 months following the installation and stand-alone testing of the AA2 components. It is anticipated that the dishes and stations will only have limited availability for scientific commissioning during the remainder of SKA construction, since this would otherwise adversely impact the construction schedule (and hence cost). However, science verification campaigns will be organised throughout the construction period as access permits and priorities allow so as to minimise the time following AA4 needed before PI and KSP observing can get underway.

Table 3. Key Events Associated with Science Verification Observing.

Science Verification Event	Duration (months)	External Event (months)	Start Date (months)
Call / Deadline for Suggestions	2		AA2 + 5.5
Internal Assessment	1		AA2 + 7.5
Allocation	0.5		AA2 + 8.5
Start Schedule = SM1	0	AA2 + 9	AA2 + 9
Observe	0.5		AA2 + 9
Repeat as needed	X		AA2 + 9 + X

3.4 Shared Risk Principal Investigator Science

As a transition between Science verification and normal PI observing, it's foreseen that there could be at least one Cycle of "shared risk" PI science. The term "shared risk" would be defined to imply that should a scheduled observation be unsuccessful, for any reason, there would be no guarantee that the proposal would be rescheduled. Allocations made in this mode would be used to exercise the end-to-end operations of the Observatory. Proposals might be scheduled that test new observing modes or otherwise contribute to the commissioning of the system.

The requirement for scheduling shared risk PI observations (which we will term Milestone SM2) is that basic science verification of at least a subset of the observing modes being offered in the Cycle has been completed successfully. Based on current information, this is foreseen to be the case about 3 months following the installation and stand-alone testing of the AA4 components. The key events associated with initiation of shared risk PI observing are summarised in Table 4.

Table 4. Key Events Associated with "Shared Risk" PI Observing.

Shared Risk PI Event	Duration (months)	External Event (months)	Start Date (months)
Proposal Call / Deadline	2		AA4 – 3
Proposal Review	3		AA4 – 1
Proposal Allocation	1		AA4 + 2
Start Schedule = SM2	0	AA4 + 3	AA4 + 3
Observe	9		AA4 + 3

3.5 Principal Investigator Science

One major component of the SKA1 science Programme will be the allocations made to projects that can typically be accommodated within a single time allocation cycle, termed "Principal Investigator" (PI) projects. While we will assume a nominal cycle duration of 12 months, we also acknowledge that there will likely be PI projects which extend over multiple cycles, although with more modest total time requirements than would apply to a KSP.

The requirement for scheduling of PI observations (which we will term Milestone SM3) is that the specific observing modes being offered in the Cycle are fully commissioned. The first fully commissioned modes are expected to be available some 12 months after the installation and stand-alone testing of the AA4 components. It is anticipated that additional observing modes would become available in subsequent Cycles. The key events associated with initiation of normal PI observing are summarised in Table 5.

Table 5. Key Events Associated with PI Observing.

Normal PI Event	Duration (months)	External Event (months)	Start Date (months)
Proposal Call / Deadline	2		AA4 + 6
Proposal Review	3		AA4 + 8
Proposal Allocation	1		AA4 + 11
Start Schedule = SM3	0	AA4 + 12	AA4 + 12
Observe	12		AA4 + 12

3.1 Key Science Projects

An important component of the SKA1 Science deliverables will be a programme of "Key Science Projects" (KSPs). As currently envisaged, a significant fraction of the available observing time of both the Low and Mid telescopes would be allocated to KSPs. A framework for how a KSP programme might be structured is attached as Appendix A. The fraction of KSP time may vary between the Low and the Mid telescopes and is likely to evolve over the course of years.

Since large projects are anticipated to be quite instrumentally demanding in one or more respects, it is deemed necessary that a stable, well-understood system be in place prior to scheduling projects of this type. While the detailed Commissioning Plan for the SKA Observatory is still under development, the working assumption is that the necessary system maturity that would allow KSP scheduling to begin would be achieved 24 months following the installation and stand-alone testing of the AA4 components (Array Assembly 4 as specified in RD1 – RD4). It's likely that only a subset of all of the anticipated observing modes would be available in the first instance, with the remainder following as they become fully commissioned. Preparatory observations for KSPs, including "Pilot Surveys" could be pursued within the "Shared Risk" and "PI" stages of the Science Commissioning process. Early access to science commissioning data (as outlined in Section 3.2) will be provided on request to nascent KSP teams to facilitate their survey and pipeline design.

Prior to, and following, the onset of scheduled KSP observations (which we will term Milestone SM4) there is a sequence of events which we outline in Table 6. We foresee issuing a Call for "Letters of Intent" to ascertain community interest in specific KSP proposals. This would be followed by a

Coordination Workshop that would seek to bring together aspiring proposal teams and facilitate the formation of collaborations where that should prove possible. This would be followed by the actual Call for KSP Proposals. We anticipate allowing an interval of 12 months following the notices of KSP time allocation, to permit successful KSP teams to secure resourcing before the KSP observations would commence. Regular progress reviews would follow KSP allocations to insure progress was being realised against the proposal schedule of deliverables.

Table 6. Key Events Associated with KSP Observing.

KSP Event	Duration (months)	External Event (months)	Start Date (months)
Preparatory activities	30		AA4 – 45
LoI Call / Deadline	3		AA4 – 15
LoI Assess	2		AA4 – 12
LoI Coordination Workshop Organise / Carry-out	6		AA4 – 10
Proposal Call / Deadline	12		AA4 – 4
Proposal Review	4		AA4 + 8
Proposal Allocation / Resource	12		AA4 + 12
Start Schedule = SM4	0	AA4 + 24	AA4 + 24
Observe	N x 12		AA4 + 24
Progress Review	N x 12		AA4 + 36, 48, …

4 Summary Timeline

As a specific example, we will consider the case where Construction contracts are awarded at C0 = 28/03/2020 and that the installation and stand-alone testing of the AA2 components has taken place at C0+44 months and the AA4 components at C0+67 months. With these assumptions, the timeline for the science milestones is as depicted in Figure 1.

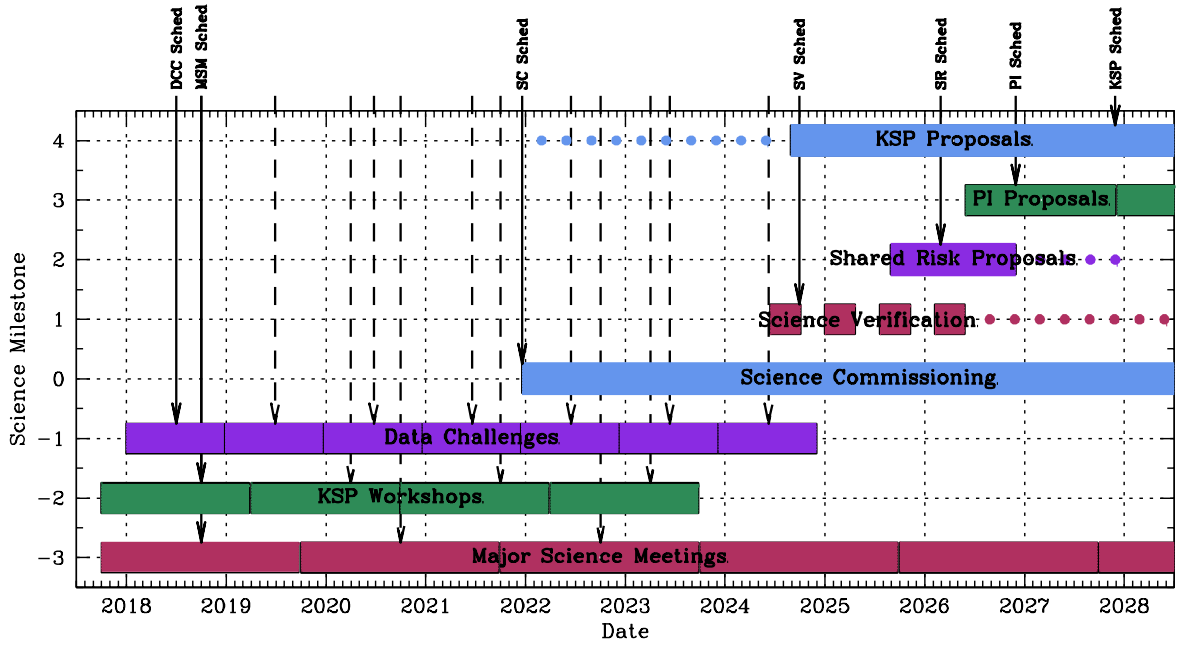

Figure 1. Timeline of Major SKA1 Science Milestones for an Assumed Availability Date of AA2 and AA4.

A Framework for SKA Key Science Projects

SKA Organisation

v3: 10th March 2017

Introduction

This paper sets out the views of the SKA Office on how the initial set of Key Science Projects (KSPs) might be implemented. It is not intended for wide release; rather, it is the basis for discussion with the science community. It may be amended at any time to reflect ongoing discussions. This paper will eventually form the basis of a KSP Policy document that will be submitted to the SKA Observatory Council for approval and promulgated to the community.

The primary driver in setting out a KSP framework is to maximise the scientific impact of SKA1. This is a *sine qua non*. However a secondary driver is that this should be achieved as efficiently and effectively as possible.

Key Science Projects

Maximising the scientific impact of SKA1 requires carrying out science projects that require very large amounts of observing time; such projects are called KSPs.

A draft SKA Access Policy has been agreed through the treaty negotiation process. It defines KSPs as follows:

> *"Key Science Projects" (KSPs) are observing projects that require large observing time allocations over a period longer than one Time allocation cycle."*

This is not a sufficient definition, since it will also be possible for some PI projects to be granted long-term status. At some point, the Observatory will revise this definition by specifying an observing time threshold, above which an approved project will be considered a KSP.

The key point is that KSPs will be large: they will consume more observatory resources (observing time, signal processing and data reduction) than PI projects. By virtue of this, they warrant different considerations. In particular, duplication (multiple KSPs addressing the same science goals) should be avoided.

Principles

1. Following from the above considerations, the ideal solution is a set of coordinated, community-wide science projects. By "community-wide" it is meant that KSPs must be in some way open to, and representative of, the entire SKA user community. This has the added advantage of encouraging collaboration among the SKA member countries – although this is a bonus rather than a driver.

   The exact mechanism by which this is to be achieved is not yet determined. The Access Policy imposes a requirement that access for each partner, across the entire science programme (KSPs and PI projects), must be proportional to share in the project; this in turn requires some

form of accounting. It follows that the KSPs cannot be completely open for anyone to join, and that some restrictions on team membership will need to be introduced.

A process for implementing this principle within the constraint of the Access Policy will be developed by the Office in consultation with stakeholders. Issues that will need to be considered include:

- achieving proportional access in both membership numbers and leadership roles;
- monitoring and retaining this balance as the KSPs evolve; and
- ensuring that new generations of researchers are able to join and contribute to KSPs.

2. The KSPs must be science-driven; that is, they must have a clearly-articulated and contained scientific case (i.e. not "cosmology" or "imaging"), and they must justify on scientific grounds the request for observing time and the requested data products.

3. Before issuing a Call for Proposals, the Observatory will conduct a preliminary coordination phase consisting of Letters of Intent and a community workshop. The purpose of the workshop will be to encourage collaboration and reduce (and ideally eliminate) duplication.

4. Following the preliminary coordination phase, and roughly 18 months before the KSP observations are expected to commence, the Observatory will issue a Call for Proposals. The time allocation process will be governed by the SKA Access Policy, augmented as necessary given the large amount of observing time. In brief, all KSP proposals will be reviewed by a set of external, independent referees; a Time Allocation Committee (TAC) will assess all KSP proposals, based in part on the external reviews; and the TAC will make recommendations to the Director-General, who will formally allocate the time.

5. Subject to the constraints on team membership described in principle 1 above, KSP teams will be autonomous. The Call for Proposals will specify a set of basic requirements that each proposal must meet in order to be awarded time; some of these will be (a) consortium management plan, (b) data management and processing plan, (c) data products and analysis algorithms release plan, and (d) regular progress reports. A full list of requirements will be developed by the Office in due course in consultation with stakeholders. Within the constraints of these requirements, each KSP team will be free to self-organise as it sees fit.

6. The Observatory will require, as a condition of approval, that higher-order data products generated by the KSP teams be made generally available. We anticipate that an SKA Science Archive capability will be developed within the SRC network for this purpose.

7. Management of the observing programme will be the responsibility of the Observatory. This will include, *inter alia*:

- issuing the call for Letters of Intent;
- coordinating and assessing the responses;
- organising the community workshop;
- issuing the Call for Proposals;
- coordinating and assessing the proposals;
- supporting the Time Allocation Committee;
- identifying and implementing commensality;
- formulating policies regarding scheduling and execution of the KSPs; and

- monitoring and assessing the progress of each KSP.

The Observatory will report on overall progress to the SKA Observatory Council, which will have the ultimate responsibility for oversight of the SKA science programme.