"Exploring the Universe with the world's largest radio telescope"

2010
Annual WP2 Meeting

SKA System Design Plan

Kobus Cloete

27 October 2010

Overview

- Memo 125
- Route to SKA

Memo 125

A Concept Design for SKA Phase 1 (SKA_1)

SSEC SKA Phase 1 Sub-committee:

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SKA Memo 125 – SKA1 Science Goals

Major Science Goals of SKA_1

The SKA Science Working Group [1, 2] has identified the science topics that can be addressed by SKA_1. Using these papers as a guide, the SKA Science & Engineering Committee (SSEC) has identified the following major science goals which drive the technical specifications for the SKA_1:

(i) Understanding the history and role of neutral Hydrogen in the Universe from the dark ages to the present-day, and

(ii) 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.

SKA_1 Technical Concept

The SKA_1 baseline technical concept is driven by the need to address the two major science goals identified earlier in this document, i.e. understanding the history and role of neutral Hydrogen in the Universe from the dark ages to the present-day, and using pulsars as probes of fundamental physics.

The technologies required to achieve these two major science goals, lead us to a baseline design concept for SKA_1 that includes the following elements:

1) a low-frequency sparse aperture array with an A/T_{sys} of up to 2000 m^2/K operating at frequencies between 70 and 450 MHz. The array will be centrally condensed but some of the collecting area will be in stations located out to a maximum baseline length of 100 km from the core, and
2) a dish array with A_{eff}/T_{sys} of up to 1000 m^2/K using approximately two hundred and fifty 15-metre antennas, employing an instrumentation package that will use single-pixel feeds to provide high sensitivity and excellent polarisation characteristics over a frequency range of 0.45-3 GHz. The array will be centrally condensed but some of the elements will be co-located with the sparse aperture array stations out to a maximum baseline length of 100 km from the core.

SKA Memo 125 – AIP

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Advanced Instrumentation Programme (AIP) for the full SKA

The SKA_1 baseline concept design presented here represents the first concrete step towards the realisation of the much larger and more ambitious SKA_2. The Advanced Instrumentation Programme (AIP) will seek to capitalise on investments made by the SKA Organisation and other parties in innovative technology development over the pre-construction period 2011-2015. In 2011-2015, advanced instrumentation systems under development for the SKA are expected to include: Phased Array Feeds (PAFs), Dense Aperture Arrays (DAAs), high frequency feeds etc.

Given the progress expected in all of these areas of instrumentation over the next 5 years, a decision identifying the most promising system for SKA_2 can be made in 2016, at the start of the initial SKA_1 construction phase. Advanced instrumentation such as PAFs or high frequency feeds may also be deployed as modular sub-systems on the SKA_1 dishes. DAAs will require the construction of a substantial standalone demonstrator. The AIP will realise an advanced system that will either greatly enhance the baseline SKA_1 telescope and/or will demonstrate an important technology prototype of direct relevance to SKA_2. The opportunity for individual research groups to fund new instrumentation relevant to the SKA should not be excluded.

Memo 125 – Summary (1)

- Baseline
  - Low frequency sparse aperture array
  - Dish array
  - Signal transport and networks
  - Correlator and Non visibility processor
  - Central Data Processing, Science Processing and System Software.
  - Central timing and synchronisation subsystem, including time and frequency reference distribution,
  - Infrastructure (buildings, roads, facilities, labs etc.),
  - Power delivery and distribution,
  - Support and maintenance equipment and facilities

Memo 125 – Summary (2)

- Advanced Instrumentation Program
  - Dense Aperture Arrays
  - Phased Array Feeds
  - Ultra Wide band Single Pixel Feeds
- Decision points for AIP identified
  - 2016, or
  - As modular sub-systems of the SKA1 dishes

- How do we continue with the SKA definition and design and at the same time take all of these aspects into consideration?

SKA High Level Conceptual Block Diagram

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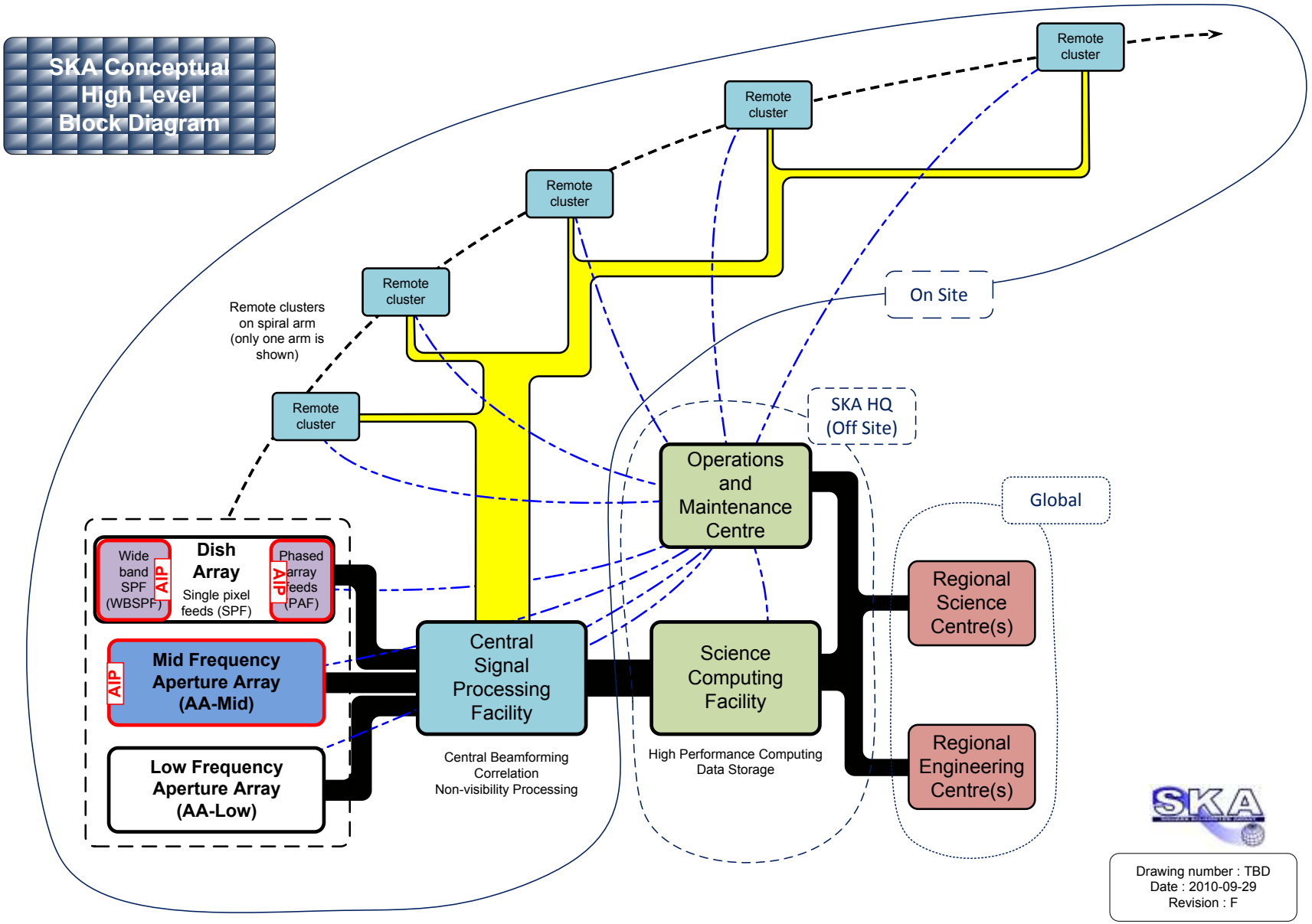
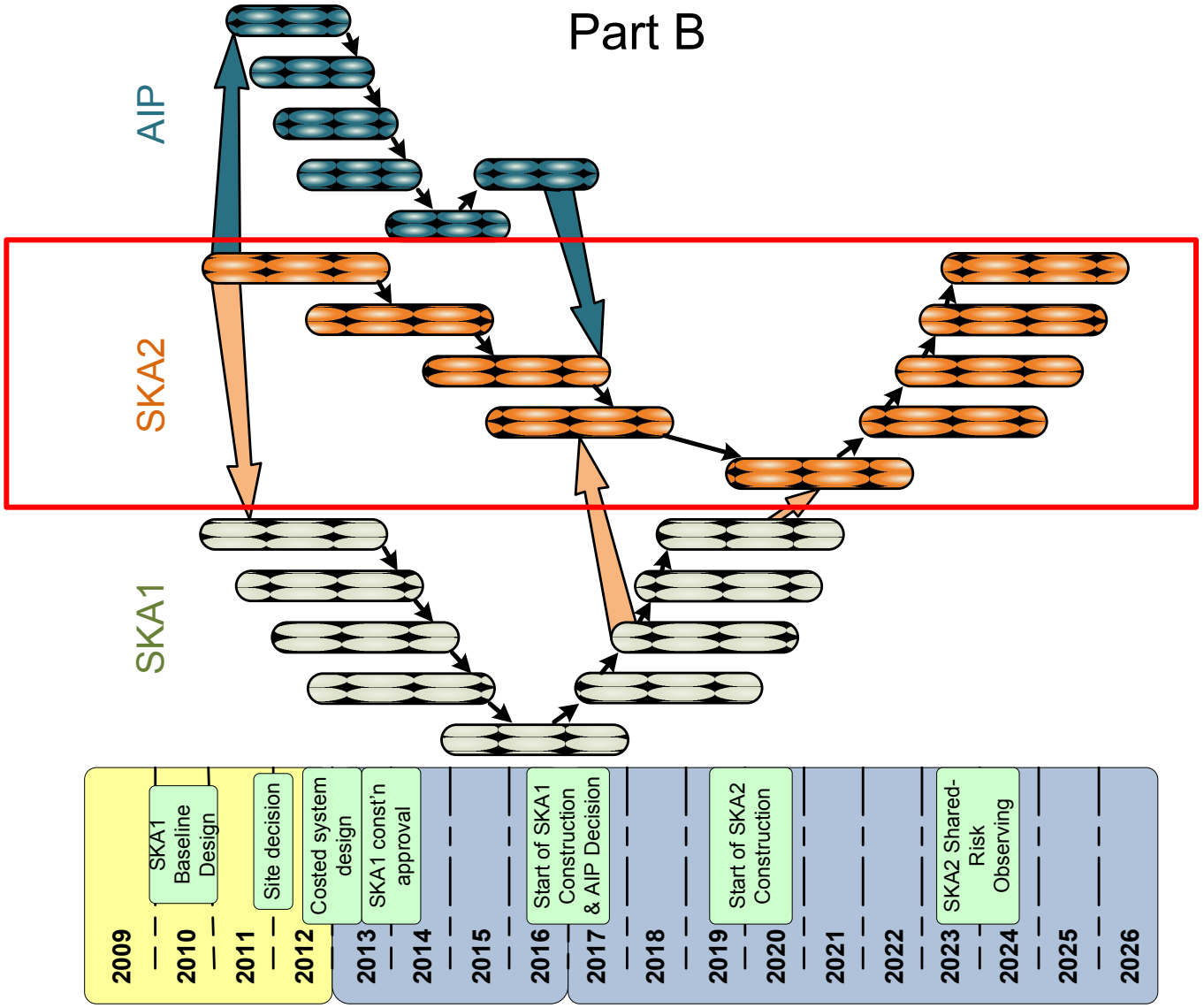
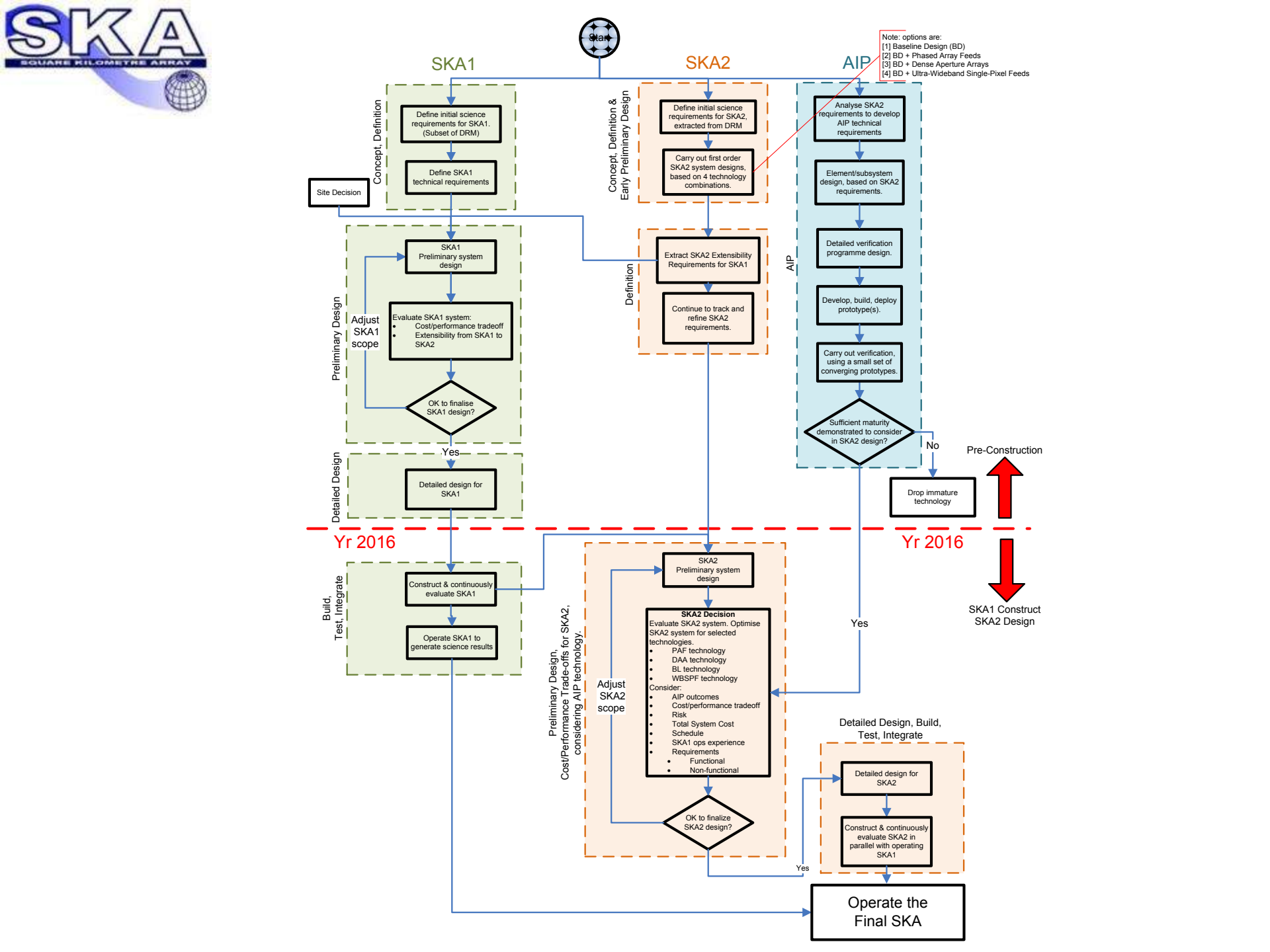


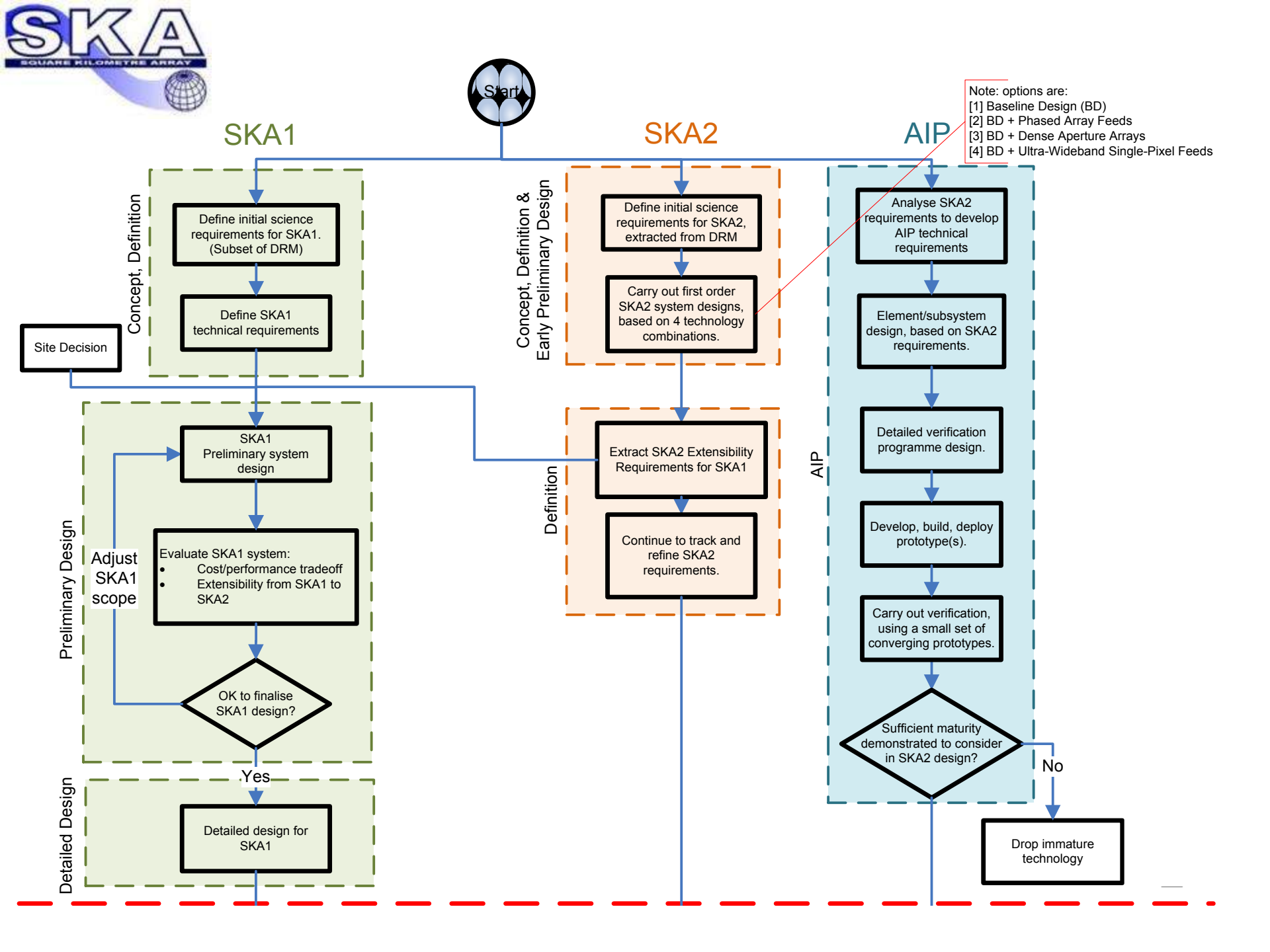
Route to SKA

- How do we continue with the SKA definition and design and at the same time take all of these aspects into consideration?
- Recently a conceptual Route to SKA was developed attempting to maintain the structure of the project but at the same time maintain flexibility to accommodate all the identified future enhancements.
- Always maintain focus on the full SKA.

Graphical Representation




Start
SKA1
SKA2
AIP
Note: options are:
[1] Baseline Design (BD)
[2] BD + Phased Array Feeds
[3] BD + Dense Aperture Arrays
[4] BD + Ultra-Wideband Single-Pixel Feeds
Concept, Definition
Define initial science requirements for SKA1. (Subset of DRM)
Define SKA1 technical requirements
Site Decision
Concept, Definition & Early Preliminary Design
Define initial science requirements for SKA2, extracted from DRM
Carry out first order SKA2 system designs, based on 4 technology combinations.
AIP
Analyse SKA2 requirements to develop AIP technical requirements
Element/subsystem design, based on SKA2 requirements.
Detailed verification programme design.
Develop, build, deploy prototype(s).
Carry out verification, using a small set of converging prototypes.
Sufficient maturity demonstrated to consider in SKA2 design?
No
Drop immature technology
Pre-Construction
Preliminary Design
SKA1 Preliminary system design
Adjust SKA1 scope
Evaluate SKA1 system:
Cost/performance tradeoff
Extensibility from SKA1 to SKA2
OK to finalise SKA1 design?
Yes
Definition
Extract SKA2 Extensibility Requirements for SKA1
Continue to track and refine SKA2 requirements.
Detailed Design
Detailed design for SKA1
Yr 2016
Yr 2016
SKA1 Construct SKA2 Design
Build, Test, Integrate
Construct & continuously evaluate SKA1
Operate SKA1 to generate science results
Preliminary Design, Cost/Performance Trade-offs for SKA2, considering AIP technology.
SKA2 Preliminary system design
SKA2 Decision
Evaluate SKA2 system. Optimise SKA2 system for selected technologies.
PAF technology
DAA technology
BL technology
WBSPF technology
Consider:
AIP outcomes
Cost/performance tradeoff
Risk
Total System Cost
Schedule
SKA1 ops experience
Requirements
Functional
Non-functional
Adjust SKA2 scope
OK to finalize SKA2 design?
Yes
Yes
Detailed Design, Build, Test, Integrate
Detailed design for SKA2
Construct & continuously evaluate SKA2 in parallel with operating SKA1
Operate the Final SKA


SKA
SQUARE KILOMETRE ARRAY
Start
SKA1
SKA2
AIP
Note: options are:
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[2] BD + Phased Array Feeds
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Element/subsystem design, based on SKA2 requirements.
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Adjust SKA1 scope
OK to finalise SKA1 design?
Yes
Definition
Extract SKA2 Extensibility Requirements for SKA1
Continue to track and refine SKA2 requirements.
Detailed Design
Detailed design for SKA1

SKA1

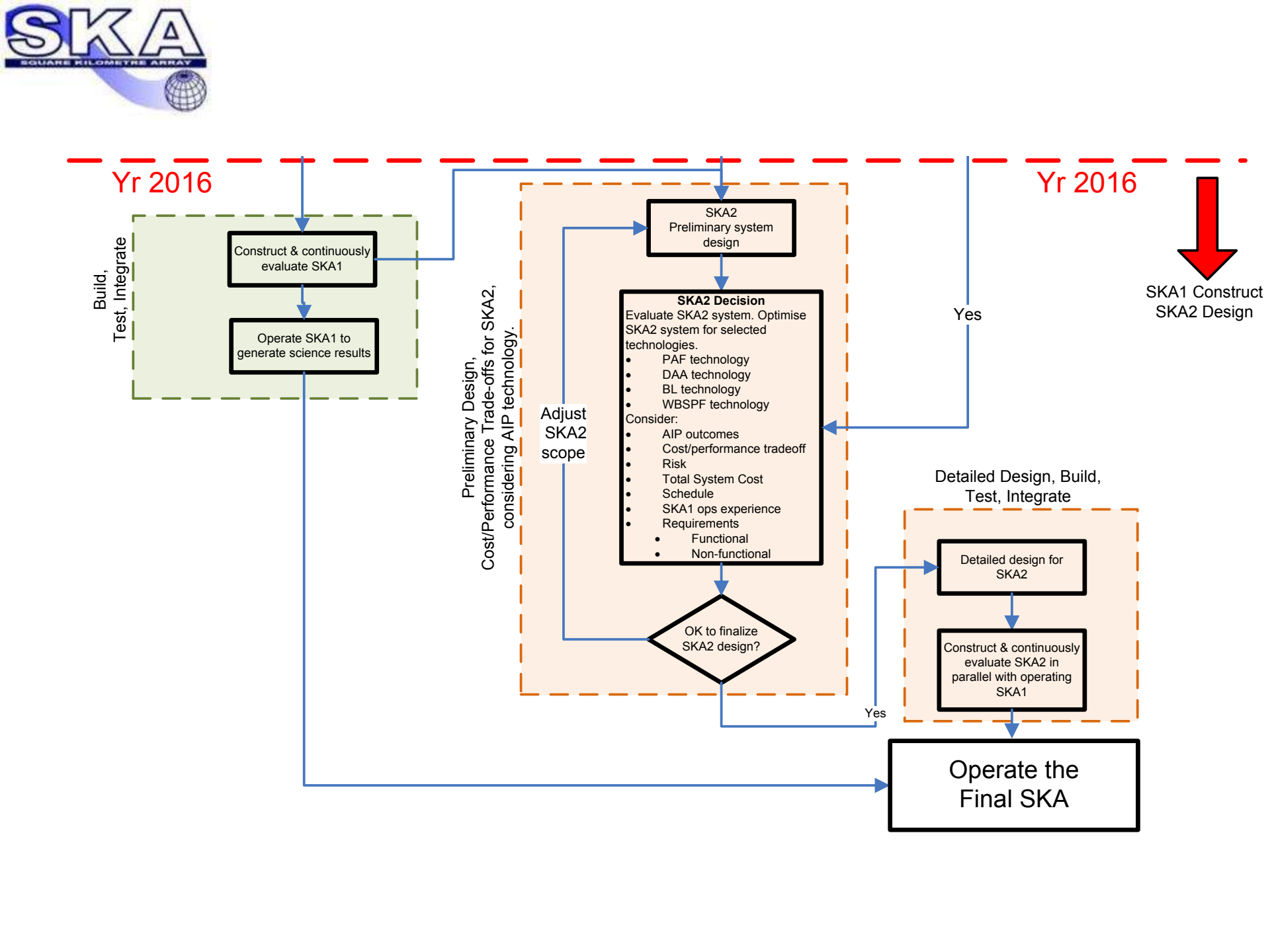
- From the SKA1 science requirements (Memo 125)
  - Derive the SKA1 technical requirements
  - Develop initial SKA2 system technical requirements based on the science requirements contained in the Design Reference Mission (DRM).
- Perform preliminary system design for SKA1
  - To be informed by early preliminary designs for the SKA2 options, so as to ensure extendibility to SKA2.
  - Tradeoffs of performance against cost.
- Full detailed design for SKA1.

SKA2

- To inform the SKA1 design process
  - Draft initial technical requirements for the four system options for SKA2 (Baseline Technology alone + the three AIP options in combination with the Baseline Technology),
  - Carry out early preliminary system designs for each of the options.
- Continue to track Phase 2 requirements to prepare for a decision on technology selection in 2016.

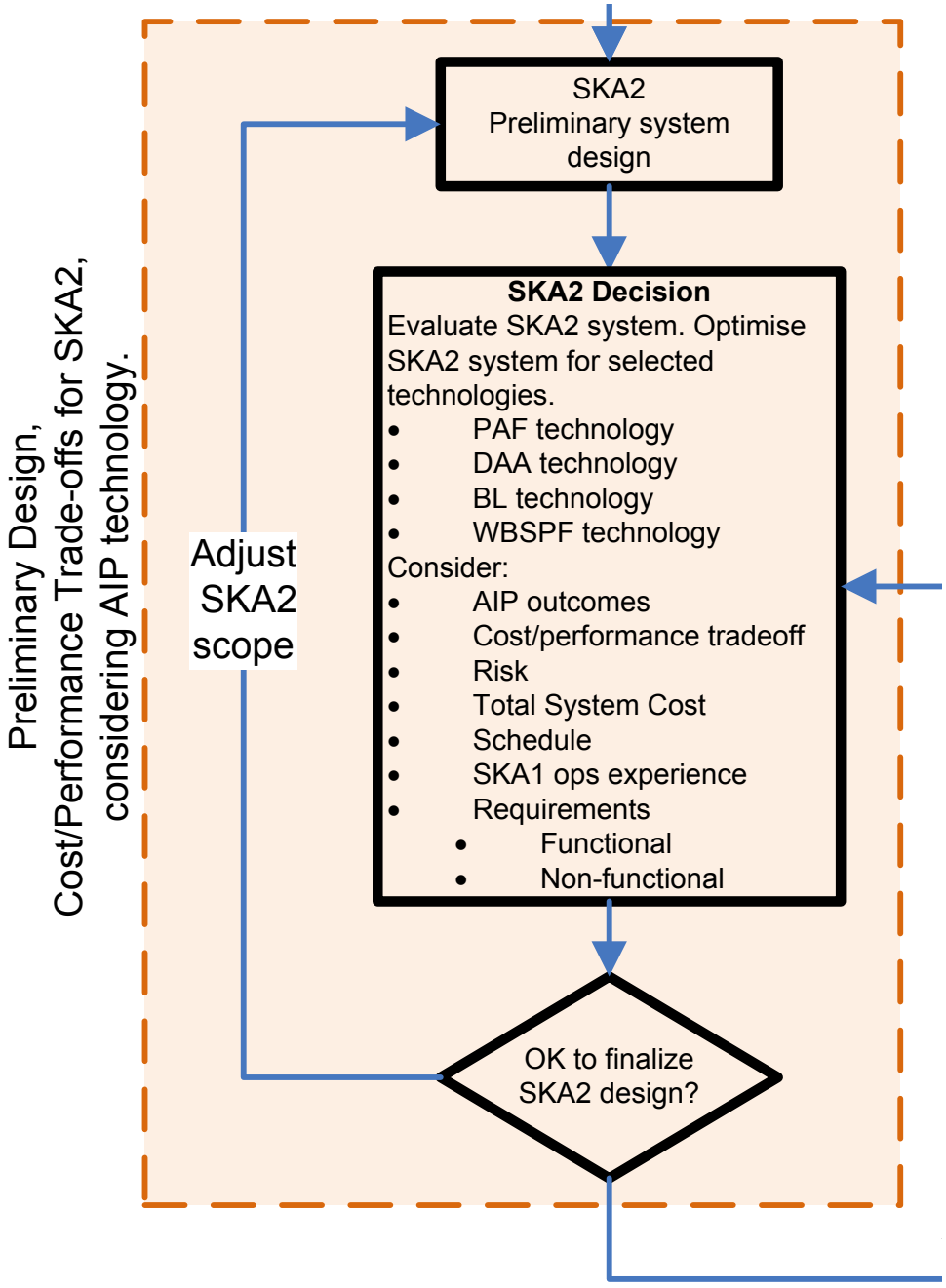
AIP

- The AIP will build up the level of maturity in anticipation of their utilisation in SKA1 and SKA2.
- General steps:
  - Analyse the SKA requirements to maximise potential to enhance system performance, achieve more of the initial system requirements and/or reduce cost, as compared with the baseline.
  - Develop a preliminary design assuming the particular AIP technology will be used at the element or subsystem level of the system.
  - Carry out a verification program to test the level of achievement of requirements, to develop performance/cost models for the AIP technology, and to ascertain remaining risk.


Yr 2016
Yr 2016
Build, Test, Integrate
Construct & continuously evaluate SKA1
Operate SKA1 to generate science results
Preliminary Design, Cost/Performance Trade-offs for SKA2, considering AIP technology.
SKA2 Preliminary system design
SKA2 Decision
Evaluate SKA2 system. Optimise SKA2 system for selected technologies.
PAF technology
DAA technology
BL technology
WBSPF technology
Consider:
AIP outcomes
Cost/performance tradeoff
Risk
Total System Cost
Schedule
SKA1 ops experience
Requirements
Functional
Non-functional
OK to finalize SKA2 design?
Adjust SKA2 scope
Yes
SKA1 Construct SKA2 Design
Detailed Design, Build, Test, Integrate
Detailed design for SKA2
Construct & continuously evaluate SKA2 in parallel with operating SKA1
Yes
Operate the Final SKA

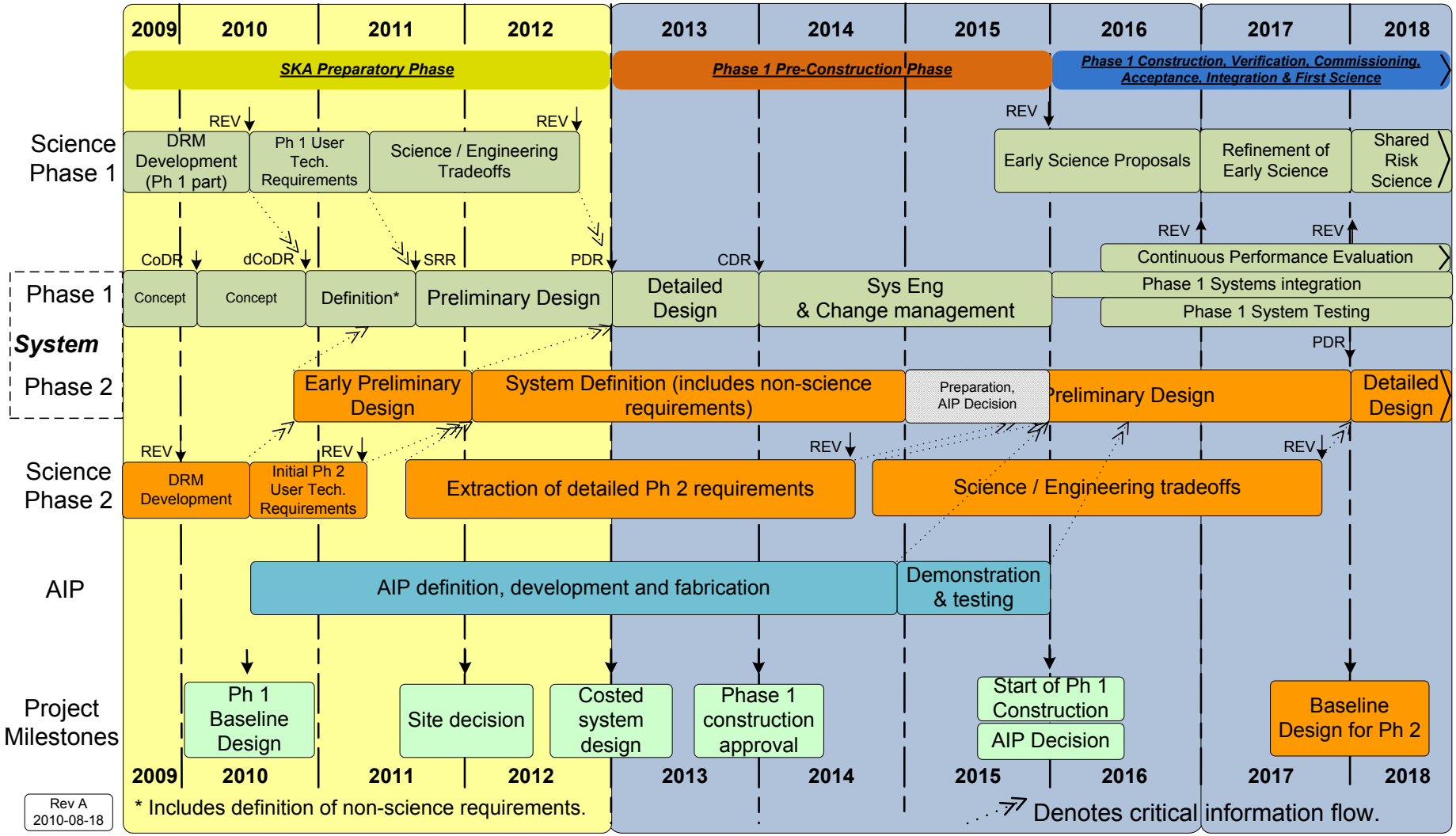
Post 2016 – SKA1 and AIP

- SKA1:
  - Build, integrate, test, operate
- AIP:
  - The expected outcomes will be data on: in-system performance; good estimates of volume manufacturing, deployment and maintenance costs; verified operational models in the physical environment; verified calibration models; risk assessments.
  - Evaluate maturity and readiness and make decsision for inclusion into SKA2


Preliminary Design,
Cost/Performance Trade-offs for SKA2,
considering AIP technology.
SKA2
Preliminary system
design
SKA2 Decision
Evaluate SKA2 system. Optimise SKA2 system for selected technologies.
PAF technology
DAA technology
BL technology
WBSPF technology
Consider:
AIP outcomes
Cost/performance tradeoff
Risk
Total System Cost
Schedule
SKA1 ops experience
Requirements
Functional
Non-functional
OK to finalize
SKA2 design?
Adjust
SKA2
scope

Post 2016 – SKA2

- SKA2 :
  - Perform Preliminary Design
  - Consider AIP technologies for inclusion
    - Separate assessment of the AIP technologies will take place to determine whether its level of maturity is sufficient to be included in the SKA2 system.
  - Detailed design for SKA2 after the selection of design option is made.
  - Feed in actual SKA1 system performance and cost


2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
SKA Preparatory Phase
Phase 1 Pre-Construction Phase
Phase 1 Construction, Verification, Commissioning, Acceptance, Integration & First Science
Science Phase 1
REV
DRM Development (Ph 1 part)
Ph 1 User Tech. Requirements
Science / Engineering Tradeoffs
Early Science Proposals
Refinement of Early Science
Shared Risk Science
CoDR
dCoDR
SRR
PDR
CDR
Continuous Performance Evaluation
Phase 1 Systems integration
Phase 1 System Testing
Phase 1
System
Phase 2
Concept
Concept
Definition*
Preliminary Design
Detailed Design
Sys Eng & Change management
Early Preliminary Design
System Definition (includes non-science requirements)
Preparation, AIP Decision
Preliminary Design
Detailed Design
Science Phase 2
DRM Development
Initial Ph 2 User Tech. Requirements
Extraction of detailed Ph 2 requirements
Science / Engineering tradeoffs
AIP
AIP definition, development and fabrication
Demonstration & testing
Project Milestones
Ph 1 Baseline Design
Site decision
Costed system design
Phase 1 construction approval
Start of Ph 1 Construction
AIP Decision
Baseline Design for Ph 2
* Includes definition of non-science requirements.
Denotes critical information flow.
Rev A
2010-08-18

Summary

- The phased construction of the SKA enables the project to make maximum use of advances in technology.
- These modifications will have a large system impact and will require a thorough impact analysis prior to deployment.
- A limited number of SKA1 subsystems may be obsolete by the construction of SKA2, and will be decommissioned accordingly.

Thank you

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