Coding Summary By Node
SKA SE Case Study
2017-01-26 10:52 PM

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On

Node

Nodes\\Methods and tools

Document

Internals\\Interview Transcript - SKA System Engineer

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.1717	7			
				1	A	2017-01-24 12:00 AM

Obviously our clients are the scientists mainly and our stakeholders are funding stakeholders and science stakeholders.

				2	A	2017-01-24 12:05 AM

No we didn’t not on Meerkat project. On Meerkat it was a very, you know I think we didn’t manage it formally or measure technology maturity formally it was informal.

				3	A	2017-01-24 12:07 AM

The South African Team specifically, had a very clear strategy to take on technologies that are low risk and can be implemented in the short time scales for Meerkat. So we didn’t have formal evaluation metrics for technology maturity but a very conscious technique for example the feed technologies we went for standard you know octave band horn feeds which are mature technology and we knew exactly what we were going to expect. But for the SKA project they are employing metrics for technology maturity but those are defined and they are going to do an assessment of technology maturity at the preliminary design phase. But its quite difficult to measure quantitatively, its often judgement call.

				4	A	2017-01-24 12:18 AM

Because it was part of our program Meerkat, we first delivered the first, its actually the cooling solution developed as first of all passive cooling without cryogenics that was the first dish in Hartbeeshoek. Then on the Kat-7 system we tried the Sterling cooler and that didn’t turn out to work so well. Then for Meerkat we reverted back to the proven technology so we had the opportunity for the prototypes to implement and build on them.

				5	A	2017-01-24 12:26 AM

So for each sub-system is customized, what are the key risks for that sub-system and how those key risks are addressed in the development process. And we approved that plan as part of the requirements review.

				6	A	2017-01-24 12:39 AM

You know I think we used modelling and simulation quite extensively and there’s a wide range of different tools that we use. We use mostly in the early phases for verifying requirements and for verifying design. An example of that is the electromagnetic performance of the system, so we did extensive electromagnetic simulations to see what is the best performance that we can get and what is the design that will give is the best performance early and we used that to influence the design and to verify that we can actually meet the requirements. Also examples of that electromagnetic modelling, the mechanical modelling and also system engineering we use CORE. We model the functionality in CORE on the system level, those are just some examples.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				7	A	2017-01-24 12:38 AM

We using core for requirements traceability and requirements management and we capture all the requirements starting off with the user requirements and traced those down to system requirements and sub-system requirements and we keep that traceability up and it is still running and we again we matured that capability over time. At this stage the sub-systems a lot of them print out their specs from CORE directly so that's turned out very useful and turned out quite well.

PDF

Internals\\Marias Botha

No		0.0555	6			
				1	A	2017-01-24 11:31 PM

KAT-7 is a science and engineering prototype radio telescope array, consisting of seven receptors situated alongside the proposed SKA core site (SKA South Africa a)

				2	A	2017-01-24 11:32 PM

The purpose of this precursor project was to identify the inherent challenges associated with designing and building a fully-functional radio-telescope array, but on a smaller, more manageable scale.

				3	A	2017-01-24 11:34 PM

This allowed the evaluation of technologies not previously used for this application, at a lower risk.

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This focus on the interactions of the parts implies that the technologies used should be of sufficient maturity.

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Based on lessons learnt since 1943, their development strategy stresses that the use of new technology or newly developed pieces of equipment, should be limited, as it invariably adversely affects the cost, schedule and risk of a project. New technologies and equipment must "buy" their way into a design, yielding either substantial performance gain, or proving that the requirements cannot be met without it (Nicolai, 1997).

				6	A	2017-01-24 11:47 PM

It was shown that many of the challenges experienced on KAT-7 resulted from the

• • •

"fragmented development" strategy. In order to minimise these challenges right from the planning stage, the strategy for the MeerKAT receiver was rather chosen to be one of "consolidated development", whereby all the receiver functions, from reception of the signal from the reflector to delivering the amplified signal to the data-processing subsystem, is to be handled by a single functional entity, labelled the "Receiver". This includes all the control and monitoring functions that are necessary to ensure its proper operation and signal any problems. Crucially, as opposed to the solution for KAT-7, the development of the complete receiver system is the responsibility of only one subcontractor. This has the major advantages of limiting the receiver system's external interfaces to clean "enabling interfaces" (i.e. mechanical / power / data / environmental) simplifying their management, whilst keeping the "operational interfaces" (between the different functions / parts of the receiver system) internal to the system. In this manner their interactions can be more intimately designed, and closely monitored during the development process.

Internals\\MeerKAT Concept Options and Tradeoffs Rev1 sanitisedB_001

No		0.0044	4			
				1	A	2017-01-25 12:35 AM

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				2	A	2017-01-25 12:24 AM
				3	A	2017-01-25 12:31 AM
				4	A	2017-01-25 12:34 AM

Internals\\MeerKAT SE Overview - Rev2

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0109	1			
				1	A	2017-01-26 10:14 PM

Processes & tools:
-SE management -Specification -Design -Qualification -Integration
-Log Eng managment -Project management -Quality management -Config managment -Procurement -Contracting -Production management -Commissioning -Operations

Internals\\MeerKAT SEMP Rev1

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0603	12			
				1	A	2017-01-23 01:03 AM

Qualification is performed on the detailed design by providing evidence to justify that the design meets all requirements. Qualification requirements shall be agreed at the PDR stage or earlier.

				2	A	2017-01-23 01:08 AM

2.9.3. Requirements traceability
Requirements traceability shall be performed throughout the system engineering process as shown in Figure 2. All requirements of an item shall be traceable to: a) Higher-level requirements. b) Architecture design in the design document. c) Lower-level requirements. d) Qualification results. e) Acceptance test procedures and results.

				3	A	2017-01-23 11:24 PM

Any change to an agreed baseline or signed off document shall be executed by means of a change management procedure described in the Configuration Management Plan [2].

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2.9.6. Risk management
As a high technology project, MeerKAT faces many risk areas. The risks on the project shall be carefully managed according to the risk management principles as described in the Project Management Plan [1].

				5	A	2017-01-23 01:15 AM

2.10. Integrated Logistic Support
A Logistic Support system shall be developed together with the engineering of the technical system, to ensure that good support will be provided throughout the operational lifecycle phase. This will be achieved by the management of specific activities of design and development (called logistic engineering activities), in close coordination with the other system engineering activities (such as reliability and safety design). This coordination is especially important during early design and development phases of the project.
These activities shall be tailored to meet the availability (reliability vs. maintainability) and safety (personnel & product) requirements of the project, and to support the technical effort needed to meet these requirements.
In particular, the Telescope segment and Infrastructure & Ancillaries segment design activities shall lead to the definition of a common Logistic Support system.
The definition of the Logistic Support system shall be based on initial operational and maintenance concepts, in order to integrate any user requirements or constraints into the design of the Logistic Support system.
The details of the logistics support management shall be described in the Logistics Engineering Management Plan [3].

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				6	A	2017-01-23 01:16 AM

2.12.1. Requirements traceability tool At least the following requirements (and all traceability between these requirements) shall be captured in CORE, which shall be kept up to date throughout the duration of the project:
a) User requirements.

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2.12.2. CAD tool and data management The CAD tool selected for use on the MeerKAT project
M2000-0000V1-01 MP Revision: 1.0
is Pro-Engineer.
In-house developed items: All in-house mechanical design and draughting shall be done in Pro-Engineer. All components / assemblies and Pro-Engineer drawings shall be linked, but electronic copies of drawings shall be stored in the configuration management system in dxf or dwg format (with pdf format as a last resort).
For all non-mechanical, in-house developed items (e.g. PC boards), a representative but not necessarily 100% complete model shall be generated – it is important that the outer dimensions and geometric interfaces are accurate.
In-house CAD model control: CAD models shall be controlled to ensure that various designers can work on models without causing loss of data or unintended changes that can affect other designers. A plan shall be developed to describe how CAD models and data will be controlled, focussing on the Pro-Engineer environment. This plan shall be applicable to all Pro-Engineer operators in SKA SA. The plan shall be the responsibility of the Telescope Segment Project Manager.
Subcontractor developed items: All mechanical design work by sub-contractors should preferably be in Pro-Engineer. In such cases, the model with the linked drawings shall be delivered as part of the manufacturing datapack as well as dxf/dwg format (pdf format last resort), and hard copy drawings. Where subcontractors do not have access to Pro- Engineer, the detail model shall be provided to SKA SA in a compatible 3D format (typically step, iges or parasolid). The model shall be provided such that the assembly structure (BOM) and the component names are the same as names and numbers indicated on drawings provided when imported into Pro-Engineer. The drawings shall be provided in dxf or dwg format (pdf as a last resort) as well as paper copies. The electronic drawing files and model shall not be linked in this instance, since this is not possible.
CAD interface data: In the event that CAD data is supplied to clients as interface information, the model that is supplied shall be stored in the configuration management system in a zip file, in a non-native Pro-Engineer format (step, iges, parasolid) in order to prevent editing of this interface information. This data shall be issued from the configuration management system. This data shall be referenced in the relevant Interface Control Document, and shall eventually form part of the Interface Control Document.
Procured components: In the event of procured components being used, an effort should be made to obtain a CAD model from the supplier that can be imported into Pro-Engineer (step, iges or parasolid formats preferred). If this cannot be done, a representative but not necessarily 100% complete model shall be generated – it is important that the geometric interfaces and outer dimensions are accurate.
Cable routings: Detailed cable routings are generally not required in CAD format.
Infrastructure items: High level 3D CAD models of the antenna foundation, dish construction shed, and array processor building shall be delivered by the Infrastructure Segment team to the Telescope Segment team to facilitate interface management. The site layouts shall be provided in GIS shape file format.

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2.13. Value engineering
The MeerKAT system consists of a large number (up to 80) of identical Antennas assembled into an integrated array. This multiplication factor needs to be considered since it can have a significant leverage on reducing or increasing costs, simplifying or complicating designs, increasing or decreasing the size and complexity of the Logic Support system elements.
To gain the most advantage of this multiplication factor on simplifying and reducing the size of the MeerKAT Logistic Support system, standardisation shall be introduced at the highest possible system breakdown structure level. Thus standardisation shall be at Segment level (level 4 of system breakdown structure) for the Telescope segment. For the Infrastructure and Ancillaries segment, since there is not a close coupling between subsystems, standardisation shall be introduced at Subsystem (level 3) or even Assembly (level 2) of the System Level breakdown structure

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ICDs will be rigorously reviewed and requests for changes (e.g. changing names of messages or inverting logic) to ensure consistency across the system should be expected.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
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4.1.1. Phase 1: Requirements definition
A supplier will only deliver what he/she is asked to deliver – if you are not sure what you want delivered, you will get just that. That means • Make sure you fully understand the requirements and their origin. • Ensure that the requirements are complete and accurate.
• Provide the supplier with a list of validated requirements, i.e. do not over specify a requirement with the intention to relax it later because there has not been sufficient work done to ensure the requirement is validated.
• Ensure the requirements are stable and if not, indicate the direction into which they are likely to change, by how much and by when. The supplier will state a date after which it will be too late to incorporate the change in requirement without attracting considerable cost and/or schedule impact.
• Ensure that each requirement supports 100% the higher level system requirement e.g. if the higher level system requires a stable temperature of one of its components of 25deg C then the system which ensures this must be specified as such including all effects of losses associated with the physical architecture.
• All parameters have tolerances i.e. in the real world there is no such thing as 25deg C/150mm/1.5mm RMS..... all these requirements shall be stated with a tolerance e.g. 25 deg C +/- 1 deg C, 150mm +/-0.1mm.
• Leave no room for misinterpretation – as it will happen
• Requirements must always be "atomic"/or "granular" i.e. a single requirement which is uniquely verifiable.

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The Means of Showing Compliance against each requirement must be recorded as one of the following:
• Test • Analysis • Similarity • Review

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Qualification testing evidence:
Often, test based evidence is accepted because of the cost and effort associated with a test and the tangibility of the test setup, however, the evidence has to be scrutinised for the following aspects:
• Most importantly are the questions – what is it that will be tested? I.e. what is the configuration of the test article? Is it as agreed? Which deviations have been recorded? How do these affect the results of the test?
• The configuration of the test article should be the first section of the QTP and must be verified as part of the QTP.
• Does the test article configuration represent the configuration of the article that will be in the field for 30 years?
• Are the deviations from the Qualification Standard acceptable for the test to commence?
o Don't just settle for the supplier's word on this – think about it clearly
o Don't hesitate to postpone a qualification test – the supplier should be aware of this possibility
o Inspect the qualification standard (perform an audit)- does it relate to the drawings/specifications/Bill of Materials?
o Test evidence gained with a test which is out of step with the qualification standard is no test evidence at all. This is especially true for software which often is not the "final build", still have some "minor bugs" that need fixing, has not been placed under configuration, has not undergone simulation verification testing and numerous other deficiencies which we are usually assured will be "easily fixed in the new version".
• As important, is the question – how well does the proposed test represent the operational, limit or ultimate environments in which the unit will function?
• Which requirements is the test trying to verify? Are there gaps in here? How are the gaps covered?
• Is the qualification test procedure written in a way that it maps directly to the requirements set that it is intending to verify? If this traceability is not evident, how was the QTP written/approved?
• Qualification tests are better delayed than repeated. • Do not rush into a qualification test – the temptation will be huge
The qualification test is the last chance for the subsystem manager to ensure that his/her system will not let down the project in the years to come – therefore the qualification test procedure is the last chance to ensure that problems are "teased out" that may have been overlooked in the design stage (There will be issues that no-one would have envisaged (we are all human), but these will only show up if your QTP is robust, if not they will show up in service , on 80 antennas and AFTER THE WARRANTY HAS EXPIRED!)

Internals\\Richard Lord

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				1	A	2017-01-24 10:13 PM

Astronomers and scientists getting involved with engineering solutions, instead of focussing on the science requirements. This highlighted the need for proper requirement elicitation and requirement management.

				2	A	2017-01-24 10:41 PM

In order to reduce both the project management risks as well as the technical risks, a number of development models were utilised:

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				3	A	2017-01-24 10:59 PM

PED
The Phased Experimental Demonstrator (PED) was a 6-antenna interferometric radio telescope, constructed on the grounds of the South African Astronomical Observatory (SAAO) in Cape Town. It provided the engineering team with an experimental platform to learn about interferometry, and it is now used by students as an outreach facility.
XDM
At the end of 2007, the Experimental Development Model (XDM) was completed at the Hartebeesthoek Radio Astronomy Observatory (HartRAO). XDM is a single-antenna radio telescope with a diameter of 15m.
Apart from addressing many technical risks, the
acquisition of the XDM was instrumental in building a coherent engineering team and in growing the systems engineering maturity of the organisation to at least Level 3, according to the Capability Maturity Model (Kossiakoff et al. 2011). It must be added that the systems engineering maturity has never been quantitatively verified, by measuring technical processes such as requirements stability, ECP change duration, number of TBDs, etc.
KAT-7 KAT-7 was developed immediately after the completion of the XDM. Tight timelines
demanded that most of the project resources had to be concentrated on the design of KAT-7, perhaps to the detriment of maximising the learning that could have been extracted from the XDM.
This paper regards KAT-7 as the Engineering Development Model (EDM) for MeerKAT, because it was meant to qualify the MeerKAT design, and to determine the suitability of the design with regard to reliability, maintainability, availability and logistic supportability, while being operational in the MeerKAT environment. It could even be regarded as the Preproduction Model, since it was intended to completely evaluate form, fit and performance for MeerKAT. However, since the commissioning work on KAT-7 has started, the MeerKAT design has undergone significant changes, and therefore, strictly speaking, KAT-7 can no longer be regarded as a Preproduction Model, or as an EDM, for MeerKAT. It nevertheless continues to perform an important risk-reduction function, since it helps to build the logistic support systems that are required for MeerKAT.

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These requirements were also captured in CORE, a systems engineering
management tool developed by Vitech Corporation (http://www.vitechcorp.com), in order to ensure requirements traceability and to capture the verification requirements. A total of 1040 system-level requirements for KAT-7 have been captured in CORE.

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Apart from analysis and simulation work, the KAT-7 concept was never demonstrated
explicitly.

				6	A	2017-01-24 11:06 PM

Nonetheless, in some aspects, the XDM could be regarded as KAT-7's advanced development model, as it demonstrated that the required technology was obtainable within the available technology base of South Africa.

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qualification testing is performed on all items.
The qualification
test procedure (QTP) verifies that the end-to-end design meets the given requirements. The SEMP stipulates that the qualification test report (together with a requirements compliance matrix) forms part of a subsystem's or subcontractor's CDR (Critical Design Review).

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It then followed that there
were no detailed design reviews, and ultimately no proper Installation ATPs. Wherever the lack of systems engineering processes was evident, problems took a long time to repair, were costly, and caused unnecessary downtime. These are therefore valuable lessons that can be carried forward to MeerKAT.

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However, once an item had been
formally accepted, it became very difficult (and costly) to change the item later on using the Engineering Change Proposal (ECP) process. Another valuable lesson was therefore not to accept waivers too easily.

				10	A	2017-01-24 11:19 PM

Extensive use was made of simulators, which mimicked their hardware counterparts. Subcontractors were instructed to provide the project with such simulators, where necessary, so that the control & monitoring system could be qualified on a representative system in the Cape Town integration lab, before being deployed to site.

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The objective of engineering verification is to verify that the system meets the system requirements. Qualification and acceptance testing is performed on all system levels. Engineering verification is seen as part of the Full Scale Engineering Development stage.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				12	A	2017-01-24 11:21 PM

The objective of user verification is to verify that the system meets the requirements of the science user and the operational user.

Internals\\SE role approach & history

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0585	3			
				1	A	2017-01-26 09:49 PM

System Integration Integration between subsystems (lab and site)
Integrated system testing

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				2	A	2017-01-26 09:49 PM

Logistic Support Engineering Design for Support; Design the Support; Support the Design

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				3	A	2017-01-26 10:01 PM

Stage 2: Product Engineering - -
Engineering culture Concept baseline:
One budget-costed concept which acceptably meets user requirements
- More formal processes - - - - -
Input
Getting the basics right: • Requirements traceability • Baselines with reviews • Qualification • Integration management
Concept exploration
User system engineering System engineering Subsystem engineering Component engineering
Integration & verification
Production / Implementation
Engineering design
Commissioning Operation
Time
Co-located engineering team Project management
System engineering management Configuration management
Procurement & contract management Quality management
Qualification Production

Nodes\\Methods and tools\Computer based design tools

Document

Internals\\Interview Transcript - SKA System Engineer

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0103	1			
				1	A	2017-01-24 12:39 AM

and we used that to influence the design and to verify that we can actually meet the requirements. Also examples of that electromagnetic modelling, the mechanical modelling

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On

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Internals\\MeerKAT SEMP Rev1

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0178	1			
				1	A	2017-01-23 01:17 AM

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Nodes\\Methods and tools\Modelling and simulation

Document

Internals\\Interview Transcript - SKA System Engineer

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0734	3			
				1	A	2017-01-24 12:36 AM

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				Reference Number	Coded By Initials	Modified On
				2	A	2017-01-24 12:37 AM

Also examples of that electromagnetic modelling, the mechanical modelling and also system engineering we use CORE. We model the functionality in CORE on the system level, those are just some examples.

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Internals\\Richard Lord

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0072	2			
				1	A	2017-01-24 11:06 PM

Apart from analysis and simulation work, the KAT-7 concept was never demonstrated explicitly.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				2	A	2017-01-24 11:19 PM

Extensive use was made of simulators, which mimicked their hardware counterparts. Subcontractors were instructed to provide the project with such simulators, where necessary, so that the control & monitoring system could be qualified on a representative system in the Cape Town integration lab, before being deployed to site.

Nodes\\Methods and tools\Other Methods and tools

Document

Internals\\Interview Transcript - SKA System Engineer

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0125	1			
				1	A	2017-01-24 12:26 AM

So for each sub-system is customized, what are the key risks for that sub-system and how those key risks are addressed in the development process. And we approved that plan as part of the requirements review.

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Internals\\MeerKAT Concept Options and Tradeoffs Rev1 sanitisedB_001

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0019	2			
				1	A	2017-01-25 12:24 AM

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				2	A	2017-01-25 12:34 AM

Internals\\MeerKAT SE Overview - Rev2

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0109	1			
				1	A	2017-01-26 10:14 PM

Processes & tools:
-SE management -Specification -Design -Qualification -Integration
-Log Eng managment -Project management -Quality management -Config managment -Procurement -Contracting -Production management -Commissioning -Operations

Internals\\MeerKAT SEMP Rev1

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0150	5			
				1	A	2017-01-23 11:24 PM

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				Reference Number	Coded By Initials	Modified On
				2	A	2017-01-23 01:14 AM

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As a high technology project, MeerKAT faces many risk areas. The risks on the project shall be carefully managed according to the risk management principles as described in the Project Management Plan [1].

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				3	A	2017-01-23 01:15 AM

2.10. Integrated Logistic Support
A Logistic Support system shall be developed together with the engineering of the technical system, to ensure that good support will be provided throughout the operational lifecycle phase. This will be achieved by the management of specific activities of design and development (called logistic engineering activities), in close coordination with the other system engineering activities (such as reliability and safety design). This coordination is especially important during early design and development phases of the project.
These activities shall be tailored to meet the availability (reliability vs. maintainability) and safety (personnel & product) requirements of the project, and to support the technical effort needed to meet these requirements.
In particular, the Telescope segment and Infrastructure & Ancillaries segment design activities shall lead to the definition of a common Logistic Support system.
The definition of the Logistic Support system shall be based on initial operational and maintenance concepts, in order to integrate any user requirements or constraints into the design of the Logistic Support system.
The details of the logistics support management shall be described in the Logistics Engineering Management Plan [3].

				Reference Number	Coded By Initials	Modified On
				4	A	2017-01-23 01:18 AM

2.13. Value engineering
The MeerKAT system consists of a large number (up to 80) of identical Antennas assembled into an integrated array. This multiplication factor needs to be considered since it can have a significant leverage on reducing or increasing costs, simplifying or complicating designs, increasing or decreasing the size and complexity of the Logic Support system elements.
To gain the most advantage of this multiplication factor on simplifying and reducing the size of the MeerKAT Logistic Support system, standardisation shall be introduced at the highest possible system breakdown structure level. Thus standardisation shall be at Segment level (level 4 of system breakdown structure) for the Telescope segment. For the Infrastructure and Ancillaries segment, since there is not a close coupling between subsystems, standardisation shall be introduced at Subsystem (level 3) or even Assembly (level 2) of the System Level breakdown structure

				Reference Number	Coded By Initials	Modified On
				5	A	2017-01-23 11:38 PM

ICDs will be rigorously reviewed and requests for changes (e.g. changing names of messages or inverting logic) to ensure consistency across the system should be expected.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On

Internals\\Richard Lord

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0007	1			
				1	A	2017-01-24 11:20 PM

Engineering Change Proposal (ECP) process.

Internals\\SE role approach & history

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0056	1			
				1	A	2017-01-26 09:49 PM

Logistic Support Engineering Design for Support; Design the Support; Support the Design

Nodes\\Methods and tools\Prototyping

Document

Internals\\Interview Transcript - SKA System Engineer

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0265	1			
				1	A	2017-01-24 12:18 AM

Because it was part of our program Meerkat, we first delivered the first, its actually the cooling solution developed as first of all passive cooling without cryogenics that was the first dish in Hartbeeshoek. Then on the Kat-7 system we tried the Sterling cooler and that didn't turn out to work so well. Then for Meerkat we reverted back to the proven technology so we had the opportunity for the prototypes to implement and build on them.

PDF

Internals\\Marias Botha

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0397	3			
				1	A	2017-01-24 11:31 PM

KAT-7 is a science and engineering prototype radio telescope array, consisting of seven receptors situated alongside the proposed SKA core site (SKA South Africa a)

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				2	A	2017-01-24 11:32 PM

The purpose of this precursor project was to identify the inherent challenges associated with designing and building a fully-functional radio-telescope array, but on a smaller, more manageable scale.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				3	A	2017-01-24 11:47 PM

It was shown that many of the challenges experienced on KAT-7 resulted from the
• • •
“fragmented development” strategy. In order to minimise these challenges right from the planning stage, the strategy for the MeerKAT receiver was rather chosen to be one of “consolidated development”, whereby all the receiver functions, from reception of the signal from the reflector to delivering the amplified signal to the data-processing subsystem, is to be handled by a single functional entity, labelled the “Receiver”. This includes all the control and monitoring functions that are necessary to ensure its proper operation and signal any problems. Crucially, as opposed to the solution for KAT-7, the development of the complete receiver system is the responsibility of only one subcontractor. This has the major advantages of limiting the receiver system’s external interfaces to clean “enabling interfaces” (i.e. mechanical / power / data / environmental) simplifying their management, whilst keeping the “operational interfaces” (between the different functions / parts of the receiver system) internal to the system. In this manner their interactions can be more intimately designed, and closely monitored during the development process.

Internals\\Richard Lord

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0397	2			
				1	A	2017-01-24 10:41 PM

In order to reduce both the project management risks as well as the technical risks, a number of development models were utilised:

				2	A	2017-01-24 10:59 PM

PED
The Phased Experimental Demonstrator (PED) was a 6-antenna interferometric radio telescope, constructed on the grounds of the South African Astronomical Observatory (SAAO) in Cape Town. It provided the engineering team with an experimental platform to learn about interferometry, and it is now used by students as an outreach facility.
XDM
At the end of 2007, the Experimental Development Model (XDM) was completed at the Hartebeesthoek Radio Astronomy Observatory (HartRAO). XDM is a single-antenna radio telescope with a diameter of 15m.
Apart from addressing many technical risks, the
acquisition of the XDM was instrumental in building a coherent engineering team and in growing the systems engineering maturity of the organisation to at least Level 3, according to the Capability Maturity Model (Kossiakoff et al. 2011). It must be added that the systems engineering maturity has never been quantitatively verified, by measuring technical processes such as requirements stability, ECP change duration, number of TBDs, etc.
KAT-7 KAT-7 was developed immediately after the completion of the XDM. Tight timelines
demanded that most of the project resources had to be concentrated on the design of KAT-7, perhaps to the detriment of maximising the learning that could have been extracted from the XDM.
This paper regards KAT-7 as the Engineering Development Model (EDM) for MeerKAT, because it was meant to qualify the MeerKAT design, and to determine the suitability of the design with regard to reliability, maintainability, availability and logistic supportability, while being operational in the MeerKAT environment. It could even be regarded as the Preproduction Model, since it was intended to completely evaluate form, fit and performance for MeerKAT. However, since the commissioning work on KAT-7 has started, the MeerKAT design has undergone significant changes, and therefore, strictly speaking, KAT-7 can no longer be regarded as a Preproduction Model, or as an EDM, for MeerKAT. It nevertheless continues to perform an important risk-reduction function, since it helps to build the logistic support systems that are required for MeerKAT.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On

Nodes\\Methods and tools\Requirement Management Tools

Document

Internals\\Interview Transcript - SKA System Engineer

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0477	3			
				1	A	2017-01-24 12:00 AM

Obviously our clients are the scientists mainly and our stakeholders are funding stakeholders and science stakeholders.

				2	A	2017-01-24 12:37 AM

Also examples of that electromagnetic modelling, the mechanical modelling and also system engineering we use CORE. We model the functionality in CORE on the system level, those are just some examples.

				3	A	2017-01-24 12:38 AM

We using core for requirements traceability and requirements management and we capture all the requirements starting off with the user requirements and traced those down to system requirements and sub-system requirements and we keep that traceability up and it is still running and we again we matured that capability over time. At this stage the sub-systems a lot of them print out their specs from CORE directly so that’s turned out very useful and turned out quite well.

PDF

Internals\\MeerKAT Concept Options and Tradeoffs Rev1 sanitisedB_001

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0025	2			
				1	A	2017-01-25 12:35 AM
				2	A	2017-01-25 12:31 AM

Internals\\MeerKAT SEMP Rev1

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0148	4			
				1	A	2017-01-23 12:54 AM

2.3.2. Requirements Definition
The purpose of this stage is to define the “problem” (WHAT is required). The aim is to capture and validate a complete, unambiguous and traceable set of requirements for an item, so that there is no misunderstanding between different stakeholders as to what is required.
This part of the process is extremely important and forms the basis for all further development work. Problems downstream are often a symptom of neglect in the requirements definition.
Requirements definition is performed at all levels. A system engineer shall be appointed for each item to be responsible for this activity.

				2	A	2017-01-23 01:08 AM

2.9.3. Requirements traceability
Requirements traceability shall be performed throughout the system engineering process as shown in Figure 2. All requirements of an item shall be traceable to: a) Higher-level requirements. b) Architecture design in the design document. c) Lower-level requirements. d) Qualification results. e) Acceptance test procedures and results.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				3	A	2017-01-23 01:16 AM

2.12.1. Requirements traceability tool At least the following requirements (and all traceability between these requirements) shall be captured in CORE, which shall be kept up to date throughout the duration of the project:
a) User requirements.

				4	A	2017-01-23 11:43 PM

4.1.1. Phase 1: Requirements definition
A supplier will only deliver what he/she is asked to deliver – if you are not sure what you want delivered, you will get just that. That means • Make sure you fully understand the requirements and their origin. • Ensure that the requirements are complete and accurate.
• Provide the supplier with a list of validated requirements, i.e. do not over specify a requirement with the intention to relax it later because there has not been sufficient work done to ensure the requirement is validated.
• Ensure the requirements are stable and if not, indicate the direction into which they are likely to change, by how much and by when. The supplier will state a date after which it will be too late to incorporate the change in requirement without attracting considerable cost and/or schedule impact.
• Ensure that each requirement supports 100% the higher level system requirement e.g. if the higher level system requires a stable temperature of one of its components of 25deg C then the system which ensures this must be specified as such including all effects of losses associated with the physical architecture.
• All parameters have tolerances i.e. in the real world there is no such thing as 25deg C/150mm/1.5mm RMS..... all these requirements shall be stated with a tolerance e.g. 25 deg C +/- 1 deg C, 150mm +/-0.1mm.
• Leave no room for misinterpretation – as it will happen
• Requirements must always be “atomic”/or “granular” i.e. a single requirement which is uniquely verifiable.

Internals\\Richard Lord

No		0.0091	2			
				1	A	2017-01-24 10:13 PM

Astronomers and scientists getting involved with engineering solutions, instead of focussing on the science requirements. This highlighted the need for proper requirement elicitation and requirement management.

				2	A	2017-01-24 11:05 PM

These requirements were also captured in CORE, a systems engineering
management tool developed by Vitech Corporation (http://www.vitechcorp.com), in order to ensure requirements traceability and to capture the verification requirements. A total of 1040 system-level requirements for KAT-7 have been captured in CORE.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On

Internals\\SE role approach & history

No		0.0469	1			
				1	A	2017-01-26 10:01 PM

Stage 2: Product Engineering - -
Engineering culture Concept baseline:
One budget-costed concept which acceptably meets user requirements
- More formal processes - - - - -
Input
Getting the basics right: • Requirements traceability • Baselines with reviews • Qualification • Integration management
Concept exploration
User system engineering System engineering Subsystem engineering Component engineering
Integration & verification
Production / Implementation
Engineering design
Commissioning Operation
Time
Co-located engineering team Project management
System engineering management Configuration management
Procurement & contract management Quality management
Qualification Production

Nodes\\Methods and tools\Technology Maturity considerations

Document

Internals\\Interview Transcript - SKA System Engineer

No		0.1377	4			
				1	A	2017-01-24 12:05 AM

No we didn’t not on Meerkat project. On Meerkat it was a very, you know I think we didn’t manage it formally or measure technology maturity formally it was informal.

				2	A	2017-01-24 12:07 AM

The South African Team specifically, had a very clear strategy to take on technologies that are low risk and can be implemented in the short time scales for Meerkat. So we didn’t have formal evaluation metrics for technology maturity but a very conscious technique for example the feed technologies we went for standard you know octave band horn feeds which are mature technology and we knew exactly what we were going to expect. But for the SKA project they are employing metrics for technology maturity but those are defined and they are going to do an assessment of technology maturity at the preliminary design phase. But its quite difficult to measure quantitatively, its often judgement call.

				3	A	2017-01-24 12:16 AM

We looked at, because the sensitivity is a key performance driver, we looked at two alternative technologies one is a helium based system which is widely used internationally in radio observatories and then the Sterling system. So we actually went for the Sterling system because it was new, it was a bit of a technology risk we took at that time but we chose it because we saw it as a much lower cost and maintenance, operational and acquisition cost option and we took a conscious risk at that stage and it turned out it wasn’t the best technology to use, it was proven in a different application, its used for space applications and other telecommunication applications. In those other applications it works fine but for radio astronomy applications it turned out not to be such a good solution. So to an extent it was that the maturity of the technology was proven in a different application but it didn’t turn out to be valid for this application. That’s one example I can think of.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				4	A	2017-01-24 12:18 AM

Because it was part of our program Meerkat, we first delivered the first, its actually the cooling solution developed as first of all passive cooling without cryogenics that was the first dish in Hartbeeshoek. Then on the Kat-7 system we tried the Sterling cooler and that didn’t turn out to work so well. Then for Meerkat we reverted back to the proven technology so we had the opportunity for the prototypes to implement and build on them.

PDF

Internals\\Marias Botha

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0158	3			
				1	A	2017-01-24 11:34 PM

This allowed the evaluation of technologies not previously used for this application, at a lower risk.

				2	A	2017-01-24 11:42 PM

This focus on the interactions of the parts implies that the technologies used should be of sufficient maturity.

				3	A	2017-01-24 11:43 PM

Based on lessons learnt since 1943, their development strategy stresses that the use of new technology or newly developed pieces of equipment, should be limited, as it invariably adversely affects the cost, schedule and risk of a project. New technologies and equipment must “buy” their way into a design, yielding either substantial performance gain, or proving that the requirements cannot be met without it (Nicolai, 1997).

Internals\\Richard Lord

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0036	1			
				1	A	2017-01-24 11:06 PM

Nonetheless, in some aspects, the XDM could be regarded as KAT-7’s advanced development model, as it demonstrated that the required technology was obtainable within the available technology base of South Africa.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On

Nodes\\Methods and tools\Testing

Document

Internals\\Interview Transcript - SKA System Engineer

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0265	1			
				1	A	2017-01-24 12:18 AM

Because it was part of our program Meerkat, we first delivered the first, its actually the cooling solution developed as first of all passive cooling without cryogenics that was the first dish in Hartbeeshoek. Then on the Kat-7 system we tried the Sterling cooler and that didn't turn out to work so well. Then for Meerkat we reverted back to the proven technology so we had the opportunity for the prototypes to implement and build on them.

PDF

Internals\\MeerKAT SEMP Rev1

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0141	1			
				1	A	2017-01-23 11:52 PM

Qualification testing evidence:
Often, test based evidence is accepted because of the cost and effort associated with a test and the tangibility of the test setup, however, the evidence has to be scrutinised for the following aspects:
• Most importantly are the questions – what is it that will be tested? I.e. what is the configuration of the test article? Is it as agreed? Which deviations have been recorded? How do these affect the results of the test?
• The configuration of the test article should be the first section of the QTP and must be verified as part of the QTP.
• Does the test article configuration represent the configuration of the article that will be in the field for 30 years?
• Are the deviations from the Qualification Standard acceptable for the test to commence?
o Don't just settle for the supplier's word on this – think about it clearly
o Don't hesitate to postpone a qualification test – the supplier should be aware of this possibility
o Inspect the qualification standard (perform an audit)- does it relate to the drawings/specifications/Bill of Materials?
o Test evidence gained with a test which is out of step with the qualification standard is no test evidence at all. This is especially true for software which often is not the "final build", still have some "minor bugs" that need fixing, has not been placed under configuration, has not undergone simulation verification testing and numerous other deficiencies which we are usually assured will be "easily fixed in the new version".
• As important, is the question – how well does the proposed test represent the operational, limit or ultimate environments in which the unit will function?
• Which requirements is the test trying to verify? Are there gaps in here? How are the gaps covered?
• Is the qualification test procedure written in a way that it maps directly to the requirements set that it is intending to verify? If this traceability is not evident, how was the QTP written/approved?
• Qualification tests are better delayed than repeated. • Do not rush into a qualification test – the temptation will be huge
The qualification test is the last chance for the subsystem manager to ensure that his/her system will not let down the project in the years to come – therefore the qualification test procedure is the last chance to ensure that problems are "teased out" that may have been overlooked in the design stage (There will be issues that no-one would have envisaged (we are all human), but these will only show up if your QTP is robust, if not they will show up in service , on 80 antennas and AFTER THE WARRANTY HAS EXPIRED!)

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On

Internals\\Richard Lord

No		0.0258	5			
				1	A	2017-01-24 10:59 PM

This paper regards KAT-7 as the Engineering Development Model (EDM) for MeerKAT, because it was meant to qualify the MeerKAT design, and to determine the suitability of the design with regard to reliability, maintainability, availability and logistic supportability, while being operational in the MeerKAT environment. It could even be regarded as the Preproduction Model, since it was intended to completely evaluate form, fit and performance for MeerKAT.

				2	A	2017-01-24 11:13 PM

qualification testing is performed on all items.
The qualification
test procedure (QTP) verifies that the end-to-end design meets the given requirements. The SEMP stipulates that the qualification test report (together with a requirements compliance matrix) forms part of a subsystem's or subcontractor's CDR (Critical Design Review).

				3	A	2017-01-24 11:15 PM

It then followed that there
were no detailed design reviews, and ultimately no proper Installation ATPs. Wherever the lack of systems engineering processes was evident, problems took a long time to repair, were costly, and caused unnecessary downtime. These are therefore valuable lessons that can be carried forward to MeerKAT.

				4	A	2017-01-24 11:16 PM

However, once an item had been
formally accepted, it became very difficult (and costly) to change the item later on using the Engineering Change Proposal (ECP) process. Another valuable lesson was therefore not to accept waivers too easily.

				5	A	2017-01-24 11:21 PM

The objective of user verification is to verify that the system meets the requirements of the science user and the operational user.

Internals\\SE role approach & history

No		0.0060	1			
				1	A	2017-01-26 09:49 PM

System Integration Integration between subsystems (lab and site)
Integrated system testing

Nodes\\Methods and tools\Verification and Validation

PDF

Internals\\MeerKAT SEMP Rev1

No		0.0017	2			
				1	A	2017-01-23 01:03 AM

Qualification is performed on the detailed design by providing evidence to justify that the design meets all requirements. Qualification requirements shall be agreed at the PDR stage or earlier.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				2	A	2017-01-23 11:45 PM

The Means of Showing Compliance against each requirement must be recorded as one of the following:
• Test • Analysis • Similarity • Review

Internals\\Richard Lord

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0247	5			
				1	A	2017-01-24 10:59 PM

This paper regards KAT-7 as the Engineering Development Model (EDM) for MeerKAT, because it was meant to qualify the MeerKAT design, and to determine the suitability of the design with regard to reliability, maintainability, availability and logistic supportability, while being operational in the MeerKAT environment. It could even be regarded as the Preproduction Model, since it was intended to completely evaluate form, fit and performance for MeerKAT.

				2	A	2017-01-24 11:13 PM

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The qualification
test procedure (QTP) verifies that the end-to-end design meets the given requirements. The SEMP stipulates that the qualification test report (together with a requirements compliance matrix) forms part of a subsystem's or subcontractor's CDR (Critical Design Review).

				3	A	2017-01-24 11:16 PM

However, once an item had been
formally accepted, it became very difficult (and costly) to change the item later on using the Engineering Change Proposal (ECP) process. Another valuable lesson was therefore not to accept waivers too easily.

				4	A	2017-01-24 11:21 PM

The objective of engineering verification is to verify that the system meets the system requirements. Qualification and acceptance testing is performed on all system levels. Engineering verification is seen as part of the Full Scale Engineering Development stage.

				5	A	2017-01-24 11:21 PM

The objective of user verification is to verify that the system meets the requirements of the science user and the operational user.

Nodes\\Organization

Document

Internals\\Interview Transcript - SKA System Engineer

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.1887	7			
				1	A	2017-01-23 11:57 PM

is organizational because we started this project from scratch without any people so we had to grow the organization along with growing the technology and growing the processes.

				2	A	2017-01-23 11:58 PM

So getting the right people and getting them trained and getting our organizational processes and cultures and everything sorted out

				3	A	2017-01-24 12:00 AM

Obviously our clients are the scientists mainly and our stakeholders are funding stakeholders and science stakeholders.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				4	A	2017-01-24 12:04 AM

The second big set of interactions is with the scientists, so there to get the requirements pinned down. So there we had very good connections to Justin Jonas who is our project scientist and he had contacts with the international community and what we did early in the project is we advertised the Meerkat capability to say these are the technical capabilities the system will have. We asked for proposals for science for scientists to use it. They generated proposals and that created a very clear set of stakeholders so those key science projects are our stakeholders and we elicited all the requirements through them and checked everything with them, the user requirements.

				5	A	2017-01-24 12:32 AM

So we had to look at each of those disciplines and see what the best way to get that technology up is and running as quickly as possible. For each different technology it worked out slightly differently so for some of them, like for software we decided to do everything in house, we decided we can get good software people and get them up and running quite quickly. For some sub-systems like the dish structures, the mechanical systems we decided to contract that out to an industry player because it would be difficult to build up that capability in a short period of time.

				6	A	2017-01-24 12:33 AM

some cases for the electromagnetics and the receivers we contracted the whole thing out to EMSS who is a technology partner for us. For the infrastructure we also had a project management and system engineering internally and we contracted out the rest. So it was a mixture depending on how quickly and also it depends on long term for a radio observatory some skills you need in house and some you don't. So we decided we only going to appoint teams of people where we need that capability long term in house, so system engineering, project management, software are basically the areas.

				7	A	2017-01-24 12:40 AM

think there are multiple stakeholders, the SKA project is administered inside as a sub section of the National Research Foundation so the NRF is part of our larger organization structure but also extending to the Department of Science and Technology so we have a lot of direct interaction with them. I think they were very supportive of financial and stakeholder support. I think sometimes we struggle, some of our issues are administrative. Initially the NRF, it is not an organization designed to do large acquisitions, it is designed to manage research and grants so we did have some problems early on to get these processes going where we can do large acquisitions within that organization but that's an example of the challenge we had but it has been improving but besides that we had very good support from the stakeholder, political and financial perspectives.

PDF

Internals\\MeerKAT Concept Options and Tradeoffs Rev1 sanitisedB_001

No		0.0014	1			
				1	A	2017-01-25 12:31 AM

Internals\\MeerKAT SE Overview - Rev2

No		0.0088	1			
				1	A	2017-01-26 10:15 PM

Organisational: -Clear Roles, Responsibilities & Relationships -Common vision -Common approach -Common vocabulary -Capacity / Resouces -Collaborative networks -Industry / contractor relationships

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On

Internals\\Richard Lord

No		0.0184	6			
				1	A	2017-01-24 10:08 PM

the SKA SA project is funded by the Department of Science and Technology (DST), and is administered by the National Research Foundation (NRF)

				2	A	2017-01-24 10:13 PM

Astronomers and scientists getting involved with engineering solutions, instead of focussing on the science requirements. This highlighted the need for proper requirement elicitation and requirement management.

				3	A	2017-01-24 10:15 PM

Developing process maturity. As SKA South Africa was a young organisation, its project management and systems engineering processes still had to be created.

				4	A	2017-01-24 10:18 PM

Lack of user domain experience. The Systems Engineering team had little experience in radio astronomy and in building radio telescopes.

				5	A	2017-01-24 10:21 PM

Non-existence of enabling systems, including operators and maintainers, once KAT-7 entered the Utilisation and Support life cycle stages.

				6	A	2017-01-24 10:54 PM

Apart from addressing many technical risks, the
acquisition of the XDM was instrumental in building a coherent engineering team and in growing the systems engineering maturity of the organisation to at least Level 3, according to the Capability Maturity Model (Kossiakoff et al. 2011).

Internals\\SE role approach & history

No		0.0089	2			
				1	A	2017-01-26 09:53 PM

Organisational maturity

				2	A	2017-01-26 09:59 PM

Stages influence: • Organisational culture • Organisational structures • Organisational process (incl. SE process)

Nodes\\Organization\Interaction

Document

Internals\\Interview Transcript - SKA System Engineer

No		0.0486	2			
				1	A	2017-01-23 11:58 PM

So getting the right people and getting them trained and getting our organizational processes and cultures and everything sorted out

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				2	A	2017-01-24 12:04 AM

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PDF

Internals\\MeerKAT SE Overview - Rev2

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0088	1			
				1	A	2017-01-26 10:15 PM

Organisational: -Clear Roles, Responsibilities & Relationships -Common vision -Common approach -Common vocabulary -Capacity / Resouces -Collaborative networks -Industry / contractor relationships

Internals\\Richard Lord

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0036	1			
				1	A	2017-01-24 10:13 PM

Astronomers and scientists getting involved with engineering solutions, instead of focussing on the science requirements. This highlighted the need for proper requirement elicitation and requirement management.

Nodes\\Organization\Organizational Issues

Document

Internals\\Interview Transcript - SKA System Engineer

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.1407	5			
				1	A	2017-01-23 11:57 PM

is organizational because we started this project from scratch without any people so we had to grow the organization along with growing the technology and growing the processes.

				2	A	2017-01-23 11:58 PM

So getting the right people and getting them trained and getting our organizational processes and cultures and everything sorted out

				3	A	2017-01-24 12:32 AM

So we had to look at each of those disciplines and see what the best way to get that technology up is and running as quickly as possible. For each different technology it worked out slightly differently so for some of them, like for software we decided to do everything in house, we decided we can get good software people and get them up and running quite quickly. For some sub-systems like the dish structures, the mechanical systems we decided to contract that out to an industry player because it would be difficult to build up that capability in a short period of time.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				4	A	2017-01-24 12:33 AM

some cases for the electromagnetics and the receivers we contracted the whole thing out to EMSS who is a technology partner for us. For the infrastructure we also had a project management and system engineering internally and we contracted out the rest. So it was a mixture depending on how quickly and also it depends on long term for a radio observatory some skills you need in house and some you don't. So we decided we only going to appoint teams of people where we need that capability long term in house, so system engineering, project management, software are basically the areas.

				5	A	2017-01-24 12:40 AM

think there are multiple stakeholders, the SKA project is administered inside as a sub section of the National Research Foundation so the NRF is part of our larger organization structure but also extending to the Department of Science and Technology so we have a lot of direct interaction with them. I think they were very supportive of financial and stakeholder support. I think sometimes we struggle, some of our issues are administrative. Initially the NRF, it is not an organization designed to do large acquisitions, it is designed to manage research and grants so we did have some problems early on to get these processes going where we can do large acquisitions within that organization but that's an example of the challenge we had but it has been improving but besides that we had very good support from the stakeholder, political and financial perspectives.

PDF

Internals\\MeerKAT SE Overview - Rev2

No		0.0088	1			
				1	A	2017-01-26 10:15 PM

Organisational: -Clear Roles, Responsibilities & Relationships -Common vision -Common approach -Common vocabulary -Capacity / Resouces -Collaborative networks -Industry / contractor relationships

Internals\\Richard Lord

No		0.0123	4			
				1	A	2017-01-24 10:15 PM

Developing process maturity. As SKA South Africa was a young organisation, its project management and systems engineering processes still had to be created.

				2	A	2017-01-24 10:18 PM

Lack of user domain experience. The Systems Engineering team had little experience in radio astronomy and in building radio telescopes.

				3	A	2017-01-24 10:21 PM

Non-existence of enabling systems, including operators and maintainers, once KAT-7 entered the Utilisation and Support life cycle stages.

				4	A	2017-01-24 10:54 PM

Apart from addressing many technical risks, the
acquisition of the XDM was instrumental in building a coherent engineering team and in growing the systems engineering maturity of the organisation to at least Level 3, according to the Capability Maturity Model (Kossiakoff et al. 2011).

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On

Internals\\SE role approach & history

No		0.0089	2			
				1	A	2017-01-26 09:53 PM

Organisational maturity

				2	A	2017-01-26 09:59 PM

Stages influence: • Organisational culture • Organisational structures • Organisational process (incl. SE process)

Nodes\\Organization\Stakeholders

Document

Internals\\Interview Transcript - SKA System Engineer

No		0.1001	3			
				1	A	2017-01-24 12:00 AM

Obviously our clients are the scientists mainly and our stakeholders are funding stakeholders and science stakeholders.

				2	A	2017-01-24 12:04 AM

The second big set of interactions is with the scientists, so there to get the requirements pinned down. So there we had very good connections to Justin Jonas who is our project scientist and he had contacts with the international community and what we did early in the project is we advertised the Meerkat capability to say these are the technical capabilities the system will have. We asked for proposals for science for scientists to use it. They generated proposals and that created a very clear set of stakeholders so those key science projects are our stakeholders and we elicited all the requirements through them and checked everything with them, the user requirements.

				3	A	2017-01-24 12:40 AM

think there are multiple stakeholders, the SKA project is administered inside as a sub section of the National Research Foundation so the NRF is part of our larger organization structure but also extending to the Department of Science and Technology so we have a lot of direct interaction with them. I think they were very supportive of financial and stakeholder support. I think sometimes we struggle, some of our issues are administrative. Initially the NRF, it is not an organization designed to do large acquisitions, it is designed to manage research and grants so we did have some problems early on to get these processes going where we can do large acquisitions within that organization but that’s an example of the challenge we had but it has been improving but besides that we had very good support from the stakeholder, political and financial perspectives.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On

PDF

Internals\\MeerKAT Concept Options and Tradeoffs Rev1 sanitisedB_001

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0014	1			
				1	A	2017-01-25 12:31 AM

Internals\\MeerKAT SE Overview - Rev2

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0088	1			
				1	A	2017-01-26 10:15 PM

Organisational: -Clear Roles, Responsibilities & Relationships -Common vision -Common approach -Common vocabulary -Capacity / Resouces -Collaborative networks -Industry / contractor relationships

Internals\\Richard Lord

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0060	2			
				1	A	2017-01-24 10:08 PM

the SKA SA project is funded by the Department of Science and Technology (DST), and is administered by the National Research Foundation (NRF)

				2	A	2017-01-24 10:13 PM

Astronomers and scientists getting involved with engineering solutions, instead of focussing on the science requirements. This highlighted the need for proper requirement elicitation and requirement management.

Nodes\\Processes

Document

Internals\\Interview Transcript - SKA System Engineer

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0877	5			
				1	A	2017-01-23 11:55 PM

So the reason there, its you know a 20 Kelvin system temperature system, so if you can save 1 Kelvin noise temperature you can basically get five percent saving on your total project cost, you basically save millions of Rands just by improving your receiver temperature one Kelvin.

				2	A	2017-01-24 12:00 AM

Obviously our clients are the scientists mainly and our stakeholders are funding stakeholders and science stakeholders.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				3	A	2017-01-24 12:04 AM

The second big set of interactions is with the scientists, so there to get the requirements pinned down. So there we had very good connections to Justin Jonas who is our project scientist and he had contacts with the international community and what we did early in the project is we advertised the Meerkat capability to say these are the technical capabilities the system will have. We asked for proposals for science for scientists to use it. They generated proposals and that created a very clear set of stakeholders so those key science projects are our stakeholders and we elicited all the requirements through them and checked everything with them, the user requirements.

				4	A	2017-01-24 12:26 AM

So for each sub-system is customized, what are the key risks for that sub-system and how those key risks are addressed in the development process. And we approved that plan as part of the requirements review.

				5	A	2017-01-24 12:39 AM

and we used that to influence the design and to verify that we can actually meet the requirements. Also examples of that electromagnetic modelling, the mechanical modelling

PDF

Internals\\MeerKAT Concept Options and Tradeoffs Rev1 sanitisedB_001

No		0.0043	4			
				1	A	2017-01-25 12:35 AM
				2	A	2017-01-25 12:24 AM
				3	A	2017-01-25 12:28 AM
				4	A	2017-01-25 12:31 AM

Internals\\MeerKAT SE Overview - Rev2

No		0.0378	5			
				1	A	2017-01-26 10:12 PM

Integrated Logistics Support

				2	A	2017-01-26 10:14 PM

Processes & tools:
-SE management -Specification -Design -Qualification -Integration
-Log Eng managment -Project management -Quality management -Config managment -Procurement -Contracting -Production management -Commissioning -Operations

				3	A	2017-01-26 10:18 PM

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				4	A	2017-01-26 10:18 PM

Metrics to quantify process quality:
1. Baseline control 2. Requirements control 3. Interface control 4. Change control

				5	A	2017-01-26 10:20 PM

Antenna production schedule: 62 dishes over 2 years (Oct 2014àSept 2016 = ~500 work days) = production rate of 8 working days per Receptor

Internals\\MeerKAT SEMP Rev1

No		0.0268	9			
				1	A	2017-01-23 12:55 AM

The output of the definition stage is a complete set of well-defined and validated requirements captured in the requirements specification document, which forms part of the requirements baseline. The requirements shall be reviewed formally at the Requirements Review (RR), involving all relevant stakeholders.

				2	A	2017-01-23 12:59 AM

Architecture design is performed at all levels. A system engineer shall be made responsible for each item to be responsible for this activity.
The architecture is derived from the requirements, and the described architecture shall demonstrate how all requirements will be achieved. In other words, there shall be clear traceability between requirements (problem) and architecture design (solution).
The recommended method for architecture design is described in [4], and should be applied after appropriate training. This method describes a structured and iterative approach for designing a complete and coherent functional and physical architecture, while ensuring that all requirements are met. This process typically results in multiple possible architectures, each with its advantages and disadvantages. In such cases a trade-off study shall be performed to decide which of the alternative solutions will best meet the requirements.

				3	A	2017-01-23 01:00 AM

The outputs of the preliminary design activity are: a) A single chosen architecture, with a rationale for the choice.
b) A functional (where applicable) and physical architecture description, captured in the design document (DD).
17 May 2010
c) A set of allocated and validated requirements for lower level items*

				4	A	2017-01-23 01:08 AM

2.9.3. Requirements traceability
Requirements traceability shall be performed throughout the system engineering process as shown in Figure 2. All requirements of an item shall be traceable to: a) Higher-level requirements. b) Architecture design in the design document. c) Lower-level requirements. d) Qualification results. e) Acceptance test procedures and results.

				5	A	2017-01-23 11:25 PM

The purpose of the change management procedure is to ensure: a) That the change is needed.
b) That the change is properly assessed and does not adversely affect the project. c) That the change, if accepted, is communicated to all affected parties. d) That the change, if accepted, is followed through to its completion.

				6	A	2017-01-23 11:37 PM

2.11. Safety
The operation of the MeerKAT Telescope system shall comply with the requirements of the Occupational Health and Safety Act, 1993 and its regulations.
In order to achieve this requirement, a Hazards or Safety Analysis shall be performed. This analysis shall be performed during the Preliminary Design and Detail Design stages at both Segment and Subsystem level so that required design influence can be achieved. A standardised format shall be made available and used for the safety analysis and operational hazards report, and shall be based on the standard presented in [7].
A final Operational Hazards report for each Segment and Subsystem shall be supplied as part of the As-Built documentation for these items.
Failure Mode and Effects Analysis shall be performed to identify product safety and reliability aspects. This shall be done as part of the Integrated Logistic Support activities (see Section 2.10).

				7	A	2017-01-23 11:38 PM

ICDs will be rigorously reviewed and requests for changes (e.g. changing names of messages or inverting logic) to ensure consistency across the system should be expected.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				8	A	2017-01-23 11:43 PM

4.1.1. Phase 1: Requirements definition
A supplier will only deliver what he/she is asked to deliver – if you are not sure what you want delivered, you will get just that. That means • Make sure you fully understand the requirements and their origin. • Ensure that the requirements are complete and accurate.
• Provide the supplier with a list of validated requirements, i.e. do not over specify a requirement with the intention to relax it later because there has not been sufficient work done to ensure the requirement is validated.
• Ensure the requirements are stable and if not, indicate the direction into which they are likely to change, by how much and by when. The supplier will state a date after which it will be too late to incorporate the change in requirement without attracting considerable cost and/or schedule impact.
• Ensure that each requirement supports 100% the higher level system requirement e.g. if the higher level system requires a stable temperature of one of its components of 25deg C then the system which ensures this must be specified as such including all effects of losses associated with the physical architecture.
• All parameters have tolerances i.e. in the real world there is no such thing as 25deg C/150mm/1.5mm RMS..... all these requirements shall be stated with a tolerance e.g. 25 deg C +/- 1 deg C, 150mm +/-0.1mm.
• Leave no room for misinterpretation – as it will happen
• Requirements must always be “atomic”/or “granular” i.e. a single requirement which is uniquely verifiable.

				9	A	2017-01-23 11:45 PM

The Means of Showing Compliance against each requirement must be recorded as one of the following:
• Test • Analysis • Similarity • Review

Internals\\Richard Lord

No		0.0524	10			
				1	A	2017-01-24 10:07 PM

Another major objective was to establish the Integrated Logistic Support (ILS) system for the KAT-7 Telescope, which will also be used for MeerKAT, and which can also be expanded to support other telescope systems within the radio astronomy reserve.

				2	A	2017-01-24 10:09 PM

Ever-changing user requirements.
Originally, the “KAT” telescope consisted of 20
antennas, and the main objective of building a telescope was to support South Africa’s bid to host the Square Kilometre Array (SKA). After a further injection of money by the government (the SKA SA project is funded by the Department of Science and Technology (DST), and is administered by the National Research Foundation (NRF)), the scope of the project was expanded to build MeerKAT, which is envisioned to become a world-class radio telescope in its own right.

				3	A	2017-01-24 11:01 PM

The life of KAT-7 did not start with a formal User Requirement Statement (URS), because the “users” of the system (at that time) were also the engineering team who designed it. Instead, during 2007, the scope and development strategy of MeerKAT were investigated

				4	A	2017-01-24 11:02 PM

This investigation limited, among other parameters, the frequency band and array configuration, based on the following considerations:
• Scientific capability; • Affordability; • Technical feasibility.

				5	A	2017-01-24 11:05 PM

Another important document at the time was the Operational Concept Description (OCD), which had the following main objectives:
• Elicit requirements for the KAT-7 Telescope; • Serve as a high-level plan for the KAT-7 Telescope operations; • Validate the achievement of the technical KAT-7 goals, which were listed in KAT-7’s System Engineering Management Plan (SEMP).

				6	A	2017-01-24 11:07 PM

Figure 4 illustrates the architecture design process, showing how the architecture driving
requirements lead to a list of requirements for each subsystem (Halligan 2008). An example of this process is shown in Figure 5, which has been extracted from the Architecture Design document, and which shows various views of the analogue part of the KAT-7 signal path.

				7	A	2017-01-24 11:11 PM

During the integration process, emergent behaviour is verified at each system level.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				8	A	2017-01-24 11:13 PM

V-Diagram emphasises a requirements-driven design and
rigorous testing. The traceability of lower-level requirements to system-level requirements is important, as this ensures that nothing is done unnecessarily, and that everything necessary is done. Furthermore, all requirements are verified by corresponding acceptance tests.

				9	A	2017-01-24 11:19 PM

The integration lab in Cape Town was used extensively for acceptance testing of
integrated subsystem items.

				10	A	2017-01-24 11:22 PM

With KAT-7 entering the utilisation life cycle stage, the emphasis is currently shifting to
the Logistic Support Functions (refer to Figure 7), which are performed by supplies, facilities, support & test equipment, as well as on all the data that is needed to support the system, such as maintenance manuals, training manuals, datasheets, etc. The logistic support system was planned from the inception of KAT-7, and managed throughout the acquisition stages according to a Logistic Engineering Management Plan (LEMP).

Internals\\SE role approach & history

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0978	8			
				1	A	2017-01-26 09:46 PM

Project Planning
Tailoring the SE process for the project Defining major project activities and milestones

				2	A	2017-01-26 09:47 PM

Engineering Process Quality Ensuring a sufficient level of SE process quality throughout the project

				3	A	2017-01-26 09:48 PM

System Design
Interpreting user requirements and translating them to system spec Designing the system architecture and deriving subsystem specs

				4	A	2017-01-26 09:49 PM

System Integration Integration between subsystems (lab and site)
Integrated system testing

				5	A	2017-01-26 09:52 PM

Development approachFocused, phased

				6	A	2017-01-26 09:54 PM

Product life cycle

				7	A	2017-01-26 10:00 PM

Concept: •The concept can still carry options for sufficiently “isolated” components •BUT, “integrative” components must be fixed (e.g. receptor). • Major cost driving specs must be fixed. • Major science driving specs must be fixed. • Major architecture driving specs must be fixed.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				8	A	2017-01-26 10:01 PM

Stage 2: Product Engineering - -
Engineering culture Concept baseline:
One budget-costed concept which acceptably meets user requirements
- More formal processes - - - - -
Input
Getting the basics right: • Requirements traceability • Baselines with reviews • Qualification • Integration management
Concept exploration
User system engineering System engineering Subsystem engineering Component engineering
Integration & verification
Production / Implementation
Engineering design
Commissioning Operation
Time
Co-located engineering team Project management
System engineering management Configuration management
Procurement & contract management Quality management
Qualification Production

Nodes\\Processes\Architecting

PDF

Internals\\MeerKAT Concept Options and Tradeoffs Rev1 sanitisedB_001

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0017	2			
				1	A	2017-01-25 12:24 AM
				2	A	2017-01-25 12:28 AM

Internals\\MeerKAT SEMP Rev1

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0140	3			
				1	A	2017-01-23 12:53 AM

2.3.1. Concept Definition
The purpose of concept definition is to identify one or more architecture options which will satisfy the requirements and to trade off these options to decide on a preferred architecture, which can then be developed in more detail.
The concept definition is driven by the higher level requirements, but the concept (and viability of the concept) also may influence the requirements. There is usually an iterative interaction between developing the higher level requirement and developing a viable concept. However, the concept should only be baselined after the higher level requirement has been baselined.
Concept Definition shall only be compulsory for the system (level 5). It is recommended that this stage also be applied in other items (segments/subsystems) where a divergent range of technologies are available to satisfy the requirements, and where convergence of the concept is needed in order to meet project timescales.
The output of the concept definition phase is a concept design document, which captures the architecture tradeoffs, a chosen architecture, with rationale for the choice, and traceability to requirements. The concept is reviewed formally in the Concept Design Review (CoDR).
For the system (level 5), the CoDR can only be closed after the user requirements baseline has been established and after the concept (with associated time and budget implications) has been approved by the steering committee.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				2	A	2017-01-23 12:58 AM

2.3.3. Preliminary design
The purpose of the preliminary design stage is to define the "solution" (HOW will the requirements be achieved): a) To describe a functional and physical architecture that will meet all requirements.

				3	A	2017-01-23 12:59 AM

Architecture design is performed at all levels. A system engineer shall be made responsible for each item to be responsible for this activity.
The architecture is derived from the requirements, and the described architecture shall demonstrate how all requirements will be achieved. In other words, there shall be clear traceability between requirements (problem) and architecture design (solution).
The recommended method for architecture design is described in [4], and should be applied after appropriate training. This method describes a structured and iterative approach for designing a complete and coherent functional and physical architecture, while ensuring that all requirements are met. This process typically results in multiple possible architectures, each with its advantages and disadvantages. In such cases a trade-off study shall be performed to decide which of the alternative solutions will best meet the requirements.

Internals\\Richard Lord

No		0.0062	1			
				1	A	2017-01-24 11:07 PM

Figure 4 illustrates the architecture design process, showing how the architecture driving
requirements lead to a list of requirements for each subsystem (Halligan 2008). An example of this process is shown in Figure 5, which has been extracted from the Architecture Design document, and which shows various views of the analogue part of the KAT-7 signal path.

Internals\\SE role approach & history

No		0.0094	1			
				1	A	2017-01-26 09:48 PM

System Design
Interpreting user requirements and translating them to system spec Designing the system architecture and deriving subsystem specs

Nodes\\Processes\Integration

PDF

Internals\\MeerKAT SEMP Rev1

No		0.0009	1			
				1	A	2017-01-23 11:38 PM

ICDs will be rigorously reviewed and requests for changes (e.g. changing names of messages or inverting logic) to ensure consistency across the system should be expected.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On

Internals\\Richard Lord

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0033	2			
				1	A	2017-01-24 11:11 PM

During the integration process, emergent behaviour is verified at each system level.

				2	A	2017-01-24 11:19 PM

The integration lab in Cape Town was used extensively for acceptance testing of integrated subsystem items.

Internals\\SE role approach & history

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0060	1			
				1	A	2017-01-26 09:49 PM

System Integration Integration between subsystems (lab and site)
Integrated system testing

Nodes\\Processes\Problem Definition

PDF

Internals\\Richard Lord

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0098	2			
				1	A	2017-01-24 11:02 PM

This investigation limited, among other parameters, the frequency band and array configuration, based on the following considerations:
• Scientific capability; • Affordability; • Technical feasibility.

				2	A	2017-01-24 11:05 PM

Another important document at the time was the Operational Concept Description (OCD), which had the following main objectives:
• Elicit requirements for the KAT-7 Telescope; • Serve as a high-level plan for the KAT-7 Telescope operations; • Validate the achievement of the technical KAT-7 goals, which were listed in KAT-7's System Engineering Management Plan (SEMP).

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On

Internals\\SE role approach & history

No		0.0184	1			
				1	A	2017-01-26 10:00 PM

Concept: •The concept can still carry options for sufficiently "isolated" components •BUT, "integrative" components must be fixed (e.g. receptor). • Major cost driving specs must be fixed. • Major science driving specs must be fixed. • Major architecture driving specs must be fixed.

Nodes\\Processes\Process Activities

PDF

Internals\\MeerKAT Concept Options and Tradeoffs Rev1 sanitisedB_001

No		0.0010	1			
				1	A	2017-01-25 12:35 AM

Internals\\MeerKAT SE Overview - Rev2

No		0.0323	4			
				1	A	2017-01-26 10:12 PM

Integrated Logistics Support

				2	A	2017-01-26 10:14 PM

Processes & tools:
-SE management -Specification -Design -Qualification -Integration
-Log Eng managment -Project management -Quality management -Config managment -Procurement -Contracting -Production management -Commissioning -Operations

				3	A	2017-01-26 10:18 PM

				4	A	2017-01-26 10:20 PM

Antenna production schedule: 62 dishes over 2 years (Oct 2014àSept 2016 = ~500 work days) = production rate of 8 working days per Receptor

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On

Internals\\MeerKAT SEMP Rev1

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0017	1			
				1	A	2017-01-23 11:25 PM

The purpose of the change management procedure is to ensure: a) That the change is needed.
b) That the change is properly assessed and does not adversely affect the project. c) That the change, if accepted, is communicated to all affected parties. d) That the change, if accepted, is followed through to its completion.

Internals\\Richard Lord

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0146	2			
				1	A	2017-01-24 11:13 PM

V-Diagram emphasises a requirements-driven design and
rigorous testing. The traceability of lower-level requirements to system-level requirements is important, as this ensures that nothing is done unnecessarily, and that everything necessary is done. Furthermore, all requirements are verified by corresponding acceptance tests.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				2	A	2017-01-24 11:22 PM

With KAT-7 entering the utilisation life cycle stage, the emphasis is currently shifting to
the Logistic Support Functions (refer to Figure 7), which are performed by supplies, facilities, support & test equipment, as well as on all the data that is needed to support the system, such as maintenance manuals, training manuals, datasheets, etc. The logistic support system was planned from the inception of KAT-7, and managed throughout the acquisition stages according to a Logistic Engineering Management Plan (LEMP).

Internals\\SE role approach & history

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0574	4			
				1	A	2017-01-26 09:46 PM

Project Planning
Tailoring the SE process for the project Defining major project activities and milestones

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				2	A	2017-01-26 09:52 PM

Development approachFocused, phased

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				3	A	2017-01-26 09:54 PM

Product life cycle

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				4	A	2017-01-26 10:01 PM

Stage 2: Product Engineering - -
Engineering culture Concept baseline:
One budget-costed concept which acceptably meets user requirements
- More formal processes - - - - -
Input
Getting the basics right: • Requirements traceability • Baselines with reviews • Qualification • Integration management
Concept exploration
User system engineering System engineering Subsystem engineering Component engineering
Integration & verification
Production / Implementation
Engineering design
Commissioning Operation
Time
Co-located engineering team Project management
System engineering management Configuration management
Procurement & contract management Quality management
Qualification Production

Nodes\\Processes\Process outputs

PDF

Internals\\MeerKAT SE Overview - Rev2

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0062	1			
				1	A	2017-01-26 10:20 PM

Antenna production schedule: 62 dishes over 2 years (Oct 2014àSept 2016 = ~500 work days) = production rate of 8 working days per Receptor

Internals\\MeerKAT SEMP Rev1

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0033	2			
				1	A	2017-01-23 12:55 AM

The output of the definition stage is a complete set of well-defined and validated requirements captured in the requirements specification document, which forms part of the requirements baseline. The requirements shall be reviewed formally at the Requirements Review (RR), involving all relevant stakeholders.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				2	A	2017-01-23 01:00 AM

The outputs of the preliminary design activity are: a) A single chosen architecture, with a rationale for the choice.
b) A functional (where applicable) and physical architecture description, captured in the design document (DD).
17 May 2010
c) A set of allocated and validated requirements for lower level items*

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On

Internals\\SE role approach & history

No		0.0065	1			
				1	A	2017-01-26 09:47 PM

Engineering Process Quality Ensuring a sufficient level of SE process quality throughout the project

Nodes\\Processes\Process quality

PDF

Internals\\MeerKAT SE Overview - Rev2

No		0.0164	2			
				1	A	2017-01-26 10:14 PM

Processes & tools:
-SE management -Specification -Design -Qualification -Integration
-Log Eng managment -Project management -Quality management -Config managment -Procurement -Contracting -Production management -Commissioning -Operations

				2	A	2017-01-26 10:18 PM

Metrics to quantify process quality:
1. Baseline control 2. Requirements control 3. Interface control 4. Change control

Internals\\SE role approach & history

No		0.0065	1			
				1	A	2017-01-26 09:47 PM

Engineering Process Quality Ensuring a sufficient level of SE process quality throughout the project

Nodes\\Processes\Requirements Analysis

Document

Internals\\Interview Transcript - SKA System Engineer

No		0.0773	4			
				1	A	2017-01-23 11:55 PM

So the reason there, its you know a 20 Kelvin system temperature system, so if you can save 1 Kelvin noise temperature you can basically get five percent saving on your total project cost, you basically save millions of Rands just by improving your receiver temperature one Kelvin.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				2	A	2017-01-24 12:00 AM

Obviously our clients are the scientists mainly and our stakeholders are funding stakeholders and science stakeholders.

				3	A	2017-01-24 12:04 AM

The second big set of interactions is with the scientists, so there to get the requirements pinned down. So there we had very good connections to Justin Jonas who is our project scientist and he had contacts with the international community and what we did early in the project is we advertised the Meerkat capability to say these are the technical capabilities the system will have. We asked for proposals for science for scientists to use it. They generated proposals and that created a very clear set of stakeholders so those key science projects are our stakeholders and we elicited all the requirements through them and checked everything with them, the user requirements.

				4	A	2017-01-24 12:26 AM

So for each sub-system is customized, what are the key risks for that sub-system and how those key risks are addressed in the development process. And we approved that plan as part of the requirements review.

PDF

Internals\\MeerKAT Concept Options and Tradeoffs Rev1 sanitisedB_001

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0038	3			
				1	A	2017-01-25 12:35 AM
				2	A	2017-01-25 12:28 AM
				3	A	2017-01-25 12:31 AM

Internals\\MeerKAT SEMP Rev1

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0201	6			
				1	A	2017-01-23 12:54 AM

2.3.2. Requirements Definition
The purpose of this stage is to define the “problem” (WHAT is required). The aim is to capture and validate a complete, unambiguous and traceable set of requirements for an item, so that there is no misunderstanding between different stakeholders as to what is required.
This part of the process is extremely important and forms the basis for all further development work. Problems downstream are often a symptom of neglect in the requirements definition.
Requirements definition is performed at all levels. A system engineer shall be appointed for each item to be responsible for this activity.

				2	A	2017-01-23 01:08 AM

2.9.3. Requirements traceability
Requirements traceability shall be performed throughout the system engineering process as shown in Figure 2. All requirements of an item shall be traceable to: a) Higher-level requirements. b) Architecture design in the design document. c) Lower-level requirements. d) Qualification results. e) Acceptance test procedures and results.

				3	A	2017-01-23 11:19 PM

Requirements traceability shall be presented and reviewed at each of the reviews described in the previous paragraphs up to and including the final product baseline.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				4	A	2017-01-23 11:37 PM

2.11. Safety
The operation of the MeerKAT Telescope system shall comply with the requirements of the Occupational Health and Safety Act, 1993 and its regulations.
In order to achieve this requirement, a Hazards or Safety Analysis shall be performed. This analysis shall be performed during the Preliminary Design and Detail Design stages at both Segment and Subsystem level so that required design influence can be achieved. A standardised format shall be made available and used for the safety analysis and operational hazards report, and shall be based on the standard presented in [7].
A final Operational Hazards report for each Segment and Subsystem shall be supplied as part of the As-Built documentation for these items.
Failure Mode and Effects Analysis shall be performed to identify product safety and reliability aspects. This shall be done as part of the Integrated Logistic Support activities (see Section 2.10).

				5	A	2017-01-23 11:43 PM

4.1.1. Phase 1: Requirements definition
A supplier will only deliver what he/she is asked to deliver – if you are not sure what you want delivered, you will get just that. That means • Make sure you fully understand the requirements and their origin. • Ensure that the requirements are complete and accurate.
• Provide the supplier with a list of validated requirements, i.e. do not over specify a requirement with the intention to relax it later because there has not been sufficient work done to ensure the requirement is validated.
• Ensure the requirements are stable and if not, indicate the direction into which they are likely to change, by how much and by when. The supplier will state a date after which it will be too late to incorporate the change in requirement without attracting considerable cost and/or schedule impact.
• Ensure that each requirement supports 100% the higher level system requirement e.g. if the higher level system requires a stable temperature of one of its components of 25deg C then the system which ensures this must be specified as such including all effects of losses associated with the physical architecture.
• All parameters have tolerances i.e. in the real world there is no such thing as 25deg C/150mm/1.5mm RMS..... all these requirements shall be stated with a tolerance e.g. 25 deg C +/- 1 deg C, 150mm +/-0.1mm.
• Leave no room for misinterpretation – as it will happen
• Requirements must always be “atomic”/or “granular” i.e. a single requirement which is uniquely verifiable.

				6	A	2017-01-23 11:45 PM

The Means of Showing Compliance against each requirement must be recorded as one of the following:
• Test • Analysis • Similarity • Review

Internals\\Richard Lord

No		0.0303	5			
				1	A	2017-01-24 10:07 PM

Another major objective was to establish the Integrated Logistic Support (ILS) system for the KAT-7 Telescope, which will also be used for MeerKAT, and which can also be expanded to support other telescope systems within the radio astronomy reserve.

				2	A	2017-01-24 10:09 PM

Ever-changing user requirements.
Originally, the “KAT” telescope consisted of 20
antennas, and the main objective of building a telescope was to support South Africa’s bid to host the Square Kilometre Array (SKA). After a further injection of money by the government (the SKA SA project is funded by the Department of Science and Technology (DST), and is administered by the National Research Foundation (NRF)), the scope of the project was expanded to build MeerKAT, which is envisioned to become a world-class radio telescope in its own right.

				3	A	2017-01-24 11:01 PM

The life of KAT-7 did not start with a formal User Requirement Statement (URS), because the “users” of the system (at that time) were also the engineering team who designed it. Instead, during 2007, the scope and development strategy of MeerKAT were investigated

				4	A	2017-01-24 11:05 PM

Another important document at the time was the Operational Concept Description (OCD), which had the following main objectives:
• Elicit requirements for the KAT-7 Telescope; • Serve as a high-level plan for the KAT-7 Telescope operations; • Validate the achievement of the technical KAT-7 goals, which were listed in KAT-7’s System Engineering Management Plan (SEMP).

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				5	A	2017-01-24 11:13 PM

V-Diagram emphasises a requirements-driven design and
rigorous testing. The traceability of lower-level requirements to system-level requirements is important, as this ensures that nothing is done unnecessarily, and that everything necessary is done. Furthermore, all requirements are verified by corresponding acceptance tests.

Internals\\SE role approach & history

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0094	1			
				1	A	2017-01-26 09:48 PM

System Design
Interpreting user requirements and translating them to system spec Designing the system architecture and deriving subsystem specs

Nodes\\Project Context

Document

Internals\\Interview Transcript - SKA System Engineer

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
Yes		0.1660	11			
				1	A	2017-01-23 11:54 PM

T: There's two specific areas I can think of, the one is, the whole project is about performance and costs so to build the most sensitive radio telescope for the limited budget you have. So the two key areas are first of all the sensitivity that's on the receiver, getting the low noise and the receiver going.

				2	A	2017-01-23 11:54 PM

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				3	A	2017-01-23 11:56 PM

So the one innovative area is the receiver technology and there's been some innovations to get the receiver noise temperature as low as possible and I think the other big area that we facing is the data rates because there's huge data rates coming out of the system that we have to process so the on the front end it's a few terabits per second of data coming in so it's a high data rate and we've developed in house signal processing boards and those were developed in house in collaboration with University of Berkley in the US and they have been so I think those are the two big innovative areas I can think of that we have been working on.

				4	A	2017-01-23 11:56 PM

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				5	A	2017-01-23 11:58 PM

is organizational because we started this project from scratch without any people so we had to grow the organization along with growing the technology and growing the processes. Karoo in the middle of nowhere and its, you know, there's nothing, it was basically sheep farms so we had to establish everything from scratch, from infrastructure and up to everything.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				6	A	2017-01-23 11:58 PM

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				7	A	2017-01-24 12:32 AM

So we had to look at each of those disciplines and see what the best way to get that technology up is and running as quickly as possible. For each different technology it worked out slightly differently so for some of them, like for software we decided to do everything in house, we decided we can get good software people and get them up and running quite quickly. For some sub-systems like the dish structures, the mechanical systems we decided to contract that out to an industry player because it would be difficult to build up that capability in a short period of time.

				8	A	2017-01-24 12:32 AM

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				9	A	2017-01-24 12:40 AM

think there are multiple stakeholders, the SKA project is administered inside as a sub section of the National Research Foundation so the NRF is part of our larger organization structure but also extending to the Department of Science and Technology so we have a lot of direct interaction with them. I think they were very supportive of financial and stakeholder support. I think sometimes we struggle, some of our issues are administrative. Initially the NRF, it is not an organization designed to do large acquisitions, it is designed to manage research and grants so we did have some problems early on to get these processes going where we can do large acquisitions within that organization but that's an example of the challenge we had but it has been improving but besides that we had very good support from the stakeholder, political and financial perspectives.

				10	A	2017-01-24 12:40 AM

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PDF

Internals\\Marias Botha

Yes		0.0318	11			
				1	A	2017-01-24 11:30 PM

In the field of radio-astronomy, there is a general goal to maximise the sensitivity of the radio telescope, in order to detect the faintest possible signals. Simplified, a radio telescope can be seen to consist of one or more receptors, each in turn consisting of a reflector, a receiver, and a data processing subsystem. The primary function of the reflector is to focus the incoming electro-magnetic radiation onto the receiver. The primary function of the receiver is to, without adding undue noise, amplify the focussed signal from the reflector to measurable levels (through several stages of RF amplification) and provide it to the data processing subsystem (which will not be dealt with further here).

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				2	A	2017-01-24 11:30 PM

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				3	A	2017-01-24 11:31 PM

Working at cryogenic temperatures present a number of design challenges.

				4	A	2017-01-24 11:31 PM

Working at cryogenic temperatures present a number of design challenges.

				5	A	2017-01-24 11:31 PM

KAT-7 is a science and engineering prototype radio telescope array, consisting of seven receptors situated alongside the proposed SKA core site (SKA South Africa a)

				6	A	2017-01-24 11:31 PM

KAT-7 is a science and engineering prototype radio telescope array, consisting of seven receptors situated alongside the proposed SKA core site (SKA South Africa a)

				7	A	2017-01-24 11:37 PM

It will consist of 64 linked receptors, each with three (possibly four) receivers in different frequency bands, and will be the largest and most sensitive radio telescope in the southern hemisphere, until the advent of the SKA (SKA South Africa b).

				8	A	2017-01-24 11:37 PM

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				9	A	2017-01-24 11:37 PM

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				10	A	2017-01-24 11:41 PM

MeerKAT is to be a fully-fledged scientific
instrument, with a design lifetime of 30 years.

				11	A	2017-01-24 11:41 PM

MeerKAT is to be a fully-fledged scientific
instrument, with a design lifetime of 30 years.

Internals\\MeerKAT SE Overview - Rev2

Yes		0.0170	9			
				1	A	2017-01-26 10:09 PM

Project overview

				2	A	2017-01-26 10:09 PM

Project overview

				3	A	2017-01-26 10:09 PM

Project overview

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				4	A	2017-01-26 10:11 PM

Infrastructure development

				5	A	2017-01-26 10:11 PM

Infrastructure development

				6	A	2017-01-26 10:15 PM

Organisational: -Clear Roles, Responsibilities & Relationships -Common vision -Common approach -Common vocabulary -Capacity / Resouces -Collaborative networks -Industry / contractor relationships

				7	A	2017-01-26 10:15 PM

Organisational: -Clear Roles, Responsibilities & Relationships -Common vision -Common approach -Common vocabulary -Capacity / Resouces -Collaborative networks -Industry / contractor relationships

				8	A	2017-01-26 10:20 PM

Antenna production schedule: 62 dishes over 2 years (Oct 2014àSept 2016 = ~500 work days) = production rate of 8 working days per Receptor

				9	A	2017-01-26 10:20 PM

Antenna production schedule: 62 dishes over 2 years (Oct 2014àSept 2016 = ~500 work days) = production rate of 8 working days per Receptor

Internals\\MeerKAT SEMP Rev1

Yes		0.0088	3			
				1	A	2017-01-23 12:49 AM

2.1. System Levels The various system items (systems, subsystems etc.) can be classified in various system breakdown structure levels, where higher levels imply a higher level of integration. These levels are shown in Table 1 and will be utilised throughout this document.

				2	A	2017-01-16 11:29 PM

The preliminary MeerKAT system breakdown structure is shown in Figure 1, and shows where some of the major items (systems/segments/subsystems) fit into the system levels. The purpose of this diagram is to illustrate how the system will be broken down into system breakdown structure "items". The items demarcate areas of responsibility for project management and system engineering. The system engineering process described in this document applies to each one of the items in the system breakdown structure.
Figure 1 is not complete or final, and will be influenced by the architecture design on level 4 and 5. The authoritative system breakdown structure will be captured in a separate document and should be completed and updated continuously until the system architecture is finalised.
The system breakdown structure shall be finalised soon after the concept design review, so that the system engineering work can proceed with clearly demarcated responsibilities at levels 3 and 4.

Internals\\Richard Lord

Yes		0.0338	18			
				1	A	2017-01-24 10:09 PM

Ever-changing user requirements.
Originally, the "KAT" telescope consisted of 20
antennas, and the main objective of building a telescope was to support South Africa's bid to host the Square Kilometre Array (SKA). After a further injection of money by the government (the SKA SA project is funded by the Department of Science and Technology (DST), and is administered by the National Research Foundation (NRF)), the scope of the project was expanded to build MeerKAT, which is envisioned to become a world-class radio telescope in its own right.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				2	A	2017-01-24 10:09 PM

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				3	A	2017-01-24 10:08 PM

the SKA SA project is funded by the Department of Science and Technology (DST), and is administered by the National Research Foundation (NRF)

				4	A	2017-01-24 10:13 PM

Astronomers and scientists getting involved with engineering solutions, instead of focussing on the science requirements. This highlighted the need for proper requirement elicitation and requirement management.

				5	A	2017-01-24 10:13 PM

Astronomers and scientists getting involved with engineering solutions, instead of focussing on the science requirements. This highlighted the need for proper requirement elicitation and requirement management.

				6	A	2017-01-24 10:14 PM

A geographically dispersed project team. The Infrastructure and Ancillaries team is based in Johannesburg, the Site Operations team is located near Carnarvon, and the Telescope Management and Engineering teams are situated in Cape Town.

				7	A	2017-01-24 10:14 PM

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				8	A	2017-01-24 10:14 PM

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				9	A	2017-01-24 10:14 PM

Challenging Karoo environment. Any system erected in the Karoo must be able to
withstand dust, strong winds, lightning, and large variations in temperature.

				10	A	2017-01-24 10:14 PM

Challenging Karoo environment. Any system erected in the Karoo must be able to
withstand dust, strong winds, lightning, and large variations in temperature.

				11	A	2017-01-24 10:15 PM

Lack of infrastructure in the Karoo. Infrastructure with regard to roads, power, water, sewage, accommodation, maintenance, support and operating facilities, etc., had to be established.

				12	A	2017-01-24 10:15 PM

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				13	A	2017-01-24 10:15 PM

Developing process maturity. As SKA South Africa was a young organisation, its project management and systems engineering processes still had to be created.

				14	A	2017-01-24 10:15 PM

Developing process maturity. As SKA South Africa was a young organisation, its project management and systems engineering processes still had to be created.

				15	A	2017-01-24 10:18 PM

Lack of user domain experience. The Systems Engineering team had little experience in radio astronomy and in building radio telescopes.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				16	A	2017-01-24 10:18 PM

Lack of user domain experience. The Systems Engineering team had little experience in radio astronomy and in building radio telescopes.

				17	A	2017-01-24 11:15 PM

It then followed that there
were no detailed design reviews, and ultimately no proper Installation ATPs. Wherever the lack of systems engineering processes was evident, problems took a long time to repair, were costly, and caused unnecessary downtime. These are therefore valuable lessons that can be carried forward to MeerKAT.

				18	A	2017-01-24 11:15 PM

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Internals\\SE role approach & history

Yes		0.0078	1

Nodes\\Project Context\Development Environment

Document

Internals\\Interview Transcript - SKA System Engineer

No		0.0522	1

				1	A	2017-01-24 12:40 AM

think there are multiple stakeholders, the SKA project is administered inside as a sub section of the National Research Foundation so the NRF is part of our larger organization structure but also extending to the Department of Science and Technology so we have a lot of direct interaction with them. I think they were very supportive of financial and stakeholder support. I think sometimes we struggle, some of our issues are administrative. Initially the NRF, it is not an organization designed to do large acquisitions, it is designed to manage research and grants so we did have some problems early on to get these processes going where we can do large acquisitions within that organization but that's an example of the challenge we had but it has been improving but besides that we had very good support from the stakeholder, political and financial perspectives.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On

PDF

Internals\\MeerKAT SE Overview - Rev2

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0107	3			
				1	A	2017-01-26 10:09 PM

Project overview

				2	A	2017-01-26 10:11 PM

Infrastructure development

				3	A	2017-01-26 10:15 PM

Organisational: -Clear Roles, Responsibilities & Relationships -Common vision -Common approach -Common vocabulary -Capacity / Resouces - Collaborative networks -Industry / contractor relationships

Internals\\Richard Lord

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0083	3			
				1	A	2017-01-24 10:08 PM

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				2	A	2017-01-24 10:14 PM

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				3	A	2017-01-24 10:15 PM

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Nodes\\Project Context\Project Challanges

Document

Internals\\Interview Transcript - SKA System Engineer

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.1086	3			
				1	A	2017-01-23 11:58 PM

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Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				2	A	2017-01-24 12:32 AM

So we had to look at each of those disciplines and see what the best way to get that technology up is and running as quickly as possible. For each different technology it worked out slightly differently so for some of them, like for software we decided to do everything in house, we decided we can get good software people and get them up and running quite quickly. For some sub-systems like the dish structures, the mechanical systems we decided to contract that out to an industry player because it would be difficult to build up that capability in a short period of time.

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PDF

Internals\\Marias Botha

No		0.0017	1			
				1	A	2017-01-24 11:31 PM

Working at cryogenic temperatures present a number of design challenges.

Internals\\Richard Lord

No		0.0279	6			
				1	A	2017-01-24 10:09 PM

Ever-changing user requirements.
Originally, the "KAT" telescope consisted of 20
antennas, and the main objective of building a telescope was to support South Africa's bid to host the Square Kilometre Array (SKA). After a further injection of money by the government (the SKA SA project is funded by the Department of Science and Technology (DST), and is administered by the National Research Foundation (NRF)), the scope of the project was expanded to build MeerKAT, which is envisioned to become a world-class radio telescope in its own right.

				2	A	2017-01-24 10:13 PM

Astronomers and scientists getting involved with engineering solutions, instead of focussing on the science requirements. This highlighted the need for proper requirement elicitation and requirement management.

				3	A	2017-01-24 10:14 PM

A geographically dispersed project team. The Infrastructure and Ancillaries team is based in Johannesburg, the Site Operations team is located near Carnarvon, and the Telescope Management and Engineering teams are situated in Cape Town.

				4	A	2017-01-24 10:15 PM

Developing process maturity. As SKA South Africa was a young organisation, its project management and systems engineering processes still had to be created.

				5	A	2017-01-24 10:18 PM

Lack of user domain experience. The Systems Engineering team had little experience in radio astronomy and in building radio telescopes.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				6	A	2017-01-24 11:15 PM

It then followed that there
were no detailed design reviews, and ultimately no proper Installation ATPs. Wherever the lack of systems engineering processes was evident, problems took a long time to repair, were costly, and caused unnecessary downtime. These are therefore valuable lessons that can be carried forward to MeerKAT.

Nodes\\Project Context\Project Innovation

Document

Internals\\Interview Transcript - SKA System Engineer

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0573	2			
				1	A	2017-01-23 11:54 PM

T: There's two specific areas I can think of, the one is, the whole project is about performance and costs so to build the most sensitive radio telescope for the limited budget you have. So the two key areas are first of all the sensitivity that's on the receiver, getting the low noise and the receiver going.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				2	A	2017-01-23 11:56 PM

So the one innovative area is the receiver technology and there's been some innovations to get the receiver noise temperature as low as possible and I think the other big area that we facing is the data rates because there's huge data rates coming out of the system that we have to process so the on the front end it's a few terabits per second of data coming in so it's a high data rate and we've developed in house signal processing boards and those were developed in house in collaboration with University of Berkley in the US and they have been so I think those are the two big innovative areas I can think of that we have been working on.

PDF

Internals\\Marias Botha

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0061	1			
				1	A	2017-01-24 11:37 PM

It will consist of 64 linked receptors, each with three (possibly four) receivers in different frequency bands, and will be the largest and most sensitive radio telescope in the southern hemisphere, until the advent of the SKA (SKA South Africa b).

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On

Nodes\\Project Context\Project Timeline

PDF

Internals\\MeerKAT SE Overview - Rev2

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0062	1			
				1	A	2017-01-26 10:20 PM

Antenna production schedule: 62 dishes over 2 years (Oct 2014àSept 2016 = ~500 work days) = production rate of 8 working days per Receptor

Internals\\SE role approach & history

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0078	1			
				1	A	2017-01-26 10:04 PM

Nodes\\Project Context\System Description

PDF

Internals\\Marias Botha

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0301	4			
				1	A	2017-01-24 11:30 PM

In the field of radio-astronomy, there is a general goal to maximise the sensitivity of the radio telescope, in order to detect the faintest possible signals. Simplified, a radio telescope can be seen to consist of one or more receptors, each in turn consisting of a reflector, a receiver, and a data processing subsystem. The primary function of the reflector is to focus the incoming electro-magnetic radiation onto the receiver. The primary function of the receiver is to, without adding undue noise, amplify the focussed signal from the reflector to measurable levels (through several stages of RF amplification) and provide it to the data processing subsystem (which will not be dealt with further here).

Reference Number	Coded By Initials	Modified On
2	A	2017-01-24 11:31 PM

KAT-7 is a science and engineering prototype radio telescope array, consisting of seven receptors situated alongside the proposed SKA core site (SKA South Africa a)

Reference Number	Coded By Initials	Modified On
3	A	2017-01-24 11:37 PM

It will consist of 64 linked receptors, each with three (possibly four) receivers in different frequency bands, and will be the largest and most sensitive radio telescope in the southern hemisphere, until the advent of the SKA (SKA South Africa b).

Reference Number	Coded By Initials	Modified On
4	A	2017-01-24 11:41 PM

MeerKAT is to be a fully-fledged scientific instrument, with a design lifetime of 30 years.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On

Internals\\MeerKAT SE Overview - Rev2

No		0.0007	1			
				1	A	2017-01-26 10:09 PM

Project overview

Internals\\MeerKAT SEMP Rev1

No		0.0088	3			
				1	A	2017-01-23 12:49 AM

2.1. System Levels The various system items (systems, subsystems etc.) can be classified in various system breakdown structure levels, where higher levels imply a higher level of integration. These levels are shown in Table 1 and will be utilised throughout this document.

				2	A	2017-01-16 11:29 PM

The preliminary MeerKAT system breakdown structure is shown in Figure 1, and shows where some of the major items (systems/segments/subsystems) fit into the system levels. The purpose of this diagram is to illustrate how the system will be broken down into system breakdown structure “items”. The items demarcate areas of responsibility for project management and system engineering. The system engineering process described in this document applies to each one of the items in the system breakdown structure.
Figure 1 is not complete or final, and will be influenced by the architecture design on level 4 and 5. The authoritative system breakdown structure will be captured in a separate document and should be completed and updated continuously until the system architecture is finalised.
The system breakdown structure shall be finalised soon after the concept design review, so that the system engineering work can proceed with clearly demarcated responsibilities at levels 3 and 4.

				3	A	2017-01-16 11:29 PM

Internals\\Richard Lord

No		0.0040	1			
				1	A	2017-01-24 10:14 PM

A geographically dispersed project team. The Infrastructure and Ancillaries team is based in Johannesburg, the Site Operations team is located near Carnarvon, and the Telescope Management and Engineering teams are situated in Cape Town.

Nodes\\Technical Management

Document

Internals\\Interview Transcript - SKA System Engineer

No		0.1973	7			
				1	A	2017-01-24 12:05 AM

No we didn’t not on Meerkat project. On Meerkat it was a very, you know I think we didn’t manage it formally or measure technology maturity formally it was informal.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				2	A	2017-01-24 12:07 AM

The South African Team specifically, had a very clear strategy to take on technologies that are low risk and can be implemented in the short time scales for Meerkat. So we didn't have formal evaluation metrics for technology maturity but a very conscious technique for example the feed technologies we went for standard you know octave band horn feeds which are mature technology and we knew exactly what we were going to expect. But for the SKA project they are employing metrics for technology maturity but those are defined and they are going to do an assessment of technology maturity at the preliminary design phase. But its quite difficult to measure quantitatively, its often judgement call.

				3	A	2017-01-24 12:08 AM

I think, as I said it was definitely very important part of the decision making but we didn't do it as I said explicitly we did it very subjectively. We looked at the different technologies and we said and we grouped them as sort of mature technologies and not mature technologies and we said we were going to go for the mature technologies.

				4	A	2017-01-24 12:26 AM

Yeah, there was a lot of tailoring for sub-systems. What we realized early on because we got such a wide range of technologies is that we needed to customize the process for each sub-system. So we put in an initial proposal in the back of our SEMP with tailored diagrams but eventually what we did is we asked each sub-system as part of their requirements review to write a development plan and that development plan basically says exactly how customized the systems engineering approach is for that sub-system. So for each sub-system is customized, what are the key risks for that sub-system and how those key risks are addressed in the development process. And we approved that plan as part of the requirements review.

				5	A	2017-01-24 12:32 AM

So we had to look at each of those disciplines and see what the best way to get that technology up is and running as quickly as possible. For each different technology it worked out slightly differently so for some of them, like for software we decided to do everything in house, we decided we can get good software people and get them up and running quite quickly. For some sub-systems like the dish structures, the mechanical systems we decided to contract that out to an industry player because it would be difficult to build up that capability in a short period of time.

				6	A	2017-01-24 12:33 AM

some cases for the electromagnetics and the receivers we contracted the whole thing out to EMSS who is a technology partner for us. For the infrastructure we also had a project management and system engineering internally and we contracted out the rest. So it was a mixture depending on how quickly and also it depends on long term for a radio observatory some skills you need in house and some you don't. So we decided we only going to appoint teams of people where we need that capability long term in house, so system engineering, project management, software are basically the areas.

				7	A	2017-01-24 12:34 AM

Yeah that's very important, if we didn't do that you would be in big trouble. You need the same core team taking it from concept right through to operations otherwise you going to get trouble.

PDF

Internals\\Marias Botha

No		0.0538	4			
				1	A	2017-01-24 11:34 PM

This allowed the evaluation of technologies not previously used for this application, at a lower risk.

				2	A	2017-01-24 11:36 PM

Because the purpose of KAT-7 was primarily to learn (often about problems that are unknown beforehand) it can be said to have had a "design for R&D" development philosophy. This was characterised by a system-level functional analysis that extended to relatively low- level subsystems, which in turn was developed separately, and often independently, from each other, in an effort to minimise technical risk.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				3	A	2017-01-24 11:43 PM

Based on lessons learnt since 1943, their development strategy stresses that the use of new technology or newly developed pieces of equipment, should be limited, as it invariably adversely affects the cost, schedule and risk of a project. New technologies and equipment must “buy” their way into a design, yielding either substantial performance gain, or proving that the requirements cannot be met without it (Nicolai, 1997).

				4	A	2017-01-24 11:47 PM

It was shown that many of the challenges experienced on KAT-7 resulted from the
• • •
“fragmented development” strategy. In order to minimise these challenges right from the planning stage, the strategy for the MeerKAT receiver was rather chosen to be one of “consolidated development”, whereby all the receiver functions, from reception of the signal from the reflector to delivering the amplified signal to the data-processing subsystem, is to be handled by a single functional entity, labelled the “Receiver”. This includes all the control and monitoring functions that are necessary to ensure its proper operation and signal any problems. Crucially, as opposed to the solution for KAT-7, the development of the complete receiver system is the responsibility of only one subcontractor. This has the major advantages of limiting the receiver system’s external interfaces to clean “enabling interfaces” (i.e. mechanical / power / data / environmental) simplifying their management, whilst keeping the “operational interfaces” (between the different functions / parts of the receiver system) internal to the system. In this manner their interactions can be more intimately designed, and closely monitored during the development process.

Internals\\MeerKAT Concept Options and Tradeoffs Rev1 sanitisedB_001

No		0.0017	1			
				1	A	2017-01-25 12:21 AM

Internals\\MeerKAT SE Overview - Rev2

No		0.0805	9			
				1	A	2017-01-26 10:08 PM

Development responsibility of the “System Team” Specification, design, integration and verification of these items 9 full-time System Engineers

				2	A	2017-01-26 10:09 PM

7 System Engineers residing in other groups within our organisation

				3	A	2017-01-26 10:11 PM

Infrastructure development

				4	A	2017-01-26 10:12 PM

Integrated Logistics Support

				5	A	2017-01-26 10:12 PM

Experienced individuals (system and subsystem): -Application know-how (requirement) -Technology know-how (solution) -Costing know-how -Time to completion know-how

				6	A	2017-01-26 10:15 PM

Organisational: -Clear Roles, Responsibilities & Relationships -Common vision -Common approach -Common vocabulary -Capacity / Resouces -Collaborative networks -Industry / contractor relationships

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				7	A	2017-01-26 10:14 PM

Processes & tools:
-SE management -Specification -Design -Qualification -Integration
-Log Eng managment -Project management -Quality management -Config managment -Procurement -Contracting -Production management -Commissioning -Operations

				8	A	2017-01-26 10:16 PM

Purpose: Define scope of the project: - Technical capability (from driving science requirements) - Cost (budget) - Timescale (project plan)
In order to achieve this we had to do the down-selection of options: - Array configuration - Dish: - Diameter & number of dishes - Configuration (prime focus vs offset; feed-high vs feed-low)
- Receivers: - Bandwidth (2:1 vs 4:1) - Cooling (ambient / Stirling / GM)
- Digitisation location (on antenna or at array processor) - Array processor location (on-site of off-site) - Correlator concept and cost model - Science processor concept - Infrastructure options

				9	A	2017-01-26 10:18 PM

Internals\\MeerKAT SEMP Rev1

No		0.0261	6			
				1	A	2017-01-23 01:05 AM

2.4. Baselines
Throughout the development stages, the MeerKAT configuration will be described and captured in a series of technical baselines. These baselines will be applicable to all Level 4 and Level 3 development activities and will typically follow the conclusion of the system engineering stages as described in the previous section.
The following baselines are required:
• Requirements baseline (RBL) – Established after completion of requirements definition stage.
• Design baseline (DBL) – Established after completion of the preliminary design stage.
• Qualification baseline (QBL) - Established after completion of the detail design stage, and is used as baseline for production.
• Product baseline (PBL) – Established after completion of the implementation stage. The baseline will be captured in the “as-built” documentation.

				2	A	2017-01-23 01:06 AM

2.5.1. Review Process Reviews of documents, especially those requiring the participation of external parties, shall be accomplished via an Observation Action Register (OAR) process as follows:
a) A review panel is agreed between author, applicable project manager and system engineer, and also with the higher-level project manager and higher-level system engineer.
b) The draft documents are distributed by the author or configuration manager to key internal stakeholders defined in (a) for high level review aimed primarily at the identification of gaps and deficiencies, and to determine whether the documentation is ready for review.
c) If the go-ahead is given for the review (by the group defined in (a)), a notice of the review is sent to all reviewers, and the author confirms the review date and participation.
d) Documents under review and an OAR template are distributed to reviewers by the configuration manager. The distributor shall ensure that reviewers have access to applicable and reference documents.
e) Completed OAR’s are received from each reviewer.
f) The author compiles a Consolidated OAR (COAR) and drafts responses for each observation.
g) The author distributes the completed COAR to all reviewers at least two days before the meeting.
h) During the review meeting only the observations without resolution (i.e. actions which are not obvious and require discussion among the review panel) are discussed. The review may also be accompanied by overview presentations.
i) The COAR is updated during the review to reflect the decisions/agreements made during the review on the unresolved issues.
j) Following the review, the author updates the document(s) according to the COAR (as updated during the review meeting).
k) The author verifies that all agreed to actions as recorded in the COAR have been completed by indicating this on the COAR.
l) The author releases the updated document(s) for sign-off. The signed documents and final COAR are submitted to configuration management.
Wherever possible international/independent reviewers/experts should be approached and included in reviews.

				3	A	2017-01-23 11:24 PM

Any change to an agreed baseline or signed off document shall be executed by means of a change management procedure described in the Configuration Management Plan [2].

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				4	A	2017-01-23 11:25 PM

The purpose of the change management procedure is to ensure: a) That the change is needed.
b) That the change is properly assessed and does not adversely affect the project. c) That the change, if accepted, is communicated to all affected parties. d) That the change, if accepted, is followed through to its completion.

				5	A	2017-01-23 11:35 PM

2.9.5. Baseline management
All baselines described in this document (see Section 2.4) shall be managed according to the baseline management principles described in the Configuration Management Plan [2]. A baseline is achieved after closure of the formal review (as described in Section 2.3).

				6	A	2017-01-23 11:40 PM

Internals\\Richard Lord

No		0.0705	10			
				1	A	2017-01-24 10:07 PM

Another major objective was to establish the Integrated Logistic Support (ILS) system for the KAT-7 Telescope, which will also be used for MeerKAT, and which can also be expanded to support other telescope systems within the radio astronomy reserve.

				2	A	2017-01-24 10:18 PM

Lack of user domain experience. The Systems Engineering team had little experience in radio astronomy and in building radio telescopes.

				3	A	2017-01-24 10:21 PM

Non-existence of enabling systems, including operators and maintainers, once KAT-7 entered the Utilisation and Support life cycle stages.

				4	A	2017-01-24 10:41 PM

In order to reduce both the project management risks as well as the technical risks, a
number of development models were utilised:

				5	A	2017-01-24 10:59 PM

PED
The Phased Experimental Demonstrator (PED) was a 6-antenna interferometric radio telescope, constructed on the grounds of the South African Astronomical Observatory (SAAO) in Cape Town. It provided the engineering team with an experimental platform to learn about interferometry, and it is now used by students as an outreach facility.
XDM
At the end of 2007, the Experimental Development Model (XDM) was completed at the Hartebeesthoek Radio Astronomy Observatory (HartRAO). XDM is a single-antenna radio telescope with a diameter of 15m.
Apart from addressing many technical risks, the
acquisition of the XDM was instrumental in building a coherent engineering team and in growing the systems engineering maturity of the organisation to at least Level 3, according to the Capability Maturity Model (Kossiakoff et al. 2011). It must be added that the systems engineering maturity has never been quantitatively verified, by measuring technical processes such as requirements stability, ECP change duration, number of TBDs, etc.
KAT-7 KAT-7 was developed immediately after the completion of the XDM. Tight timelines
demanded that most of the project resources had to be concentrated on the design of KAT-7, perhaps to the detriment of maximising the learning that could have been extracted from the XDM.
This paper regards KAT-7 as the Engineering Development Model (EDM) for MeerKAT, because it was meant to qualify the MeerKAT design, and to determine the suitability of the design with regard to reliability, maintainability, availability and logistic supportability, while being operational in the MeerKAT environment. It could even be regarded as the Preproduction Model, since it was intended to completely evaluate form, fit and performance for MeerKAT. However, since the commissioning work on KAT-7 has started, the MeerKAT design has undergone significant changes, and therefore, strictly speaking, KAT-7 can no longer be regarded as a Preproduction Model, or as an EDM, for MeerKAT. It nevertheless continues to perform an important risk-reduction function, since it helps to build the logistic support systems that are required for MeerKAT.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				6	A	2017-01-24 11:01 PM

The life of KAT-7 did not start with a formal User Requirement Statement (URS), because the “users” of the system (at that time) were also the engineering team who designed it. Instead, during 2007, the scope and development strategy of MeerKAT were investigated

				7	A	2017-01-24 11:02 PM

Nevertheless, a considerable effort had gone into the concept definition and exploration phase, in order to develop an instrument that will be as close as possible to the final MeerKAT design.

				8	A	2017-01-24 11:11 PM

One of the most fundamental systems development models adopted at the SKA South Africa organisation is encapsulated in the engineering V-Diagram,

				9	A	2017-01-24 11:13 PM

V-Diagram emphasises a requirements-driven design and
rigorous testing. The traceability of lower-level requirements to system-level requirements is important, as this ensures that nothing is done unnecessarily, and that everything necessary is done. Furthermore, all requirements are verified by corresponding acceptance tests.

				10	A	2017-01-24 11:15 PM

It then followed that there
were no detailed design reviews, and ultimately no proper Installation ATPs. Wherever the lack of systems engineering processes was evident, problems took a long time to repair, were costly, and caused unnecessary downtime. These are therefore valuable lessons that can be carried forward to MeerKAT.

Internals\\SE role approach & history

No		0.0883	9			
				1	A	2017-01-26 09:46 PM

Project Planning
Tailoring the SE process for the project Defining major project activities and milestones

				2	A	2017-01-26 09:47 PM

Engineering Process Quality Ensuring a sufficient level of SE process quality throughout the project

				3	A	2017-01-26 09:48 PM

System Design
Interpreting user requirements and translating them to system spec Designing the system architecture and deriving subsystem specs

				4	A	2017-01-26 09:49 PM

System Integration Integration between subsystems (lab and site)
Integrated system testing

				5	A	2017-01-26 09:52 PM

Development approachFocused, phased

				6	A	2017-01-26 09:53 PM

Organisational maturity

				7	A	2017-01-26 09:54 PM

Product life cycle

				8	A	2017-01-26 09:59 PM

Stages influence: • Organisational culture • Organisational structures • Organisational process (incl. SE process)

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				9	A	2017-01-26 10:01 PM

Stage 2: Product Engineering - -
Engineering culture Concept baseline:
One budget-costed concept which acceptably meets user requirements
- More formal processes - - - - -
Input
Getting the basics right: • Requirements traceability • Baselines with reviews • Qualification • Integration management
Concept exploration
User system engineering System engineering Subsystem engineering Component engineering
Integration & verification
Production / Implementation
Engineering design
Commissioning Operation
Time
Co-located engineering team Project management
System engineering management Configuration management
Procurement & contract management Quality management
Qualification Production

Nodes\\Technical Management\Planning

Document

Internals\\Interview Transcript - SKA System Engineer

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0433	1			
				1	A	2017-01-24 12:26 AM

Yeah, there was a lot of tailoring for sub-systems. What we realized early on because we got such a wide range of technologies is that we needed to customize the process for each sub-system. So we put in an initial proposal in the back of our SEMP with tailored diagrams but eventually what we did is we asked each sub-system as part of their requirements review to write a development plan and that development plan basically says exactly how customized the systems engineering approach is for that sub-system. So for each sub-system is customized, what are the key risks for that sub-system and how those key risks are addressed in the development process. And we approved that plan as part of the requirements review.

PDF

Internals\\Marias Botha

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0037	1			
				1	A	2017-01-24 11:43 PM

new technology or newly developed pieces of equipment, should be limited, as it invariably adversely affects the cost, schedule and risk of a project.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On

Internals\\MeerKAT SE Overview - Rev2

No		0.0548	5			

1	A	2017-01-26 10:11 PM

Infrastructure development

2	A	2017-01-26 10:12 PM

Integrated Logistics Support

3	A	2017-01-26 10:14 PM

Processes & tools:
-SE management -Specification -Design -Qualification -Integration
-Log Eng managment -Project management -Quality management -Config managment -Procurement -Contracting -Production management -Commissioning -Operations

4	A	2017-01-26 10:16 PM

Purpose: Define scope of the project: - Technical capability (from driving science requirements) - Cost (budget) - Timescale (project plan)
In order to achieve this we had to do the down-selection of options: - Array configuration - Dish: - Diameter & number of dishes - Configuration (prime focus vs offset; feed-high vs feed-low)
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- Digitisation location (on antenna or at array processor) - Array processor location (on-site of off-site) - Correlator concept and cost model - Science processor concept - Infrastructure options

5	A	2017-01-26 10:18 PM

Internals\\MeerKAT SEMP Rev1

No		0.0348	8			

1	A	2017-01-23 12:53 AM

2.3.1. Concept Definition
The purpose of concept definition is to identify one or more architecture options which will satisfy the requirements and to trade off these options to decide on a preferred architecture, which can then be developed in more detail.
The concept definition is driven by the higher level requirements, but the concept (and viability of the concept) also may influence the requirements. There is usually an iterative interaction between developing the higher level requirement and developing a viable concept. However, the concept should only be baselined after the higher level requirement has been baselined.
Concept Definition shall only be compulsory for the system (level 5). It is recommended that this stage also be applied in other items (segments/subsystems) where a divergent range of technologies are available to satisfy the requirements, and where convergence of the concept is needed in order to meet project timescales.
The output of the concept definition phase is a concept design document, which captures the architecture tradeoffs, a chosen architecture, with rationale for the choice, and traceability to requirements. The concept is reviewed formally in the Concept Design Review (CoDR).
For the system (level 5), the CoDR can only be closed after the user requirements baseline has been established and after the concept (with associated time and budget implications) has been approved by the steering committee.

2	A	2017-01-23 01:05 AM

2.4. Baselines
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The following baselines are required:
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• Qualification baseline (QBL) - Established after completion of the detail design stage, and is used as baseline for production.
• Product baseline (PBL) – Established after completion of the implementation stage. The baseline will be captured in the "as-built" documentation.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				3	A	2017-01-23 01:06 AM

2.5.1. Review Process Reviews of documents, especially those requiring the participation of external parties, shall be accomplished via an Observation Action Register (OAR) process as follows:
a) A review panel is agreed between author, applicable project manager and system engineer, and also with the higher-level project manager and higher-level system engineer.
b) The draft documents are distributed by the author or configuration manager to key internal stakeholders defined in (a) for high level review aimed primarily at the identification of gaps and deficiencies, and to determine whether the documentation is ready for review.
c) If the go-ahead is given for the review (by the group defined in (a)), a notice of the review is sent to all reviewers, and the author confirms the review date and participation.
d) Documents under review and an OAR template are distributed to reviewers by the configuration manager. The distributor shall ensure that reviewers have access to applicable and reference documents.
e) Completed OAR's are received from each reviewer.
f) The author compiles a Consolidated OAR (COAR) and drafts responses for each observation.
g) The author distributes the completed COAR to all reviewers at least two days before the meeting.
h) During the review meeting only the observations without resolution (i.e. actions which are not obvious and require discussion among the review panel) are discussed. The review may also be accompanied by overview presentations.
i) The COAR is updated during the review to reflect the decisions/agreements made during the review on the unresolved issues.
j) Following the review, the author updates the document(s) according to the COAR (as updated during the review meeting).
k) The author verifies that all agreed to actions as recorded in the COAR have been completed by indicating this on the COAR.
l) The author releases the updated document(s) for sign-off. The signed documents and final COAR are submitted to configuration management.
Wherever possible international/independent reviewers/experts should be approached and included in reviews.

				4	A	2017-01-23 11:19 PM

Requirements traceability shall be presented and reviewed at each of the reviews described in the previous paragraphs up to and including the final product baseline.

				5	A	2017-01-23 11:24 PM

Any change to an agreed baseline or signed off document shall be executed by means of a change management procedure described in the Configuration Management Plan [2].

				6	A	2017-01-23 11:25 PM

The purpose of the change management procedure is to ensure: a) That the change is needed.
b) That the change is properly assessed and does not adversely affect the project. c) That the change, if accepted, is communicated to all affected parties. d) That the change, if accepted, is followed through to its completion.

				7	A	2017-01-23 11:35 PM

2.9.5. Baseline management
All baselines described in this document (see Section 2.4) shall be managed according to the baseline management principles described in the Configuration Management Plan [2]. A baseline is achieved after closure of the formal review (as described in Section 2.3).

				8	A	2017-01-23 11:40 PM

Internals\\Richard Lord

No		0.0076	2			
				1	A	2017-01-24 10:07 PM

Another major objective was to establish the Integrated Logistic Support (ILS) system for the KAT-7 Telescope, which will also be used for MeerKAT, and which can also be expanded to support other telescope systems within the radio astronomy reserve.

				2	A	2017-01-24 11:02 PM

Nevertheless, a considerable effort had gone into the concept definition and exploration phase, in order to develop an instrument that will be as close as possible to the final MeerKAT design.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On

Internals\\SE role approach & history

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0156	3			
				1	A	2017-01-26 09:46 PM

Project Planning
Tailoring the SE process for the project Defining major project activities and milestones

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				2	A	2017-01-26 09:54 PM

Product life cycle

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				3	A	2017-01-26 09:59 PM

Stages influence: • Organisational culture • Organisational structures • Organisational process (incl. SE process)

Nodes\\Technical Management\Process sequencing

PDF

Internals\\MeerKAT SE Overview - Rev2

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0163	3			
				1	A	2017-01-26 10:11 PM

Infrastructure development

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				2	A	2017-01-26 10:12 PM

Integrated Logistics Support

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				3	A	2017-01-26 10:18 PM

Internals\\MeerKAT SEMP Rev1

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0059	1			
				1	A	2017-01-23 11:40 PM

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On

Internals\\Richard Lord

No		0.0056	1			
				1	A	2017-01-24 11:13 PM

V-Diagram emphasises a requirements-driven design and
rigorous testing. The traceability of lower-level requirements to system-level requirements is important, as this ensures that nothing is done unnecessarily, and that everything necessary is done. Furthermore, all requirements are verified by corresponding acceptance tests.

Internals\\SE role approach & history

No		0.0480	2			
				1	A	2017-01-26 09:54 PM

Product life cycle

				2	A	2017-01-26 10:01 PM

Stage 2: Product Engineering - -
Engineering culture Concept baseline:
One budget-costed concept which acceptably meets user requirements
- More formal processes - - - - -
Input
Getting the basics right: • Requirements traceability • Baselines with reviews • Qualification • Integration management
Concept exploration
User system engineering System engineering Subsystem engineering Component engineering
Integration & verification
Production / Implementation
Engineering design
Commissioning Operation
Time
Co-located engineering team Project management
System engineering management Configuration management
Procurement & contract management Quality management
Qualification Production

Nodes\\Technical Management\Project team

Document

Internals\\Interview Transcript - SKA System Engineer

No		0.0815	3			
				1	A	2017-01-24 12:32 AM

So we had to look at each of those disciplines and see what the best way to get that technology up is and running as quickly as possible. For each different technology it worked out slightly differently so for some of them, like for software we decided to do everything in house, we decided we can get good software people and get them up and running quite quickly. For some sub-systems like the dish structures, the mechanical systems we decided to contract that out to an industry player because it would be difficult to build up that capability in a short period of time.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				2	A	2017-01-24 12:33 AM

some cases for the electromagnetics and the receivers we contracted the whole thing out to EMSS who is a technology partner for us. For the infrastructure we also had a project management and system engineering internally and we contracted out the rest. So it was a mixture depending on how quickly and also it depends on long term for a radio observatory some skills you need in house and some you don't. So we decided we only going to appoint teams of people where we need that capability long term in house, so system engineering, project management, software are basically the areas.

				3	A	2017-01-24 12:34 AM

Yeah that's very important, if we didn't do that you would be in big trouble. You need the same core team taking it from concept right through to operations otherwise you going to get trouble.

PDF

Internals\\MeerKAT SE Overview - Rev2

No		0.0257	4			
				1	A	2017-01-26 10:08 PM

Development responsibility of the "System Team" Specification, design, integration and verification of these items 9 full-time System Engineers

				2	A	2017-01-26 10:09 PM

7 System Engineers residing in other groups within our organisation

				3	A	2017-01-26 10:12 PM

Experienced individuals (system and subsystem): -Application know-how (requirement) -Technology know-how (solution) -Costing know-how -Time to completion know-how

				4	A	2017-01-26 10:15 PM

Organisational: -Clear Roles, Responsibilities & Relationships -Common vision -Common approach -Common vocabulary -Capacity / Resouces -Collaborative networks -Industry / contractor relationships

Internals\\MeerKAT SEMP Rev1

No		0.0038	1			
				1	A	2017-01-23 12:50 AM

2.2.2. Technical responsibilities
The role of system engineer shall be appointed to a single person for each item in the breakdown for levels 3, 4 and 5. The person appointed in the role shall be responsible to fulfil the system engineering process requirements set out in this document, and shall be the single point of contact. One person may assume this responsibility for multiple items.
The system breakdown structure shown in Figure 1 determines the technical lines of responsibility. For example, the system engineer of a Segment shall approve all documentation for the Subsystems of the Segment.
ICDs shall be approved by the system engineers from both interfacing items as well as the higher level system engineer.

Internals\\Richard Lord

No		0.0096	3			
				1	A	2017-01-24 10:18 PM

Lack of user domain experience. The Systems Engineering team had little experience in radio astronomy and in building radio telescopes.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				2	A	2017-01-24 10:21 PM

Non-existence of enabling systems, including operators and maintainers, once KAT-7 entered the Utilisation and Support life cycle stages.

				3	A	2017-01-24 10:54 PM

Apart from addressing many technical risks, the
acquisition of the XDM was instrumental in building a coherent engineering team and in growing the systems engineering maturity of the organisation to at least Level 3, according to the Capability Maturity Model (Kossiakoff et al. 2011).

Internals\\SE role approach & history

No		0.0234	4			
				1	A	2017-01-26 09:47 PM

Engineering Process Quality Ensuring a sufficient level of SE process quality throughout the project

				2	A	2017-01-26 09:48 PM

System Design
Interpreting user requirements and translating them to system spec Designing the system architecture and deriving subsystem specs

				3	A	2017-01-26 09:49 PM

System Integration Integration between subsystems (lab and site)
Integrated system testing

				4	A	2017-01-26 09:53 PM

Organisational maturity

Nodes\\Technical Management\Risk Management

PDF

Internals\\Marias Botha

No		0.0163	3			
				1	A	2017-01-24 11:34 PM

This allowed the evaluation of technologies not previously used for this application, at a lower risk.

				2	A	2017-01-24 11:36 PM

Because the purpose of KAT-7 was primarily to learn (often about problems that are unknown beforehand) it can be said to have had a “design for R&D” development philosophy. This was characterised by a system-level functional analysis that extended to relatively low- level subsystems, which in turn was developed separately, and often independently, from each other, in an effort to minimise technical risk.

				3	A	2017-01-24 11:43 PM

new technology or newly developed pieces of equipment, should be limited, as it invariably adversely affects the cost, schedule and risk of a project.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On

Internals\\MeerKAT Concept Options and Tradeoffs Rev1 sanitisedB_001

No		0.0017	1			
				1	A	2017-01-25 12:21 AM

Internals\\Richard Lord

No		0.0454	3			
				1	A	2017-01-24 10:41 PM

In order to reduce both the project management risks as well as the technical risks, a number of development models were utilised:

				2	A	2017-01-24 10:59 PM

PED
The Phased Experimental Demonstrator (PED) was a 6-antenna interferometric radio telescope, constructed on the grounds of the South African Astronomical Observatory (SAAO) in Cape Town. It provided the engineering team with an experimental platform to learn about interferometry, and it is now used by students as an outreach facility.
XDM
At the end of 2007, the Experimental Development Model (XDM) was completed at the Hartebeesthoek Radio Astronomy Observatory (HartRAO). XDM is a single-antenna radio telescope with a diameter of 15m.
Apart from addressing many technical risks, the
acquisition of the XDM was instrumental in building a coherent engineering team and in growing the systems engineering maturity of the organisation to at least Level 3, according to the Capability Maturity Model (Kossiakoff et al. 2011). It must be added that the systems engineering maturity has never been quantitatively verified, by measuring technical processes such as requirements stability, ECP change duration, number of TBDs, etc.
KAT-7 KAT-7 was developed immediately after the completion of the XDM. Tight timelines
demanded that most of the project resources had to be concentrated on the design of KAT-7, perhaps to the detriment of maximising the learning that could have been extracted from the XDM.
This paper regards KAT-7 as the Engineering Development Model (EDM) for MeerKAT, because it was meant to qualify the MeerKAT design, and to determine the suitability of the design with regard to reliability, maintainability, availability and logistic supportability, while being operational in the MeerKAT environment. It could even be regarded as the Preproduction Model, since it was intended to completely evaluate form, fit and performance for MeerKAT. However, since the commissioning work on KAT-7 has started, the MeerKAT design has undergone significant changes, and therefore, strictly speaking, KAT-7 can no longer be regarded as a Preproduction Model, or as an EDM, for MeerKAT. It nevertheless continues to perform an important risk-reduction function, since it helps to build the logistic support systems that are required for MeerKAT.

				3	A	2017-01-24 11:15 PM

It then followed that there
were no detailed design reviews, and ultimately no proper Installation ATPs. Wherever the lack of systems engineering processes was evident, problems took a long time to repair, were costly, and caused unnecessary downtime. These are therefore valuable lessons that can be carried forward to MeerKAT.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On

Internals\\SE role approach & history

No		0.0022	1			
				1	A	2017-01-26 09:52 PM

Development approachFocused, phased

Nodes\\Technical Management\Technical Development Strategy

PDF

Internals\\Marias Botha

No		0.0407	2			
				1	A	2017-01-24 11:36 PM

Because the purpose of KAT-7 was primarily to learn (often about problems that are unknown beforehand) it can be said to have had a “design for R&D” development philosophy. This was characterised by a system-level functional analysis that extended to relatively low- level subsystems, which in turn was developed separately, and often independently, from each other, in an effort to minimise technical risk.

				2	A	2017-01-24 11:47 PM

It was shown that many of the challenges experienced on KAT-7 resulted from the
• • •
“fragmented development” strategy. In order to minimise these challenges right from the planning stage, the strategy for the MeerKAT receiver was rather chosen to be one of “consolidated development”, whereby all the receiver functions, from reception of the signal from the reflector to delivering the amplified signal to the data-processing subsystem, is to be handled by a single functional entity, labelled the “Receiver”. This includes all the control and monitoring functions that are necessary to ensure its proper operation and signal any problems. Crucially, as opposed to the solution for KAT-7, the development of the complete receiver system is the responsibility of only one subcontractor. This has the major advantages of limiting the receiver system’s external interfaces to clean “enabling interfaces” (i.e. mechanical / power / data / environmental) simplifying their management, whilst keeping the “operational interfaces” (between the different functions / parts of the receiver system) internal to the system. In this manner their interactions can be more intimately designed, and closely monitored during the development process.

Internals\\MeerKAT SE Overview - Rev2

No		0.0138	1			
				1	A	2017-01-26 10:18 PM

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On

Internals\\Richard Lord

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0502	4			
				1	A	2017-01-24 10:43 PM

PED
The Phased Experimental Demonstrator (PED) was a 6-antenna interferometric radio telescope, constructed on the grounds of the South African Astronomical Observatory (SAAO) in Cape Town. It provided the engineering team with an experimental platform to learn about interferometry, and it is now used by students as an outreach facility.
XDM
At the end of 2007, the Experimental Development Model (XDM) was completed at the Hartebeesthoek Radio Astronomy Observatory (HartRAO). XDM is a single-antenna radio telescope with a diameter of 15m.
Apart from addressing many technical risks, the
acquisition of the XDM was instrumental in building a coherent engineering team and in growing the systems engineering maturity of the organisation to at least Level 3, according to the Capability Maturity Model (Kossiakoff et al. 2011). It must be added that the systems engineering maturity has never been quantitatively verified, by measuring technical processes such as requirements stability, ECP change duration, number of TBDs, etc.
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This paper regards KAT-7 as the Engineering Development Model (EDM) for MeerKAT, because it was meant to qualify the MeerKAT design, and to determine the suitability of the design with regard to reliability, maintainability, availability and logistic supportability, while being operational in the MeerKAT environment. It could even be regarded as the Preproduction Model, since it was intended to completely evaluate form, fit and performance for MeerKAT. However, since the commissioning work on KAT-7 has started, the MeerKAT design has undergone significant changes, and therefore, strictly speaking, KAT-7 can no longer be regarded as a Preproduction Model, or as an EDM, for MeerKAT. It nevertheless continues to perform an important risk-reduction function, since it helps to build the logistic support systems that are required for MeerKAT.

				2	A	2017-01-24 11:01 PM

The life of KAT-7 did not start with a formal User Requirement Statement (URS), because the “users” of the system (at that time) were also the engineering team who designed it. Instead, during 2007, the scope and development strategy of MeerKAT were investigated

				3	A	2017-01-24 11:11 PM

One of the most fundamental systems development models adopted at the SKA South Africa organisation is encapsulated in the engineering V-Diagram,

				4	A	2017-01-24 11:13 PM

V-Diagram emphasises a requirements-driven design and
rigorous testing. The traceability of lower-level requirements to system-level requirements is important, as this ensures that nothing is done unnecessarily, and that everything necessary is done. Furthermore, all requirements are verified by corresponding acceptance tests.

Internals\\SE role approach & history

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.0491	2			
				1	A	2017-01-26 09:52 PM

Development approachFocused, phased

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
				2	A	2017-01-26 10:01 PM

Stage 2: Product Engineering - -
Engineering culture Concept baseline:
One budget-costed concept which acceptably meets user requirements
- More formal processes - - - - -
Input
Getting the basics right: • Requirements traceability • Baselines with reviews • Qualification • Integration management
Concept exploration
User system engineering System engineering Subsystem engineering Component engineering
Integration & verification
Production / Implementation
Engineering design
Commissioning Operation
Time
Co-located engineering team Project management
System engineering management Configuration management
Procurement & contract management Quality management
Qualification Production

Nodes\\Technical Management\Technology maturity assessment

Document

Internals\\Interview Transcript - SKA System Engineer

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On
No		0.1317	4			
				1	A	2017-01-24 12:05 AM

No we didn’t not on Meerkat project. On Meerkat it was a very, you know I think we didn’t manage it formally or measure technology maturity formally it was informal.

				2	A	2017-01-24 12:07 AM

The South African Team specifically, had a very clear strategy to take on technologies that are low risk and can be implemented in the short time scales for Meerkat. So we didn’t have formal evaluation metrics for technology maturity but a very conscious technique for example the feed technologies we went for standard you know octave band horn feeds which are mature technology and we knew exactly what we were going to expect. But for the SKA project they are employing metrics for technology maturity but those are defined and they are going to do an assessment of technology maturity at the preliminary design phase. But its quite difficult to measure quantitatively, its often judgement call.

				3	A	2017-01-24 12:08 AM

I think, as I said it was definitely very important part of the decision making but we didn’t do it as I said explicitly we did it very subjectively. We looked at the different technologies and we said and we grouped them as sort of mature technologies and not mature technologies and we said we were going to go for the mature technologies.

				4	A	2017-01-24 12:09 AM

We looked at, because the sensitivity is a key performance driver, we looked at two alternative technologies one is a helium based system which is widely used internationally in radio observatories and then the Sterling system. So we actually went for the Sterling system because it was new, it was a bit of a technology risk we took at that time but we chose it because we saw it as a much lower cost and maintenance, operational and acquisition cost option and we took a conscious risk at that stage and it turned out it wasn’t the best technology to use, it was proven in a different application, its used for space applications and other telecommunication applications. In those other applications it works fine but for radio astronomy applications it turned out not to be such a good solution. So to an extent it was that the maturity of the technology was proven in a different application but it didn’t turn out to be valid for this application. That’s one example I can think of.

Aggregate	Classification	Coverage	Number Of Coding References	Reference Number	Coded By Initials	Modified On

PDF

Internals\\Marias Botha

No		0.0105	1			
				1	A	2017-01-24 11:43 PM

Based on lessons learnt since 1943, their development strategy stresses that the use of new technology or newly developed pieces of equipment, should be limited, as it invariably adversely affects the cost, schedule and risk of a project. New technologies and equipment must “buy” their way into a design, yielding either substantial performance gain, or proving that the requirements cannot be met without it (Nicolai, 1997).