# PDR.11 Preliminary Element Integrated Logistics Support Plan

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## ORGANISATION DETAILS

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# 4 LIST OF ABBREVIATIONS

See SKA-TEL-SDP-0000056 Glossary.

# 5 APPLICABLE DOCUMENTS

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

| Reference Number | Reference |
|---|---|
| [AD01] | SKA.TEL.SDP-0000013 - SKA preliminary SDP architecture and System Description PDR.01 |
| [AD02] | PDR.02.01 Sub-element design: COMP |
| [AD03] | PDR.02.02 Sub-element design: Data Delivery |

| | |
|---|---|
| [AD04] | PDR.02.04 Sub-element design document: LMC |
| [AD05] | PDR.06 Preliminary Software Engineering "Development" Plan (SWE) |
| [AD06] | PDR.08 Preliminary Plan for Construction |
| [AD07] | PDR.01.01 SKA-TEL-SDP-0000014 - ASSUMPTIONS AND NON-CONFORMANCE |
| [AD08] | SKA-TEL-SKO-0000104 - SKA INTEGRATED LOGISTIC SUPPORT PLAN (ILSP) |
| [AD09] | PDR.02.05 Sub-element design document: PIP |

# 6 REFERENCE DOCUMENTS

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

| Reference Number | Reference |
|---|---|
| RD01 | MIL-STD-785, Reliability Program for Systems and Equipment Development and Production, U.S. Department of Defense. See for example http://reliabilityanalytics.com/reliability_engineering_library/Rome_Laboratory_Reliability_Engineers_Toolkit_1993/Rome_Laboratory_Reliability_Engineers_Toolkit_1993_pp_260.htm |
| RD02 | MIL-STD-1629A, Procedures for Performing a Failure Mode, Effects and criticality analysis.<br>See for example http://everyspec.com/MIL-STD/MIL-STD-1600-1699/MIL_STD_1629A_1556/ |
| RD03 | MIL-STD 1388-1A Logistic Support Analysis (LSA) - see ld.hq.nasa.gov/docs/MIL-STD-1388-1A_Logistic_Support_Analysis.pdf |
| RD04 | A Holistic Approach to System Reliability in Blue Gene published in Innovative Architecture for Future Generation High Performance Processors and Systems, 2006 IWIA'06 |
| RD05 | Symmetric Active/Active High Availability for<br>High-Performance Computing System Services<br>JOURNAL OF COMPUTERS, VOL. 1, NO. 8, DECEMBER 2006 |

| | |
|---|---|
| RD06 | Engelmann, C., Ong, H. H., and Scott, S. L. The case for modular redundancy in large-scale high performance computing systems. In Proceedings of the 8th IASTED International Conference on Parallel and<br>Distributed Computing and Networks (PDCN) 2009 (Innsbruck, Austria, Feb. 16-18, 2009), ACTA Press, Calgary, AB, Canada, pp. 189–194. |

# 7 INTRODUCTION

## 7.1 PURPOSE OF THE DOCUMENT

The Preliminary Integrated Logistic Support Plan (ILSP) will help to develop a process supporting the activities for project management, system engineering design and development together with full life-cycle management of the SDP hardware, software and infrastructure. The ILSP should address how the project team shall manage and execute the Logistic Engineering & Support activities for the SDP up to the achievement of the Operational Baseline (OBL). It is used as the principal management tool for the execution, assessment and tracking of the ILS activities. The ILSP will address Support and Maintenance of the SDP once deployed. The aspects of the SDP through factory build and test, acceptance at factory, installation on-site, acceptance on-site are aspects of AIV. The impact of the ILS will be measured in terms of metrics such as reliability, availability, maintainability and testability (RAMT). The process will ultimately include a costing process centred on the life cycle cost and Level of Repair Analysis; engineering process which influences the design via means of reliability, modularisation, and reproducibility; technical documentation publishing process encompassing international specifications and standards where appropriate; and an ordering administration process for supply support.

The ILSP takes into consideration the SKA INTEGRATED LOGISTIC SUPPORT PLAN (ILSP) [AD08] and requirements identified in the section below. The timeline for ILS in the context of the SKA development and operational phases is shown below.

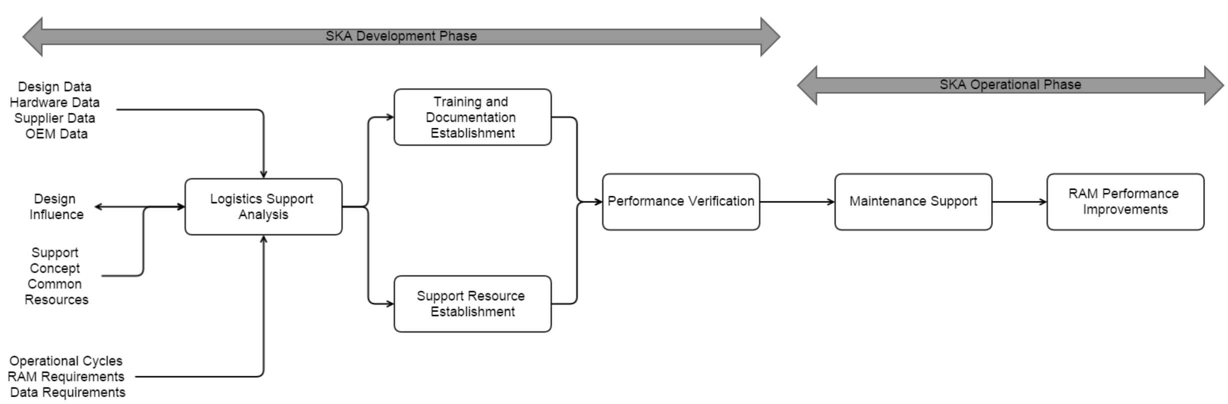


*Figure 1: Context diagram showing ILS Timeline*

## 7.2 Scope of the document

The SKA SDP Architecture [AD01] led to a number of set up principles for the development of the architecture:

- Achieve scalability by exploiting data parallelism. By adopting this as our driving principle it means for example we are willing to allow, for example, data duplication if it maintains scalability via data parallelism.
- Achieve efficiency. This has a direct implication of implying affordability. Here the leading consideration is to maintain data locality, but also implies a strong alignment of software and physical hardware architectures.
- Maintainability. By this we mean that it must be possible for the SKA Observatory to keep running and improve the software as it learns about actual characteristics of the SKA telescopes and as the underlying hardware on which SDP run is refreshed. This is translated into the way we structure the software layer.
- Must support *current* best-practice algorithms used in aperture-synthesis imaging. By this we mean that the architecture must support processing of data in a way which complements precursor and pathfinder experiments. This is to say that the architecture cannot *depend* on future improvements in algorithms used in radio-astronomy, but of course it should be capable of using those if and when these are proven to be useful.

From these underlying principles a preliminary implementation of the architecture was constructed. On the basis of these preliminary aspects this document outlines the Integrated Logistics Support activities which are summarized in the figure below and which will be fully described in the Integrated Logistics Support process.

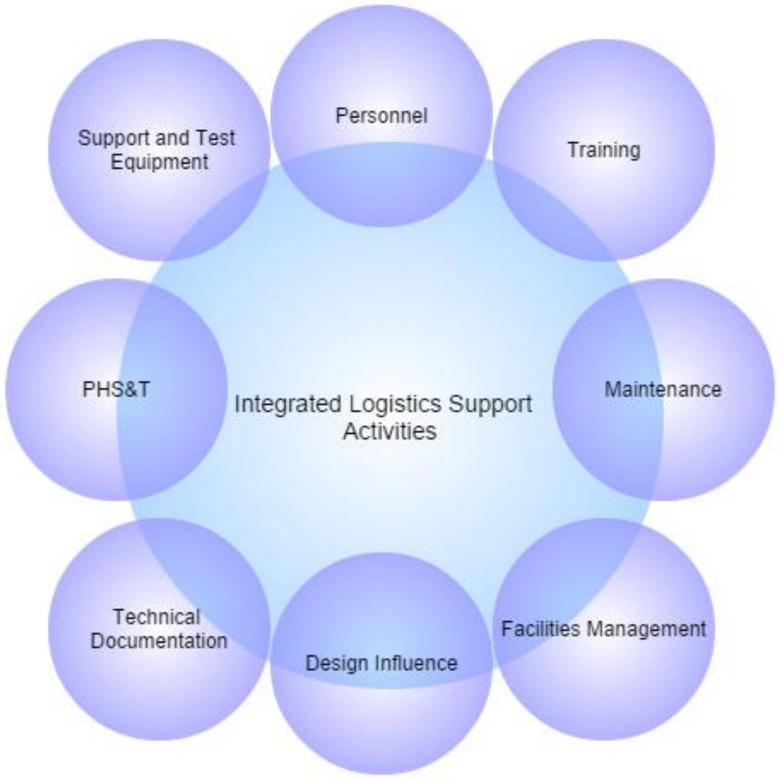


*Figure 2: ILSP Activities*

By the integration of these activities the ILS plans will lead through to a Logistics Support Analysis to develop a final system that is:

- environmentally sound;
- affordable (lowest life cycle cost);
- operable;
- sustainable;
- supportable.

## 7.3 SDP OVERVIEW

Because of the very large number of components in the SDP hardware and the nature of IT systems it is expected that failure of individual components will be an everyday or even continuous event for which redundancy and spares will be necessary and consequently Support and Maintenance be critical. The SDP system will be designed to gracefully handle these failures as far as possible and where appropriate or practical be able to tolerate failures by redundancy. An understanding of the hardware failure modes and rates is therefore extremely important. As the design of the SDP hardware matures, a detailed level-of-repair-analysis will be maintained. This analysis will also lead to requirements on the application and system software for ability to tolerate and recover from a hot-swap replacement of a unit in the SDP.

The rest of this document is structured by an assessment of the activities that will form part of the plan together with an assessment of the Logistics Support Analysis which will be provided in Section 3.

## 7.4 Updating Procedures

The Integrated Logistics Support process and plan will be updated based on:

- Design Reviews
- New project directives from the SKAO
- System configuration changes
- Logistics support changes
- Prior to a system release board

# 8 Logistics Support Activities

The activities comprising the Integrated Logistics Support were introduced in section 1. Below we identify the key aspects and considerations of the process.

## 8.1 Design Influence and Optimisation.

Design influence becomes an iterative process applied during all the design phases and in each of the project tasks. It will be performed by documenting results and providing recommendations emanating from system engineering. These recommendations will be evaluated by the design team for possible changes to the systems design and/or changes to the support system of the SDP. The following logistics-related parameters in the sections below will be applied by the ILS analysis to the design:

### 8.1.1 Product Tree Breakdown

A list of the components and their modularity will be defined together with their level of redundancy and their impact, and level of repair and how they will be replaced. The list of products is defined by the product tree as shown below in Figures 2 and 3 (See for example [AD01]).

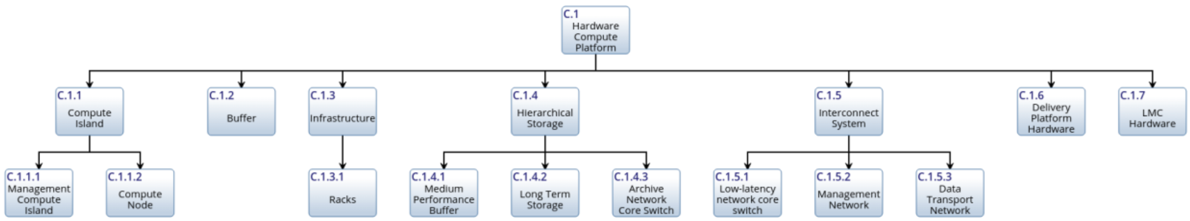


*Figure 3: SDP Hardware compute platform product subtree*

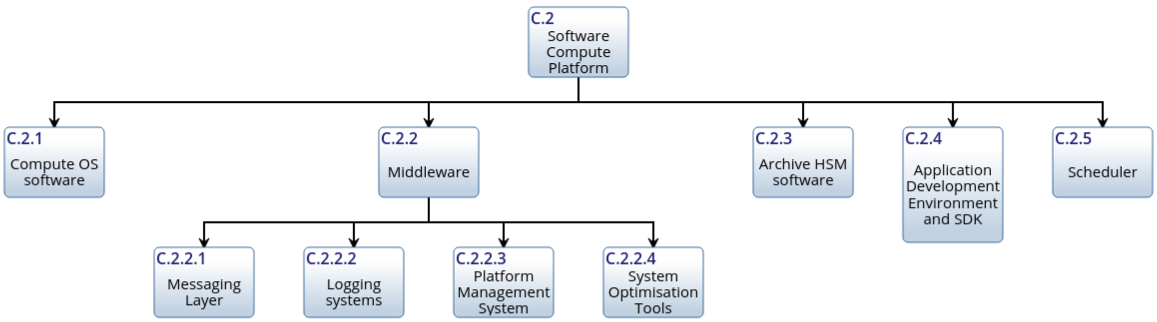


*Figure 4: SDP Software compute platform product subtree*

### 8.1.2 Reliability, Availability and Maintainability (RAM) Figures

An analysis of potential reliability improvements, through active-active and active-passive redundancy and failover will be performed. This will lead to potential maintainability improvements by focusing on accessibility, ease of removal, availability of dedicated support and test equipment.

### 8.1.3 Failure Modes, Effects and Criticality Analysis (FMECA)

Given the inherent nature of the IT systems and the complexity of system and application software, hardware failure detection will be a fundamental aspect of Logistics Support. The analysis will focus on identification of single point failures, critical failures and unacceptable failures. This will lead to the development of both automatic and operator-driven High Availability strategies. Suitable standards to be adopted will be based on MIL-STD-1629a [RD02].

## 8.2 Support Technical Documentation

A list of technical publications will be required in order to correctly and safely operate the SDP element, with minimum time loss. All technical information should be easily understood and followed by users, operators and maintainers using appropriate standards. Such documentation will include:

- Technical manuals;
- Technical whitepapers and supply bulletins;
- Technical and Safety Data Sheets including a Safety Plan considering AIV and Construction;
- Spare parts list;
- Preventive (scheduled and unscheduled) maintenance instructions;
- Corrective maintenance instructions;
- Installation, test, commissioning, acceptance and change management procedures and reports;
- Drawings and part lists;
- Specifications;
- Application and System Software.

## 8.3 Maintenance Planning

Scope of this activity is to:

- Define the actions and all the support aspects necessary to ensure that the SDP attains the specified system readiness objectives with minimum Life Cycle Cost;
- State specific maintenance tasks to be performed on the machine;
- Define levels of replacements, repair, task times, testability requirements, support equipment and automatic test equipment needs, training, manpower skills and facilities;
- Develop the preventive maintenance programme in accordance with observation periods and refine this from experience gained;
- Analyse the proposed work environment on the health and safety of operations team, and define relevant qualifications and/or training requirements as well as safety equipment;
- Minimize the use of hazardous materials and take into account local regulations for disposal methods for hazardous, recyclable and non-recyclable waste.
- Obsolescence Management.

## 8.4 Support Tools and Instrumentation

Scope of this activity is:

- Automatic and Interactive performance measurement tools to assess individual components (e.g. power consumption, performance, reliability, tolerance) and sub-systems. Where possible these should reflect the aspects of the processing pipelines [AD09];
- Equipment for in-situ and ex-situ diagnosis and repair of SDP components (LRU);
- Safety Devices;
- Handling and Lifting Devices.
- Life-Cycle Costs of Support Tools

## 8.5 Support Personnel

As part of this activity it will be necessary to identify personnel with the qualifications and the skills required to operate, maintain and support a large IT facility. Manpower requirements are based on related ILS elements and other considerations. Human factors engineering (HFE) is applied to ensure a good man-machine-environment interface. In addition, to on-site support staff it will be necessary to provide suitable working areas for sub-contractors. Provision for on-site induction training will be covered.

## 8.6 Supply Support

Supply Support will define actions, procedures and techniques necessary to determine requirements to acquire, catalogue, receive, store, transfer, issue and dispose of spare and repair parts, consumables and supplies. This activity will ensure that the right spares, repairs and all classes of supplies are available in the right quantities, at the right place, at the right time and at the optimum cost. The process usually includes provisioning for initial, half-life and entire lifetime support.

During the supply support definition the quantity and location of spares will be determined from the Logistics Support Analysis (LSA) data, in particular from Mean-Time-Between Failure (MTBF) and Mean-Time-To-Repair (MTTR) and anticipated lifetime data. A preliminary analysis will be run to estimate the necessary recovery actions for the system lifetime. The final spare parts quantity is defined during the LSA process also taking into account the experience on similar applications and on the base of additional engineering evaluations and prototyping and including identification to high failure rate parts. The assessment also covers the corrective and preventive maintenance interventions. Early assessment of this will ensure that INFRA has timely access to this information for adequate storage of spares.

## 8.7 Package, Handling Storage and Transportability (PHS&T)

The planning of packing, handling, storage and transportability aspects can have considerable impacts on cost and delivery time. Therefore, customs requirements, air, rail, sea and road transport requirements, container considerations, special movement precautions, mobility and transportation asset impact of the shipping mode will be assessed. In particular:

- system constraints (such as design specifications, item configuration and safety precautions for any hazardous material);
- use of packing materials that are adequate for the intended purpose of transporting;
- design and packaging all components, materials and equipment so that the loads incurred, vehicles and shipping containers used in transportation can negotiate the roads to the storage site;
- geographic and environmental restrictions;
- special security requirements;
- special handling equipment and procedures;
- proper and complete identification labelling of all packaging;
- anticipated timescales through customs, road, etc.

## 8.8 Facilities and Facilities Management

Support and Maintenance considerations with respect to facilities will be considered. In particular:

- loading bays and access;
- geographic and environmental restrictions;
- special security requirements;
- special handling equipment and procedures;
- seismic disturbances;
- weather impacts

# 9 LOGISTICS SUPPORT ANALYSIS (LSA)

A Logistics Support Analysis programme (see for example [RD03]) will be developed to instruct maintenance plans providing input to technical publications, training and system installation and provisioning of the SDP element. Inputs to the LSA will be from the design team, system engineering. These will include:

- System, sub-system and equipment data to define what will be analysed (design data);
- An expected support concept to define how the system could be supported;
- A definition of how the system is expected to be operated;
- LSA data requirements to allow simulation and modelling of the support system;
- Reliability, Availability and Maintainability (RAM) requirements [RD01].

The output of the LSA will be a consolidated definition of the system support requirements to provide the relevant support system. During the LSA process, technical and logistical issues will be fed-back to system engineering and trade-offs will be determined to ensure that the SDP can be supported at the appropriate cost. This will include feedback in-line with the Construction Plan [AD06] and in particular lessons learnt from milli-SDP and centi-SDP. The LSA activities to be performed will be:

- Life-Cycle Cost Analysis
- Maintenance Test Analysis
- Mean-time to Repair Analysis
- Reliability, Availability and Maintainability
- Spare Parts Analysis
- Safety Analysis (EMC, Power, etc.)
- Failure Modes, Effects and Criticality Analysis (FMECA see Figure 5)

These will be updated with reference to the SKA ILSP [AD08]. The process to be conducted is described in the following diagram:

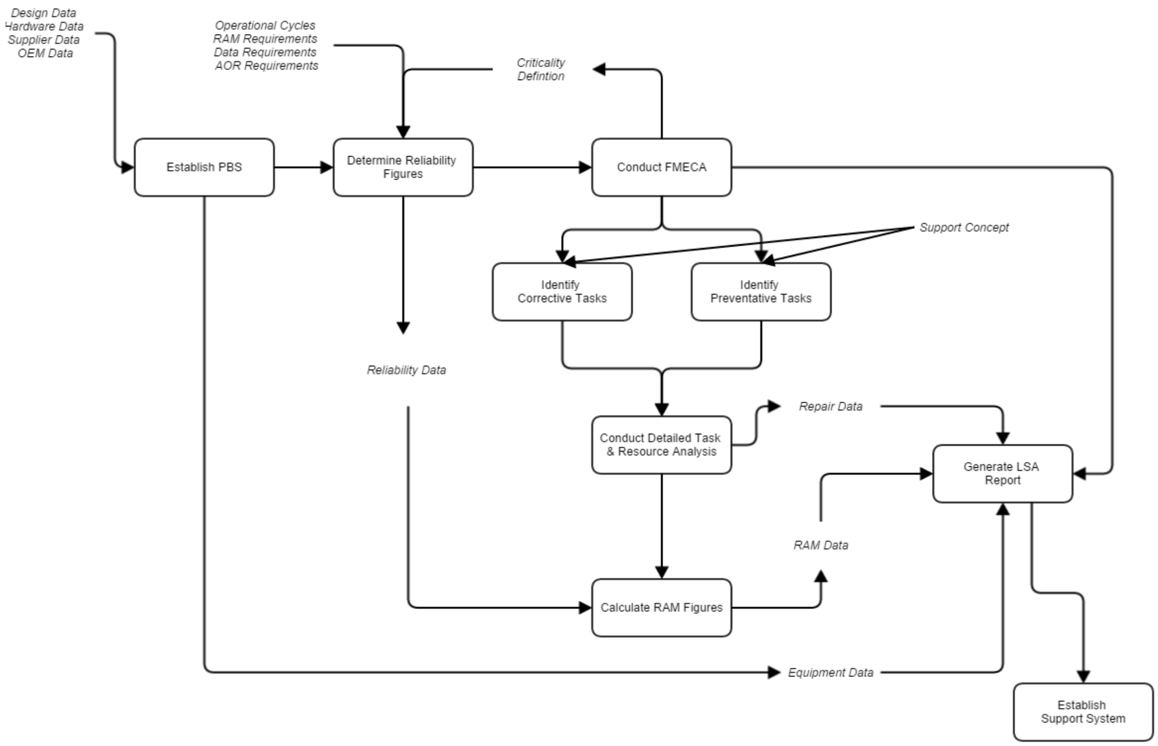


*Figure 5: LSA Process*

## 9.1 Reliability, Availability and Maintainability

The overall availability of the SDP system will be affected by the reliability and maintainability of the system components. In general failures can be summarised as follows:

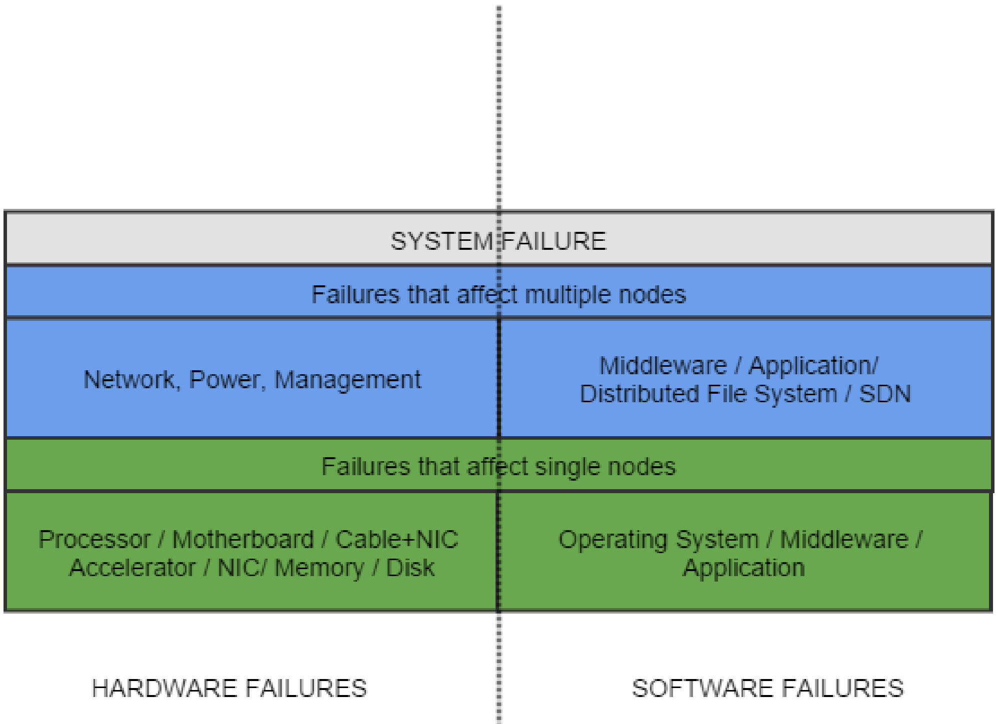


*Figure 6: Context diagram indicating potential hardware and software failures and their impact*

### 9.1.1 Hardware Failures

The hardware failure rate over the life-time of the system is typically described by the "Bathtub" model as shown in Figure 6. Early failures can be improved by appropriate build and test strategies in the factory. The normal operating period is typically 3-5 years for IT equipment, where it is expected that the MTBF is constant. This is followed by a wear-out period where it is expected that components will be replaced more often, ideally by scheduled maintenance periods, or the availability of the service will be compromised.

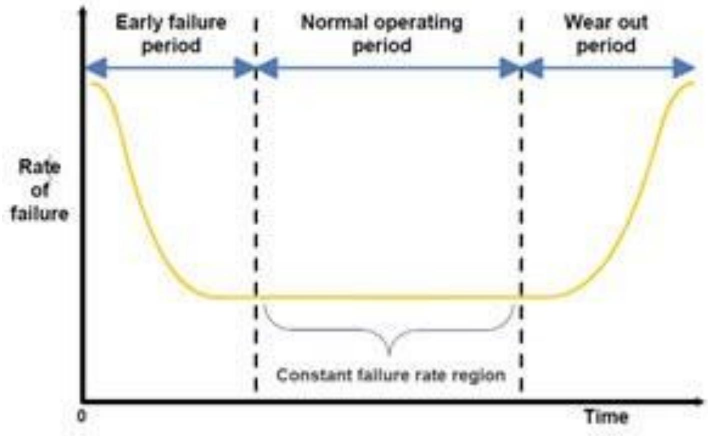


*Figure 7: Schematic Diagram Showing Rate of Failures over Time for IT Systems - "Bathtub Effect"*

Hardware failures during a product's life can be attributed to the following causes:

- **Design failures**: This class of failures take place due to inherent design flaws in the system. In a well-designed system this class of failures should make a very small contribution to the total number of failures.
- **Infant Mortality**: This class of failures cause newly manufactured hardware to fail. This type of failure can be attributed to manufacturing problems like poor soldering, leaking capacitor etc. These failures should not be present in systems leaving the factory as these faults will show up in factory system burn in tests. As such it is critical that factory tests are representative of the processing to be performed in production.
- **Random Failures**: Random failures can occur during the entire life of a hardware module. These failures can lead to system failures although redundancy is provided to recover from this class of failures.
- **Wear Out**: Once a hardware module has reached the end of its useful life, degradation of component characteristics will cause hardware modules to fail. This type of fault can be mitigated by preventive maintenance.

In terms of the current product tree breakdown, the hardware components are described as follows and the impact of failure will be described by a FCEMA analysis and will inform the overall SKA ILS Plan [AD08].

| | | | |
|---|---|---|---|
| C | Science Data Processor | SDP Product Tree top level | Describe Impact (TBD) |
| C.1 | Hardware Compute Platform | The set of hardware components comprising the SDP element from which logical compute and storage sub-systems are instantiated. | |
| C.1.1 | Compute Island | Scalable Unit consisting of N compute Nodes and 2 Management Nodes, 1st Stage Interconnect, Buffer and management network. A compute island may constitute a number of logical data islands in the data-driven architecture. | |
| C.1.1.1 | Management Compute Island | A High Availability Active/Active Management Node pair providing Compute Island management and control | |
| C.1.1.2 | Compute Node | A computational unit consisting of a single address space.<br>A data-island may consist of 1 to M compute nodes where M <= N (compute nodes within a compute island) | |
| C.1.2 | Buffer | A mechanism for pseudo real-time storage and/or processing of intermediate visibility data from ingest | |
| C.1.3 | Infrastructure | | |
| C.1.3.1 | Racks | Standard commercial racks with PDUs supporting commodity compute and storage servers and switches | |
| C.1.4 | Hierarchical Storage | A hierarchy of storage devices for short, medium and long-term storage. | |
| C.1.4.1 | Medium Performance Buffer | A storage medium for short-term storage of processed data | |
| C.1.4.2 | Long Term Storage | A storage medium for long-term storage of processed data | |
| C.1.4.3 | Archive Network Core | A network providing connectivity between Buffer and Archive | |

| | | | |
|---|---|---|---|
| | Switch | | |
| C.1.5 | Interconnect System | A number of networks providing data, management and control connectivity | |
| C.1.5.1 | Low-latency network core switch | A low-latency network for inter compute-node communication | |
| C.1.5.2 | Management Network | Inter and Intra Compute Island management network connecting to LMC | |
| C.1.5.3 | Data Transport Network | A uni-directional network connecting CSP with SDP via ingest | |
| C.1.6 | Delivery Platform Hardware | A set of hardware components consisting of compute nodes, storage and networking for reliable delivery of Science Data Products. | |
| C.1.7 | LMC Hardware | A set of hardware components consisting of compute nodes, storage and networking for reliable management and control of the SDP and interaction with the TM. | |

*Table 1– Product Tree Impact Analysis To Be Performed*

### 9.1.2 Software failures

Software failures (including application and middleware) can be characterized by keeping track of software defect density in the system. This number can be obtained by keeping track of historical software defect history. Defect density will depend on the following factors:

- Software Engineering process used to develop the design and code [AD05]
- Complexity of the software
- Size of the software
- Experience of the team developing the software
- Percentage of code reused from a previous stable project
- Rigour and depth of testing before product is shipped.

#### 9.1.3 Availability Calculations

A method for calculating availability is provided below where we will use the following definitions:

- ***Mean Time between Failures (MTBF)*** is the average (expected) time between two successive failures of a component. It is a basic measure of a system's reliability and availability and is represented as units of hours. MTBF for hardware components will be obtained from the vendor for off-the-shelf hardware modules. MTBF for in-house developed hardware modules, if appropriate, is calculated using a FIT (failures in test) method – representing the number of FIT over 1,000,000 hours. MTBF for software is determined by typically multiplying the defect rate with KLOCs executed per second. A goal of the design of the system is to maximize the MTBF by increasing the reliability of the individual components and the system implementation.
- ***Mean Time to Repair (MTTR)*** is the average (expected) time taken to repair a failed unit (LRU). This time includes the time it takes to detect the defect; the time it takes to bring in a repair; the time it takes to physically repair the failed unit; the time to bring the failed unit up and test; and the time to return the unit to service. MTTR is usually stated in units of hours and is design dependant. A goal of the design of the system should be to minimise the MTTR value while still providing an acceptable and reliable service. The calculations below assume that MTBF is a constant and therefore only apply during the normal operating period.
- ***Availability* –** A measure of the degree to which an item is in an operable and committable state at the start of a mission when the mission is called for an unknown (random) time.
- ***Maintenance* –** All actions necessary for retaining an item or restoring it to a specified condition.
- ***Preventive Maintenance* –** All actions performed in an attempt to retain an item in specified condition by providing systematic inspection, detection, and prevention of failures.
- ***Corrective Maintenance* –** All actions performed as a result of failure to restore an item to a specified condition; Corrective maintenance can include any or all of the following steps: Localization, Isolation, Disassembly, Interchange, Reassembly, Alignment and Checkout.

Using these 2 parameters the Availability can be expressed as

$$Availability = \frac{MTBF}{MTBF + MTTR} \quad \text{Equation 1}$$

$$Reliability = \exp(-\frac{t}{MTBF})$$

*Equation 2*

The following conclusions can be reached based on these formulae:

- The higher the MTBF value is, the higher the reliability and availability of the system.
- MTTR affects availability. This means if it takes a long time to recover a system from a failure, the system is going to have a low availability.
- High availability can be achieved if MTBF is very large compared to MTTR.

These three considerations define the potential trade-offs when designing the system against a given operational requirement. The above calculations provide the appropriate availability for individual components. To model the availability of sub-systems we adopt here, the serial, parallel and hybrid methods for calculating availability [RD05]. These are:

$$Availability(Serial) = \prod_{i}^{n} Component(i)$$ (Eq. 3)

$$Availability(Parallel) = 1 - \prod_{i}^{n} Component(i)$$ (Eq. 4)

For highly parallel operation, greater consideration may be given to increasing the reliability of components as the overall availability will be correlated to the weakest link in the chain. [see RD04] which identifies maximization of availability through system-wide reliability improvements]. For more loosely coupled systems, where applications may span single or relatively few compute nodes (c.f. Data Islands) the need for enhanced reliability may well be traded against the MTTR of the failed component. Such sensitivities will need to be addressed in terms of precious data. This is shown in more detail in the “Availability Example” below.

Calculating the availability of the hybrid system occurs when multiple components consisting of serial and parallel operate. In order to calculate the availability of such a system, the availability of subsystems with measurable availability are required in order to be able to complete the calculation. This requires the creation of Reliability Block Diagrams (RBD) which will be required for the components and subsystems of the SDP. A reliability block diagram defines the series dependence or independence of all functions of a system or functional group for each life-cycle event. The RBD will provide identification of function interdependencies for the system and can be used for a functional method FMECA. The RBD for each of the processing pipelines will be uniquely defined by the Physical Deployment Graph (Sub-element Design: LMC [AD04]).

The following schematic provides a mechanism for this analysis:

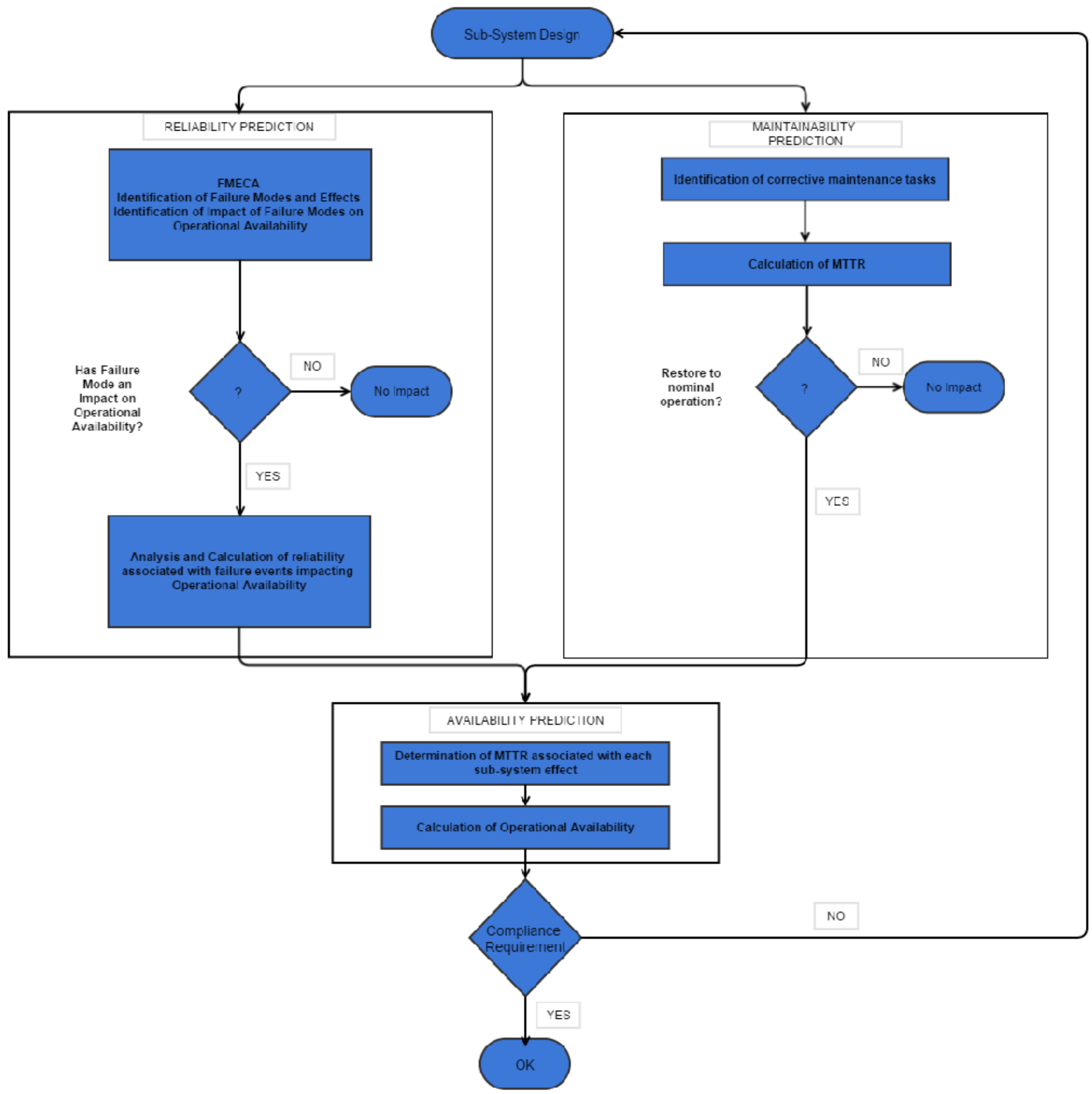


*Figure 8: Reliability, Availability and Maintainability Flow Chart*

#### 9.1.4 Availability Example - Compute Island

The table below provides typical MTBF figures for a Compute Node with MTTR values for on-site 24x7 Operation v. Next Business Day. With an overall availability computed as the serial availability of the individual components.

| Compute Node | MTBF | MTTR | Availability | Downtime (hrs/yr) | MTTR | Availability | Downtime (hrs/yr) |
|---|---|---|---|---|---|---|---|
| Server | 100000 | 8 | 99.9920% | 0.70 | 24 | 99.9760% | 2.10 |
| Accelerator | 120000 | 8 | 99.9933% | 0.58 | 24 | 99.9800% | 1.75 |
| Accelerator | 120000 | 8 | 99.9933% | 0.58 | 24 | 99.9800% | 1.75 |
| Middleware | 20000 | 0.08 | 99.9996% | 0.04 | 0.08 | 99.9996% | 0.04 |
| Application | 5000 | 0.08 | 99.9983% | 0.15 | 0.08 | 99.9983% | 0.15 |
| Disk (Single) | 200000 | 8 | 99.9960% | 0.35 | 24 | 99.9880% | 1.05 |
| **Availability of Compute Node** | | | **99.973%** | **2.40** | | **99.922%** | **6.84** |

*Table 2: MTBF, MTTR and Derived Availability for Compute Node*

The table below provides typical MTBF figures for a Data Island with typical MTTR values for on-site 24x7 operation and Next Business Day. With an overall availability computed as the hybrid availability of the individual components and the provision of H/A components in terms of management nodes and switch configuration. This will be extended to incorporate multiple compute nodes for particular pipelines.

| Compute Island | MTBF | MTTR 1 | Availability | Downtime (hrs/yr) | MTTR 2 | Availability | Downtime (hrs/yr) |
|---|---|---|---|---|---|---|---|
| Server | 100000 | 8 | 99.9920% | 0.70 | 24 | 99.9760% | 2.10 |
| Accelerator | 120000 | 8 | 99.9933% | 0.58 | 24 | 99.9800% | 1.75 |
| Accelerator | 120000 | 8 | 99.9933% | 0.58 | 24 | 99.9800% | 1.75 |
| Middleware | 20000 | 0.083 | 99.9996% | 0.04 | 0.083 | 99.9996% | 0.04 |
| Application | 5000 | 0.083 | 99.9983% | 0.15 | 0.083 | 99.9983% | 0.15 |
| Disk | 200000 | 8 | 99.9960% | 0.35 | 24 | 99.9880% | 1.05 |
| Switch | 200000 | 24 | 99.9880% | 1.05 | 24 | 99.9880% | 1.05 |
| Switch | 200000 | 24 | 99.9880% | 1.05 | 24 | 99.9880% | 1.05 |
| H/A Switch | | | 99.999999% | 0.00 | 0 | 99.999999% | 0.00 |
| Management Node | 100000 | 24 | 99.9760% | 2.10 | 24 | 99.9760% | 2.10 |
| Management Node | 100000 | 24 | 99.9760% | 2.10 | 24 | 99.9760% | 2.10 |
| H/A Management Node | | | 99.999994% | 0.00 | 0 | 99.999994% | 0.00 |
| Boot Node | 100000 | 24.00 | 99.9760% | 2.10 | 24.00 | 99.9760% | 2.10 |

*Table 3:MTBF, MTTR and Derived Availability for Compute Island*

# 10 REQUIREMENTS TRACEABILITY

The following requirements will be addressed in the ILS process.

| ID | Description (Short) | Traceability |
|---|---|---|
| SKA1-SYS_REQ-2116 | South African Engineering Operations Centre | Facilities |
| SKA1-SYS_REQ-2540 | Test and support equipment lifecycle costs. | Support Tools and Instrumentation |
| SKA1-SYS_REQ-2123 | Australian Science Processing Centre | Facilities |
| SKA1-SYS_REQ-2711 | Component obsolescence plan | Maintenance Planning |
| SKA1-SYS_REQ-2437 | Design for hazard elimination. | Maintenance Planning |
| SKA1-SYS_REQ-2519 | Reliability testing. | LSA |
| SKA1-SYS_REQ-2521 | Component derating. | TBD |
| SKA1-SYS_REQ-2435 | Hazard analysis. | Maintenance Planning |
| SKA1-SYS_REQ-2491 | Safety. | Facilities |
| SKA1-SYS_REQ-2529 | Maintenance test and support equipment | Support Tools and Instrumentation |
| SKA1-SYS_REQ-2570 | Parts availability. | Maintenance Planning |
| SKA1-SYS_REQ-2518 | High failure rate parts. | Supply Support |
| SKA1-SYS_REQ-2526 | Maintainability budgets | TBD |
| SKA1-SYS_REQ-2541 | Test equipment reliability | Support Tools and Instrumentation |
| SKA1-SYS_REQ-2505 | Sand and Dust. | Facilities |
| SKA1-SYS_REQ-2517 | Known failure rate parts. | LSA |
| SKA1-SYS_REQ-2449 | Construction Safety Plan. | Technical Documentation |
| SKA1-SYS_REQ-2465 | Electricity network Electromagnetic Compatibility | LSA |

| | | |
|---|---|---|
| SKA1-SYS_REQ-2603 | Mounting guides. | TBD |
| SKA1-SYS_REQ-2439 | Emergency stop. | LSA |
| SKA1-SYS_REQ-2566 | Materials list. | Technical Documentation |
| SKA1-SYS_REQ-2580 | LRU electrostatic warnings | Maintenance Planning |
| SKA1-SYS_REQ-2448 | Stand-off and handles. | Maintenance Planning |
| SKA1-SYS_REQ-2516 | Matching components. | LSA |
| SKA1-SYS_REQ-2528 | Level of maintenance | LSA |
| SKA1-SYS_REQ-2121 | Australian Engineering Operations Centre | Facilities |
| SKA1-SYS_REQ-2806 | Product Assurance | TBD |
| SKA1-SYS_REQ-2483 | Environment protection plan. | PHS&T/Facilities |
| SKA1-SYS_REQ-2546 | Continuous performance monitoring. | Support Tools and Instrumentation |
| SKA1-SYS_REQ-2578 | Package serial number marking. | Maintenance Planning |
| SKA1-SYS_REQ-2601 | Shock mounting provision. | LSA |
| SKA1-SYS_REQ-2798 | Protection of equipment in stationary use at non-weather protected locations | PHS&T/Facilities |
| SKA1-SYS_REQ-2790 | Environmental Impact Assessment | PHS&T/Facilities |
| SKA1-SYS_REQ-2446 | Electrical safety | PHS&T/Facilities |
| SKA1-SYS_REQ-2445 | Electrical circuit interlocks. | Support Tools and Instrumentation |
| SKA1-SYS_REQ-2460 | Occupational health legislation and regulations. | Support Personnel |
| SKA1-SYS_REQ-2481 | Emergency communication | Facilities |
| SKA1-SYS_REQ-2595 | Maintenance provisions. | Maintenance Planning |
| SKA1-SYS_REQ-2605 | Label robustness. | Maintenance Planning |
| SKA1-SYS_REQ-2525 | Fail safe provisions. | Maintenance Planning |

| | | |
|---|---|---|
| SKA1-SYS_REQ-2544 | Self-test. | Support Tools and Instrumentation |
| SKA1-SYS_REQ-2509 | Scope of workmanship standards. | Support Personnel |
| SKA1-SYS_REQ-2576 | Electronically readable or scannable ID | Maintenance Planning |
| SKA1-SYS_REQ-2599 | Component removal. | Maintenance Planning |
| SKA1-SYS_REQ-2650 | Seismic resilience | Facilities |
| SKA1-SYS_REQ-2583 | Cable identification. | Maintenance Planning |
| SKA1-SYS_REQ-2500 | Operating Humidity. | Maintenance Planning |
| SKA1-SYS_REQ-2457 | Illumination. | Support Personnel |
| SKA1-SYS_REQ-2786 | Safety documentation file | Technical Documentation |
| SKA1-SYS_REQ-2834 | SKA1_Mid-MeerKAT infrastructure reuse | TBD |
| SKA1-SYS_REQ-2819 | Safety of machinery risk assessment | LSA |
| SKA1-SYS_REQ-2598 | Module access. | Maintenance Planning |
| SKA1-SYS_REQ-2718 | Availability budgets | LSA |
| SKA1-SYS_REQ-2575 | Marking method. | Technical Documentation |
| SKA1-SYS_REQ-2506 | Fungus. | Facilities |
| SKA1-SYS_REQ-2543 | Direct fault indicators | Maintenance Planning |
| SKA1-SYS_REQ-2479 | Archive security | Facilities |
| SKA1-SYS_REQ-2450 | Safety information for use | Technical Documentation |
| SKA1-SYS_REQ-2491 | Safety. | Facilities |
| SKA1-SYS_REQ-2466 | EMC compatibility marking. | Maintenance Planning |
| SKA1-SYS_REQ-2801 | Storage of equipment | PHS&T/Facilities |
| SKA1-SYS_REQ-2827 | System Availability | LSA |
| SKA1-SYS_REQ-2443 | Protection from high voltages. | Maintenance Planning |
| SKA1-SYS_REQ-2478 | Equipment security | Supply Support |

| | | |
|---|---|---|
| SKA1-SYS_REQ-2542 | Training | LSA |
| SKA1-SYS_REQ-2574 | Drawing numbers. | Technical Documentation |
| SKA1-SYS_REQ-2559 | Design for economic production. | LSA |
| SKA1-SYS_REQ-2520 | Spares and repair parts testing. | Maintenance Planning |
| SKA1-SYS_REQ-2501 | Storage and transport Humidity. | PHS&T/Facilities |
| SKA1-SYS_REQ-2800 | Transportation of equipment | PHS&T |
| SKA1-SYS_REQ-2716 | Telescope availability | LSA |
| SKA1-SYS_REQ-2552 | Malfunction detection. | Maintenance Planning |
| SKA1-SYS_REQ-2584 | Connector plates. All connector plates shall carry identification labels for connectors | Technical Documentation |
| SKA1-SYS_REQ-2822 | Information security risk assessment | LSA |
| SKA1-SYS_REQ-2512 | Best practice. | LSA |
| SKA1-SYS_REQ-2462 | Electromagnetic Radiation | LSA |
| SKA1-SYS_REQ-2503 | Pressure. | PHS&T |
| SKA1-SYS_REQ-2444 | Safety grounding and bonding. | Facilities |
| SKA1-SYS_REQ-2816 | Design for testability | Supply Support |
| SKA1-SYS_REQ-2538 | Test and support equipment | Support Tools and Instrumentation |
| SKA1-SYS_REQ-2802 | Design for maintainability | LSA |
| SKA1-SYS_REQ-2577 | Package part number marking. | PHS&T |
| SKA1-SYS_REQ-2600 | Secure mounting of modules. | TBD |


PDR.11 Preliminary Element Integrated Logistics Support Plan

# PDR11PreliminaryILSPlan JMT CE

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