

LFAA TO INFRA AUS INTERFACE CONTROL DOCUMENT

Document number 100-000000-003
Document Type ..... ICD
Revision..... 04
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Date 2019-06-13
Document Classification ..... FOR PROJECT USE ONLY
Status ..... Released

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DOCUMENT HISTORY

Revision	Date of Issue	Engineering Change Number or Author Initials	Comments
01	2015-12-10	NA	First release of document
02	2016-11-02	ECP-160064	Second release of the document. Implementation of actions tabled in SKA-TEL-SKO-0000617: System PDR review report (Part 1).
03	2018-01-18	CN-170001	Third release of the document to close out some of the TBC and TBDs.
03A	2019-03-05	ECP-160071 ECP-170010 ECP-170023 ECP-180008	Update of document to align with INAU and LFAA CDR baselines. Substantial changes include: - LFAA_INFRA-AUS.001: Interface moved from APIU within Field Station to FNDH outside Field Station. New reference drawings added. - LFAA_INFRA-AUS.002: New reference drawings added. - LFAA_INFRA-AUS.004: Interface was previously a composite interface so was split into 2. Updated description of fibre entry based on INAU design. - LFAA_INFRA-AUS.005. New interfaces to DDBH cabinet (CPF) and Muxponders (RPF). Composite interface split into 4. Power consumption of MCCS increased. - LFAA_INFRA-AUS.006 and 007 deleted as not in scope (transferred to SADT-INAU ICD) - LFAA_INFRA-AUS.008. New interfaces to DDBH cabinet (CPF) and Muxponders (RPF). Composite interface split into 4. - LFAA_INFRA-AUS.009. New interfaces to DDBH cabinet (CPF), Muxponders (RPF) and splice cabinets (CPF and RPF). Composite interface split into 4.
04	2019-06-13	CN-190016	Release of version 04 for signature.

DOCUMENT SOFTWARE

	Package	Version	Filename
Word Processor	Microsoft Word	2	100-000000-003-04 LFAA-INAU ICD_dhayden_13June2019
Block diagrams			
Other			

ORGANISATION DETAILS

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LIST OF ABBREVIATIONS

AA.....Aperture Array
AADC .....Aperture Array Design and Construction – Consortium
AD-n .....nth document in the list of Applicable Documents
AD .....Applicable Document
AIV.....Assembly Integration and Verification
AN .....Another
APIU.....Antenna Power Interface Unit
AUS.....Australia
CDU.....Clock Distribution Unit
CI.....Configuration Identification
CPF .....Central Processing Facility
DDBH .....Digital Data Back Haul
EX.....Example
FCA .....Fibre Cable Assembly
FNDH .....Field Node Distribution Hub
ICD .....Interface Control Document
INFRA.....Infrastructure
INAU……. .....Infrastructure Australia Consortium
LFAA .....Low Frequency Aperture Array
MCCS.....Monitor Calibration and Control System
PBS .....Product Breakdown Structure
PaSD.....Power and Signal Distribution
RD .....Referenced Document
RFI…….Radio Frequency Interference
RPF .....Remote Processing Facility
SaDT .....Signal and Data Transport
SAT .....Synchronisation and Timing
SKA .....Square Kilometre Array
TBC .....To be confirmed
TBD .....To be determined
TM .....Telescope Manager
TPM.....Tile Processing Module

1 Introduction

1.1 Scope and Purpose

This Interface Control Document defines the interfaces between the Low Frequency Aperture Array (LFAA) System (as designed by AADC) and Infrastructure Australia (as designed by INAU) of the SKA Phase 1 system for the SKA1 Low telescope.

This interface complies with requirement SKA1-SYS_REQ-2421 as defined within the SKA Phase 1 System Requirements Specification [AD1].

This document complies with the SKA Interface Management Plan [AD2] as appropriate for an interface control document.

1.2 SKA1 Low Telescope Overview

The SKA1 Low Telescope will be constructed in Western Australia at the Murchison Radio Observatory in the SKA designated land as defined in the SKA license agreement and consists of the following elements namely:

- Low Frequency Aperture Array (LFAA),
- Low Central Signal Processing (CSP),
- Science Data Processing (SDP),
- Telescope Manager (TM),
- Signal and Data Transport (SaDT), and
- Infrastructure Australia (INAU).

The SKA1 Low Telescope will consist of 512 Field Nodes. Each field node will be populated with 256 antennas, therefore the Low Telescope will consist 131,072 (2^{17}) log periodic antennas. LFAA is responsible for converting the received RF signal from each antenna into station beams and transporting these beams to the CSP Element. CSP is responsible for correlating the data for each antenna sub-array (there can be any integer number of sub-arrays between 1 and 16). The correlated array data will then be passed on to the SDP element for the final processing. SDP is responsible for reducing, analysing and preparing the science data products for archiving. TM is responsible for the overall control and monitoring of the LOW telescope. SaDT is the element responsible for the distribution of a 1 PPS and a 10 MHz clock to the rest of elements; it is also responsible for transporting long haul data between the Remote Processing Facilities (RPF) and the Central Processing Facility (CPF). Finally, the INAU element is responsible for providing infrastructure, power and other supporting facilities.

1.3 Interface Identification

This Interface Control Document (ICD) defines the interfaces between the Low Frequency Aperture Array (101-000000) and Infrastructure Australia (500-000000) and is identified with the following designation:

- I.S1L.LFAA_INAU “Low Frequency Aperture Array and Infrastructure Australia Interface”

[Note: the interface identifier used is I.S1t.xxx_yyy.nnn, where:

I = Interface

S = SKA,

1 = Phase 1,

t = Telescope: M for MID, L for LOW.

XXXX = Interfacing element 1

YYYYY = Interfacing element 2

nnn = identification number]

Seven primary interfaces have been identified between LFAA and INAU. The interface identification numbers are composed as follows: I.S1L.LFAA_INAU.XXX, where XXX is the interface number.
These interfaces are described below:

I.S1L.LFAA_INAU.001: is used to supply power to the Antenna Assemblies via the Power and Signal Distribution (PaSD) at each Field Node.

I.S1L.LFAA_INAU.002: is the cable path between the PaSD in each Field Node and the processing facilities (CPF and RPFs).

I.S1L.LFAA_INAU.003: defines the interface between the mesh (Ground Plane) and the terrain (Prepared Ground). It also defines the interface between the antenna and the terrain. Although the antenna will be clipped onto the mesh, the structural interface will however be provided by the Prepared Ground.

I.S1L.LFAA_INAU.004: provides the fibre entry paths for the Fibre Cable Assemblies into the processing facilities (CPF and RPFs) as well as providing the routing paths (on cable trays) for the TPM patch cords from the Splice Cabinets to the SPS cabinets. The Fibre Cable Assemblies will be spliced and connected to the TPM Patch Cords within the Splice Cabinets. It is also important to note that the number of CPF and the RPFs entry points shall be determined and provided for by INAU, while the Fibre Cable Assemblies shall be provided by LFAA.

I.S1L.LFAA_INAU.005: is the interface that will supply power to all the LFAA cabinets (SPS and MCCS), as well as the DDBH equipment which is also part of SPS. The power requirements for all SPS Cabinets are the same, however the power requirements for the MCCS cabinets are higher and are defined in the SKAO Power Budget [AD10].

I.S1L.LFAA_INAU.008: provides the interface to deliver cold fluid to each of the LFAA cabinets (SPS and MCCS) as well as the DDBH equipment, for cooling of the cabinets. This interface also includes the return path for the warm fluid to be recycled.

I.S1L.LFAA_INAU.009: provides the space and infrastructure to mount and house all the LFAA cabinets in both the CPF and the RPFs. This includes the SPS Cabinets, MCCS Cabinets, DDBH equipment and Splice Cabinets.

The LFAA and INAU product pairs participating in the interfaces are identified in Table 1-1: below. This table also shows the entity crossing the interface where relevant, as well as the interface class in accordance with the SKA Interface Management Plan [AD2]. Several of the interfaces are composite interfaces, meaning there are multiple pairs of products involved. These multiple pairs, each of which describes a sub-interface, are also shown in Table 1-1.

Table 1-1: Interface Identification List

Interface Identifier	LFAA Product	Entity across the interface	INAU Product	Interface Class
I.S1L.LFAA_INFRA-AUS.001	Field Node Distribution Hub	Power	Power distribution	PWR
I.S1L.LFAA_INFRA-AUS.002	Fibre Cable Assembly	-	Power distribution (trenching)	MEC
I.S1L.LFAA_INFRA-AUS.003	Ground Plane	-	Prepared terrain	MEC ENV
I.S1L.LFAA_INFRA-AUS.004	Fibre Cable Assembly	-	Ingress infrastructure	MEC ENV
	RFoF Signal Cable Assembly	-	Cable trays	MEC ENV
I.S1L.LFAA_INFRA-AUS.005	AC Power Distribution (SPS)	Power	Power sockets	PWR
	MCCS Cabinet Power Network (MCCS)	Power	Power sockets	PWR
	DDBH Cabinet	Power	Power sockets	PWR
	Muxponder	Power	Power sockets	PWR
I.S1L.LFAA_INFRA-AUS.008	Cooling System (SPS)	Cooling fluid	Cooling Plant	FLD
	MCCS Cooling System (MCCS)	Cooling fluid	Cooling Plant	FLD
	DDBH Cabinet	TBD83	TBD83	TBC
	Muxponder	TBD84	TBD84	TBD
I.S1L.LFAA_INFRA-AUS.009	SPS Cabinet (populated)		CPF, RPFs	MEC ENV
	MCCS Compute Processor		CPF	MEC ENV
	DDBH Cabinet		CPF	MEC ENV
	Muxponder		Outer 10 RPFs	MEC ENV
	Splice Cabinet		CPF, RPFs	MEC ENV

KEY:	
Data	DAT
Clock and Timing	CLK
Environment	ENV
Electromagnetic	EMC
Optical	OPT
Fluid	FLD
Human-Machine Interface	HMI
Mechanical	MEC
Power	PWR
Thermal	THR

1.4 Key Terminology

Defined below is the key terminology used throughout this Interface Control Document:

1. **Antenna Assembly** refers to one LFAA log-periodic antenna. In this document Antenna and Antenna Assembly are used interchangeably and thus refer to the same configuration item.
2. **Field Station** refers to array of 256 antenna elements within a circular area that has a clear physical boundary and a specific geographic location.
3. **Fibre Cable Assembly** refers to the RF over Fibre (RFoF) assembly that carries the dual polarisation signal from each Field Station to a Processing Facility (either CPF or RPF). Several of its 288 fibres also enable monitoring and control functionality for the APIUs
4. **Power and Signal Distribution** refers to the power and signal distribution within the boundaries of the Field Station. This includes 4 Antenna Power Interface Units (APIUs), which are the power and signal connection points for 64 antennas each, and 1 Field Node Distribution Hub (FNDH), which distributes power and signal from the Fibre Cable Assembly and power interface with INAU to the 4 APIUs. It also enables monitoring and antenna-level control.
5. A **Field Node** is the aggregation of a Field Station, the Power and Signal Distribution, and the Fibre Cable Assembly.
6. **Ground Plane** is a metallic grid made of galvanised wire mesh. This is laid directly on the Prepared Ground and covers an area large enough to accommodate 256 antennas (a Field Station) that are separated by a minimum distance of 1.7 metres, and slightly beyond this area.
7. **Prepared Ground** is an area cleared for the installation of a Field Station.
8. **Tile** refers to a grouping of 16 antennas located near one another.
9. A **Station** encompasses a Field Station, each antenna element of which is connected to a digitiser and all signal processing equipment required to produce channelised, beam-formed signal streams.
10. **DDBH** (or Digital Data Back Haul) refers to the long range transmission equipment that sends the digitised station beams from the outer 10 RPFs to the CPF.
11. **Central Processing Facility (CPF)** refers to the facility housing the equipment for the beamforming of the RFoF signals received from Field Stations in the central area; the LFAA Monitor, Control and Calibration System (MCCS); the Central Signal Processing (CSP) element; the Telescope Manager (TM) element and the SKA1 Low Frequency Reference.
12. **Remote Processing Facility (RPF)** refers to the intermediate processing facilities that house the equipment for the beamforming of the RFoF signals received from Field Stations outside the central area. There are 36 RPFs in total – one for each of the 12 clusters in each spiral arm that are outside the central area.

1.5 Roles and Responsibilities

The **owner** of this ICD is the SKA Office, contact: Low System Engineer. The Owner of the interface acts as the authority of the system architecture and is responsible for the initial identification and description of the interface, and for nominating Leading and Following Parties. All agreements and control documents governing this interface are under SKA Office control.

The leading party is the Aperture Array Design Consortium (AADC) who is responsible for the development of LFAA. AADC is responsible for defining the interfaces requirements and implementation details; for providing methods and procedures for the verification of the interface; for designing and provisioning of test, diagnostic and maintenance functions at the interface; for verifying the interface for integration and acceptance purposes and submitting the ICD for review and approval. The contact is the LFAA Systems Engineer.

The **following party** is the Infrastructure Australia consortium (INAU) who will assist in the definition of the interface definition. INAU will sign off the agreed interface definition and make sure that the resulting interface requirements are incorporated in the INAU Level 2/3 Requirements Specification. The contact is the INAU Systems Engineer.

Table 1-2 below lists the roles and responsibilities for the relevant parties.

Table 1-2: Roles and Responsibilities

Role	Element	Point of contact	Responsibilities
Leading party	LFAA	Systems Engineer (SE)	Define, record, and maintain the interface definitions in this document.
Following party	INAU	SE	Contribute, and work to reach a mutual agreement regarding the interface definitions as recorded in this document. Ensure that the LFAA infrastructure requirements are captured correctly in the LFAA Requirements Specification.
Owning party		SKAO	Oversight, approval and release.

2 Applicable and Referenced Documents

2.1 Applicable Documents

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

[AD1]	SKA Phase 1 System Requirements Specification	SKA-TEL-SKO-0000008	11
[AD2]	SKA Interface Management Plan	SKA-TEL-SKO-0000025	02
[AD3]	SKA-Low Configuration Coordinates – Complete Set	SKA-TEL-SKO-0000422	03
[AD4]	RPF Locations	Drawings: SKA-TEL-INAU-DWG-CC-000003/04/05/06/07/40/ 41/42/43/44 and 45 read in conjunction with SKA-TEL-SKO-0000422	B
[AD5]	RPF LFAA Cabinet Layout Drawing	SKA-TEL-INAU-DWG-JJ-0000301	F
[AD6]	Not Used		
[AD7]	CPF Cabinet Layout Drawing	SKA-TEL-INAU-DWG-JJ-0000204	C
[AD8]	SKA EMI/EMC STANDARDS AND PROCEDURES	SKA-TEL-SKO-0000202	03
[AD9]	SKAO Power Quality Standard	SKA-TEL-SKO-0000293	03
[AD10]	SKAO Power Budget	SKA-TEL-SKO-0000035	05
[AD11]	Not used		
[AD12]	Not used		
[AD13]	Not used		
[AD14]	SKA Project Safety Management Plan	SKA-TEL-SKO-0000740	01
[AD15]	Field Node Power Distribution Layout	CDR2-G-GAD-01	01
[AD16]	Field Node Hub Power Module Schematic Diagram Electrical	CDR2-E-SCD-01	01
[AD17]	Field Node Distribution Hub External Layout	CDR-C-COD-03	01
[AD18]	Access & Civil Services Central Core Layout Plan	SKA-TEL-INAU-DWG-CC-0000003	B
[AD19]	Access & Civil Services Standard Details Trenching	SKA-TEL-INAU-DWG-CC-0000033	B
[AD20]	Access & Civil Services Central Processing Facility Layout Plan	SKA-TEL-INAU-DWG-CC-0000002	B
[AD21]	Central Processing Facility Fibre Entry Details – Sheet 1 or 4	SKA-TEL-INAU-DWG-FE-0000110	C
[AD22]	Buildings Design Report	SKA-TEL-INAU-0000015	8
[AD23]	Central Processing Facility Fibre Entry Details – Sheet 3 of 4	SKA-TEL-INAU-DWG-FE-0000112	C
[AD24]	Remote Processing Facility RFI Shield Penetrations Plan	SKA-TEL-INAU-DWG-FE-0000300	C
[AD25]	Remote Processing Facility RFI Shield Penetrations Schedule	SKA-TEL-INAU-DWG-FE-0000301	B
[AD26]	Electrical Services Central Processing Facility Ground Floor Plan Cable Containment High Level	SKA-TEL-INAU-DWG-EL-0000103	E

[AD27]	Removed		
[AD28]	LFAA Fibre Cable Assembly Technical Data Sheet		
[AD29]	Access & Civil Services Northern Spiral Layout	SKA-TEL-INAU-DWG-CC-0000004	B
[AD30]	Access & Civil Services Eastern Spiral Layout	SKA-TEL-INAU-DWG-CC-0000005	B
[AD31]	Access & Civil Services Southern Spiral Layout	SKA-TEL-INAU-DWG-CC-0000006	B
[AD32]	Access & Civil Services Typical Cluster Layout Plan	SKA-TEL-INAU-DWG-CC-0000007	B

2.2 Referenced Documents

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

[RD1]	Electrical installations	AS3000:2016	NA
[RD2]	Equipment Engineering (EE); Environmental conditions and environmental tests for telecommunication equipment. Part 1-3: Classification of environmental conditions Stationary use at weather protected locations	ETSI EN 300 019-1-3	NA
[RD3]	Interface Control Document SADT to LFAA	100-000000-026	05
[RD4]	Not used		
[RD5]	SKA System Budget – Low Rack Space	SKA-TEL-SKO-0000634	2
[RD6]	LFAA Requirements Specification	SKA-TEL-LFAA-0200026	2
[RD7]	Fibre Cable Assembly Technical Data Sheet, AFL A57SLF2288BK, 24/08/2016		

3 Low Frequency Aperture Array Layout

The LFAA equipment will be deployed in three types of locations each with its own distinct operational environment.

Firstly, the Antenna Assemblies will be deployed in the field unprotected from the environment on top of a mesh to form a Ground Plane and can be classified as stationary equipment at non-weather protected locations. In addition, the PaSD will also be deployed in the same area; however, the power modules and fibre interconnections will be packaged in weather protected enclosures as specified in the LFAA Requirements Specification [RD6] [AD27]and is therefore out of scope of this document.

Secondly, 148 out of 256 Signal Processing Sub-System cabinets will be housed in a designated area within the CPF. The cabinets (maximum 4 off) housing the Local Monitor and Control equipment will also be accommodated in the same area. This area will also house 1 DDBH cabinet and 30 Splice Cabinets.

Finally, RPFs will be erected to house the remainder (108) of the Signal Processing System cabinets to allow the processing of signals received by the Antenna Assemblies installed too far away from the CPF in the outlying areas. A single Muxponder will be housed in each of the outer 10 RPFs.

The following locations and environments have been identified and the equipment at each is defined in more detail in Sections 3.1, 3.3 and 3.2 respectively:

a. Field
b. RPF
c. CPF.

3.1 Field equipment

The following field equipment will be installed in the field and as such will be directly exposed to the climate:

a. Antenna Assemblies (quantity = 131072).
b. Antenna Power Interface Units (APIU).
c. Field Node Distribution Hubs (FNDHs)
d. Ground Planes

001 The minimum Prepared Ground diameter to accommodate the 256 Antenna Assemblies is 42 metres. This is equal to the Ground-plane Station diameter, as specified in [AD3].

125 The location of the centre of each Field Station Prepared Ground is as specified in [AD3].

003 The mesh will be laid on top of the Prepared Ground as described in Section 4.1.3.

3.2 Remote Processing Facilities equipment

004 Each RPF will contain the following LFAA equipment:

- 3 SPS Cabinets
- 1 Muxponder (the 10 outer RPFs)
- 1 Splice Cabinet

005 There will be 36 RPFs [AD3]. These process antenna signals from the 216 Field Nodes in the outer spiral.

006 The RPFs shall be located by INAU as in [AD4].

007 The cabinet positions and the power connection points within each RPF are defined in "RPF Cabinet Layout" [AD5].

008 Each RPF shall house 3 full size signal processing (SPS) cabinets of the following dimensions/weight:

a. Width = 800 mm
b. Depth = 1200 mm
c. Height ≤ 2000 mm floor to top of cabinet external surface
d. Weight ≤ 620 kg.

Note: Each cabinet is self-contained, with the dimensions stated accounting for the use of an integral heat exchanger within each cabinet.)

009 A clearance of at least 900 mm in front and behind each LFAA cabinet shall be provided for access and maintenance purposes. Please note there will be only a single row of cabinets.

010 Access shall be provided to allow for cabinets to be brought into the RPFs.

011 Each RPF shall comply with ETSI EN 300 019-1-3 [RD2] to ensure that the equipment housed within the RPF will operate in an environment suitable for stationary equipment in a weather protected location.

012 The total routed length of the Fibre Cable Assembly (FCA) from the FNDH to the RPFs shall not exceeds 10 km.

112 Each of the 10 outer RPFs shall house 1 Muxponder requiring no more than 3U of rack space. This will be housed in the single SADT-provided rack in these RPFs [RD3].

113 The Splice Cabinet shall have dimensions 900mm (W) x 2000mm (H) x 300mm (D).

3.3 Central Processing Facility equipment

114 The CPF will contain the following LFAA equipment:

- 148 SPS Cabinets
- 4 MCCS Cabinets (referred to in the PBS as MCCS Compute Processors)
- 1 DDBH Cabinet
- 30 Splice Cabinets

021 The Signal Processing Sub-System (SPS) and Monitor, Control and Calibration Sub-system (MCCS) equipment designated to be installed in the CPF, and the power connection points shall be installed as detailed in [AD7].

022 The LFAA designated area within the CPF shall be large enough to house the cabinets referred to in 114 above.

023 The power connection points for the LFAA cabinets shall be installed at the positions as detailed in [AD7].

024 The dimensions/weight of the cabinets (SPS, MCCS and DDBH cabinets) are:

a. Width = 800 mm
b. Depth = 1200 mm
c. Height ≤ 2000 mm floor to top of cabinet external surface
d. Weight ≤ 620 kg

Note: Each cabinet is self-contained, with the dimensions stated accounting for the use of an integral heat exchanger within each cabinet.

116 The 30 Splice Cabinets shall have dimensions 900mm (W) x 2000mm (H) x 300mm (D)

025 A clearance of at least 900 mm in front and behind each LFAA cabinet shall be provided for access and maintenance purposes.

027 Temperature range in the CPF cabinet room area shall be controlled as to provide an operating temperature range between 15°C and 27°C.

029 The relative humidity of the ambient air within the CPF cabinet room area shall be maintained between 40 % and 60 %.

030 Access shall be provided to allow for cabinets to be brought into the CPF.

4 Interface Definition

4.1.1 Field Node Power (I.S1L.LFAA_INFRA-AUS.001)

Interface I.S1L.LFAA_INFRA-AUS.001 is between products:

- Field Node Distribution Hub (LFAA)
- Power Distribution (INAU)

The interface shall comply with the following interface definitions:

040 A power supply connection shall be provided at one service connection point 3 metres outside the Ground Plane boundary (defined in [AD3] as a circle of diameter 42m centred at the Field Station location) (see drawings [AD15], [AD16] and [AD17]) with the following characteristics:

a. Nominal supply voltage: Low voltage (230 V), single phase alternating current (AC).
b. Supply capacity: ≥ 5 A.
c. Shall be delivered via industrial standard power cables suitable to withstand the environmental conditions as defined in [AD1] in weather unprotected areas.

041 Power consumption at each service connection point meets the following characteristics:

a. Nominal power consumption: ≤ 1000 Watts
b. Peak power consumption: Limited to the nominal power +20% for a maximum duration of 50 ms.

045 Low voltage electrical protection shall be provided in accordance with AS3000 [RD1].

046 Power supply characteristics shall comply with the SKA EMI/EMC Standards and Procedures [AD8] and SKAO Power Quality Standard [AD9] including:

a. Frequency
b. Supply voltage
c. Voltage unbalance
d. Harmonic voltages
e. Transients
f. Power interruptions

047 Consumer load parameters shall comply with the SKAO Power Quality Standard [AD9] including:

a. Power factor
b. Voltage flicker
c. Harmonic currents
d. Current unbalance

094 INAU is responsible for providing the power cable. LFAA is responsible for supplying the cable gland and terminating the cable onto the terminals on the inside of the FNDH enclosure.

4.1.2 Fibre Cable Assembly Routing and Trenching (I.S1L.LFAA_INFRA-AUS.002)

Interface I.S1L.LFAA-INFRA-AUS.002 is between products:

- Fibre Cable Assembly (LFAA)
- Power Distribution (Trenching) (INAU)

050 INAU is responsible for providing the trenches for power between each Field Node and either the CPF or its associated RPF. These power trenches will also accommodate the FCA (see [RD7] for data sheet) from the FNDH to the CPF/RPF.

117 For the 296 Field Nodes in the Central Area (224 core + 72 inner spiral), the routing of the trench for the FCAs to the CPF is defined in [AD18].

118 For the 216 outer spiral Field Nodes, the routing of the trench for the FCAs to the nearest RPF is defined in [AD19][AD29][AD30][AD31] and [AD32] .

119 The interface between the FCA and the trench is as defined in [AD19], where the 5 cases shown correspond to the five numbered points on drawing [AD18].

120 The trench entry of the 296 Fibre Cable Assemblies into the CPF fibre pit is shown in [AD20] and [AD21].

121 The entry of the 6 Fibre Cable Assemblies into each RPF is shown in [AD24] and [AD25].

122 The length of Fibre Cable Assembly that is required by LFAA to satisfy the routing is TBD93 (ref TBD94).

4.1.3 Prepared Ground(I.S1L.LFAA_INFRA-AUS.003)

Interface I.S1L.LFAA-INFRA-AUS.003 is between products:
- Ground Plane (LFAA)
- Prepared Ground (INAU)

055 The ground will be prepared and referred to as “Prepared Ground” by grading the area and removing large boulders, rocks and vegetation.

056 Where required holes will be filled and where infrastructure construction activities degrade the general condition of the Prepared Ground it will be repaired.

059 The maximum slope across an area of Prepared Ground to accommodate the Antenna Assemblies for any Field Node is 2% (equivalent to 1 in 50). It is acceptable for the slope of the Prepared Ground for any field node to be in multiple directions from its centre (i.e. that generally the area can retain its existing topography).

4.1.4 Fibre Entry to Buildings(I.S1L.LFAA_INFRA-AUS.004)

Interface I.S1L.LFAA-INFRA-AUS.004 is a composite interface. Table 4-1 shows its sub interfaces, and the interfacing products and location of each.

Table 4-1: Sub-interfaces for I.S1L.LFAA_INFRA-AUS.004

Interface identifier	LFAA Product	INAU Product	Location
I.S1L.LFAA_INFRA-AUS.004A	Fibre Cable Assembly	Ingress infrastructure	CPF, RPF
I.S1L.LFAA_INFRA-AUS.004B	RFoF Signal Cable Assembly	Cable trays	CPF, RPF

4.1.4.1 I.S1L.LFAA-INFRA-AUS.004A

017 RfoF cable ingress into each RPF should be sized to accommodate six cables. Each cable consists of 288 cores and the diameter of each fibre bundle (cable) is 17.5 ± 5 mm. The minimum bend radius shall be ≥ 540 mm (18 x 30).

018 RfoF cable ingress into the CPF should be sized to accommodate 296 cables. Each cable consists of 288 cores and the diameter of each fibre bundle (cable) is 17.5 ± 5 mm. The minimum bend radius shall be ≥ 540 mm (OD x 30).

123 For both the CPF and RPF, the description of the fibre entry process is as follows [AD22]:

- Fibre cables come into the penetration boxes from the fibre pit.
- The fibres are then split by hand into 4 bundles.
- Each of these bundles is then fed through a protective cover.
- The outer diameter of each bundle including the protective tubing is 5.5mm.
- These then get threaded through two waveguides (CPF, one for each shield) or one waveguide (RPF, one shield only). Each waveguide is 60mm long with an aperture of 7mm.
- The minimum bend radius shall be larger than 90 mm.

124 Once through the inner shield, the bundles pass into Splice Cabinets. The CPF shall contain 30 Splice Cabinets, each serving 11 Fibre Cable Assemblies TBC95. Each RPF will contain 1 Splice Cabinet.

051 INAU shall provide the waveguides required to provide compliance with [AD8] for the Fibre Cable Assemblies entering either the CPF or its associated RPFs.

The abovementioned process and associated equipment in the CPF are illustrated in drawing [AD23].

4.1.4.2 I.S1L.LFAA-INFRA-AUS.004B

062 Overhead cable trays are used for the routing of RfoF Signal Cable Assemblies (to and from the Splice Cabinets to each of the SPS Cabinets). See drawing [AD26].

4.1.5 SPS and MCCS Power (I.S1L.LFAA_INFRA-AUS.005)

Interface I.S1L.LFAA-INFRA-AUS.005 is a composite interface. Table 4-2 shows its sub interfaces, and the interfacing products and location of each.

Table 4-2: Sub-interfaces for I.S1L.LFAA_INFRA-AUS.005

Interface identifier	LFAA Product	INAU Product	Location
I.S1L.LFAA_INFRA-AUS.005A	AC Power Distribution (SPS)	Power sockets	CPF, RPF
I.S1L.LFAA_INFRA-AUS.005B	MCCS Cabinet Power Network (MCCS)	Power sockets	CPF
I.S1L.LFAA_INFRA-AUS.005C	DDBH Cabinet	Power sockets	CPF
I.S1L.LFAA_INFRA-AUS.005D	Muxponder	Power sockets	RPF (outer 10)

065 Normal power will be delivered to each of the power connection points as listed in [AD5] and [AD7] and consists of standard electrical socket outlets, terminal connections and supplementary earthing connections.

066 The power sockets shall be installed at the positions identified below the floating (false) floor as defined in [AD5] and [AD7].

067 Each power socket shall be of type IEC/EN 60309 (6H), IP44, 32A, 400V, 3P+N+E.

070 Power supply characteristics shall comply with the SKA EMI/EMC Standards and Procedures [AD8] and SKAO Power Quality Standard [AD9], including:

a. Frequency
b. Supply voltage
c. Voltage unbalance
d. Harmonic voltages
e. Transients
f. Power interruptions

071 Consumer load parameters shall comply with the SKAO Power Quality Standard [AD9] including:

a. Power factor
b. Voltage flicker
c. Harmonic currents
d. Current unbalance

077 Low voltage electrical protection shall be provided in accordance with AS3000 [RD1].

078 Power cables (to and from cabinets) are routed via cable conduits provide under the false floor at the power socket. The power socket shall be provided by INAU, and the power cables shall be provided by LFAA.

4.1.5.1 I.S1L.LFAA-INFRA-AUS.005A

072 The power supply provided to each SPS power outlet complies with the following characteristics:

a. Nominal supply voltage: Low voltage (400 V), three phase alternating current (AC).
b. Supply capacity: ≥ 32 A.

073 Power consumption at each SPS cabinet power outlet shall meet the following characteristics:

a. Average power consumption: ≤ 5 kW (Note: this value will be utilised by INAU for central plant sizing)
b. Peak power consumption: Limited to 5 kW +20% for a maximum duration of 50 ms.
c. Be compliant with the SKAO Power Budget [AD10].

074 Central power and cooling plant shall be sized to suit an average load of 5 kW power at each SPS cabinet (outlet) by INAU.

4.1.5.2 I.S1L.LFAA-INFRA-AUS.005B

079 The power supply provided to each MCCS power outlet complies with the following characteristics:

a. Nominal supply voltage: Low voltage (400 V), three phase alternating current (AC).
b. Supply capacity: ≥ 32 A.

076 Power consumption at each MCCS cabinet power outlet shall meet the following characteristics:

a. Average power consumption: ≤ 22.5 kW TBC98
b. Peak power consumption: Limited to 22kW +20% TBC98 for a maximum duration of 50 ms.
c. Be compliant with the SKAO Power Budget [AD10].

081 The MCCS UPS delivers a minimum of 22.5 kW TBC98 (per MCCS Cabinet) of uninterruptable power for at least 10 minutes to allow the MCCS servers to shut-down the system in an orderly fashion in compliance with the SKAO Power Budget [AD10].

082 Central power and cooling plant shall be sized to provide an average load of 22.5 kW TBC98 power at each of the four MCCS cabinet (outlet) by INAU.

4.1.5.3 I.S1L.LFAA-INFRA-AUS.005C

087 The power supply provided to the DDBH cabinet power outlet complies with the following characteristics:

a. Nominal supply voltage: Low voltage (400 V), three phase alternating current (AC).
b. Supply capacity: ≥ 32 A.

088 Power consumption at the DDBH cabinet power outlet shall meet the following characteristics:

a. Average power consumption: ≤ 6 kW TBC81 (Note: this value will be utilised by INAU for central plant sizing)
b. Peak power consumption: Limited to 6 kW +20% TBC81 for a maximum duration of 50 ms.
c. Be compliant with the SKAO Power Budget [AD10].

089 Central power and cooling plant shall be sized to suit an average load of 6kW TBC81 power at the DDBH cabinet (outlet) by INAU.

4.1.5.4 I.S1L.LFAA-INFRA-AUS.005D

090 Power consumption of the Muxponder in each of the 10 outer RPFs shall meet the following characteristics:

a. Average power consumption: ≤ 350 W TBC82
b. Peak power consumption: Limited to 350 W +20% TBC82 for a maximum duration of 50 ms.
c. Be compliant with the SKAO Power Budget [AD10].

091 Central power and cooling plant shall be sized to suit an average load of 350 W TBC82 power for the Muxponder in each of the 10 outer RPFs.

Note: As indicated in interface definition 112 in section 3.2, these Muxponders in the outer 10 RPFs will each be housed in the single SADT-provided rack in these RPFs. Therefore, the power and cooling provided to the Muxponders is via the power and cooling interfaces to the SADT rack. Interface definitions 090 and 091 above must be considered by INAU in the design of these interfaces.

4.1.6 SPS and MCCS Cooling (I.S1L.LFAA_INFRA-AUS.008)

Interface I.S1L.LFAA-INFRA-AUS.008 is a composite interface. Table 4-3 shows its sub interfaces, and the interfacing products and location of each.

Table 4-3: Sub-interfaces for I.S1L.LFAA_INFRA-AUS.008

Interface identifier	LFAA Product	INAU Product	Location
I.S1L.LFAA_INFRA-AUS.00A8	Cooling System (SPS)	Cooling Plant	CPF, RPF
I.S1L.LFAA_INFRA-AUS.008B	MCCS Cooling System (MCCS)	Cooling Plant	CPF
I.S1L.LFAA_INFRA-AUS.008C	DDBH Cabinet	TBD	CPF
I.S1L.LFAA_INFRA-AUS.008D	Muxponder	TBD	RPF (outer 10)

079 Cooling water (to and from cabinets) are routed under the false floor from the self-sealing valve connection point (valve connections (cool water in and hot water out). Cooling water coupling points (inlet and outlet) shall be positioned for easy coupling with the electronic cabinet's cooling unit.

080 The cooling fluid for the LFAA cabinets shall have the following characteristics:

a. Filter water containing corrosion inhibiters.
b. Cleanliness of cooling fluid will not contain particles of greater than 300 microns.
c. Fluid maximum flow rate of 0.78 L/s
d. Fluid inlet temperature between 6°C to 15°C
e. Inlet location at below floor level adjacent to each cabinet as defined in [AD5] and [AD7].
f. Outlet location – floor level adjacent to each cabinet as defined in [AD5] and [AD7] .

Design Note: Cooling water is provided at floor level via a valve connection points adjacent to and underfloor to each electronics cabinet. It is intended that the flexible pipes to connect to the valves will be delivered as part of the LFAA cabinet heat exchanger. Each heat exchanger will provide internal controls and sensors to control the speed of the fans and the water supply to and from the cabinet heat exchanger.

4.1.6.1 I.S1L.LFAA-INFRA-AUS.006A

083 The cooling capacity provided to each SPS electronics cabinet shall be sized to cater for an average thermal load of 5 kW.

4.1.6.2 I.S1L.LFAA-INFRA-AUS.006B

084 The cooling capacity provided to each MCCS electronics cabinet shall be sized to cater for an average thermal load of 22.5 kW TBC98.

4.1.6.3 I.S1L.LFAA-INFRA-AUS.006C

092 The cooling capacity provided to the DDBH cabinet shall be sized to cater for an average thermal load of 6 kW TBC81.

4.1.6.4 I.S1L.LFAA-INFRA-AUS.006D

093 The cooling capacity provided to the Muxponder in each of the 10 outer RPFs (housed in the SADT-provided rack) shall be sized to cater for an average thermal load of 350 W TBC82.

4.1.7 SPS and MCCS Floor Space (I.S1L.LFAA_INFRA-AUS.009)

Interface I.S1L.LFAA-INFRA-AUS.009 is a composite interface. Table 4-4 shows its sub interfaces, and the interfacing products and location of each.

Table 4-4: Sub-interfaces for I.S1L.LFAA_INFRA-AUS.009

Interface identifier	LFAA Product	INAU Product	Location
I.S1L.LFAA_INFRA-AUS.009A	SPS Cabinet (populated)	CPF and RPFs	CPF, RPF
I.S1L.LFAA_INFRA-AUS.009B	MCCS Compute Processor	CPF	CPF
I.S1L.LFAA_INFRA-AUS.009C	DDBH Cabinet	CPF	CPF
I.S1L.LFAA_INFRA-AUS.009D	Muxponder	Outer 10 RPFs	RPF (outer 10)
I.S1L.LFAA_INFRA-AUS.009E	Splice Cabinet	CPF and RPFs	CPF, RPF

086 The LFAA cabinet positions within remote processing facilities (RPFs) are defined in [AD5].

085 The LFAA cabinet positions within the central enclosed floor area (CPF cabinet room) are defined in [AD7].

5 Safety

There are no safety critical aspects to considered specifically regarding the interfaces defined in this ICD other that are already covered by AS3000 [RD1].

There are no safety-critical signalling interfaces between the LFAA and INAU elements.

6 Test, diagnostic or Maintenance Features

There will be a requirement to test the power at each power delivery point both in the field and at each power point in the CPF and RPFs in a safe manner to confirm the correctness of the power outlet.

6.1 Requirements

The LFAA to INAU mechanical interface shall comply with SKA Phase 1 System Requirement Specification Earthquakes Requirements SYS-REQ-2491 and SYS_REQ-2650.

6.2 Alarm Events

All notifications of alarm events (e.g. loss of power, failure of cooling system, overheating, fire etc.) will be provided via the TM element i.e. there will be no direct signalling of alarm events between the two interface parties. If an alarm event is detected, appropriate actions to safeguard personnel, equipment and infrastructure will be taken as well as notifying TM.

7 Interface Verification

There will be a test and evaluation plan for all the aspects of the interface including:

- Prepared Ground for antennas.
- Power requirements for antennas and processing facilities.
- Physical robustness of power cables for all environmental aspects.
- Power capabilities and requirements.
- RFI protection.

7.1 Verification Stages

The Interface validation and verification process occurs in at least three stages:

a) Review: Validation and verification of the interface control document through formal reviews during the design phase. This stage is the responsibility of the leading party in collaboration with the SKA Office, using models and analysis methods which they themselves define.

b) Standalone: Verification of the interface implementation by individual sub-elements during their design qualification phase by means of exercising the interface with the use of test equipment and/or simulators. This verification is the responsibility of the individual sub-elements, under the supervision of the Element System Engineering team.

c) Integration: Verification of the interface during integration of the elements, as part of system integration testing. This verification is the joint responsibility of the system AIV team and the leading party. This stage has two phases – a formal Acceptance verification made at Element level and in isolation, followed by a carefully controlled sequence of making and verifying made interfaces as part of integration.

7.2 Element Interface Requirements

Requirements to implement each of the definitions defined in this document, designated with XXX, shall be created for each of the elements on either side of the boundary. These requirements shall be verified as part of the Assembly, Integration and Test activity for each element. Therefore, when the two elements either side of the boundary are integrated with one another the interface should work.

The LFAA – INAU building interfaces cannot be tested in isolation. The infrastructure needs to be available first and can be inspected prior to installing the LFAA equipment within the CPF and RFPs.

The various inspections and tests for all the interfaces covered in this document are defined in Table 7-1.

Table 7-1: Verification List

Interface ID	Parameter	Verification Methodology
001	Deployment of antennas	Inspection by measurement
002	Prepare ground level	Inspection by measurement
003	Prepared ground and mesh	Inspection
004	Remote Processing Facilities (RPF)	Inspection
005	Number of RPF	Inspection
006	Positioning of RPF	Inspection by measurement
007	RPF SPS cabinet positions	Inspection by measurement
008	RPF SPS cabinet physical characteristics	Inspection by measurement
009	Cabinet clearance	Inspection by measurement
010	RPF access	Inspection
011	Housing standard	Test Certificate
012	RfoF routed length	Inspection by measurement
021	CPF cabinet Positions	Inspection
022	CSP and RPFs to house cabinets	Inspection
023	Power connection points	Inspection
024	CPF cabinet physical characteristics	Inspection by measurement
025	Cabinet clearance	Inspection by measurement
027	CPF cabinet room area temperature	Test by monitoring
029	CPF cabinet room humidity	Test by monitoring
030	CPF access	Inspection
	Field Node Input Power	**(I.S1L.LFAA_INFRA-AUS.001)**
040	Power connection	Testing
041	Power consumption	Testing
045	Low voltage electrical protection	Testing
046	Power supply characteristics	Testing
047	Consumer load parameters	Tested as part of Final Acceptance
	Fibre Cable Assembly Interface & Routing	**(I.S1L.LFAA_INFRA-AUS.002)**
050	Trenching	Inspection
	Prepared Ground Interface	**(I.S1L.LFAA_INFRA-AUS.003)**
055 056	Prepared ground preparation	Inspection
057 058	Field node slope (N-S and E-W)	Inspection by measurement

	Fibre Cable Assembly Ingress	**(I.S1L.LFAA_INFRA-AUS.004)**
017	RfoF RPF ingress number of cables	Inspection
018	Splitting of core RfoF cable – for waveguide	Inspection
031	RfoF CPF ingress number of cables	Inspection
051	Waveguide delivery	Inspection
62	Cable trays	Inspection
	LFAA Cabinet Power	**(I.S1L.LFAA_INFRA-AUS.005)**
065	Power connection points	Inspection
066	Power sockets	Inspection
067	Power socket type	Inspection
070	Power supply quality characteristics	Testing
071	Consumer load parameter	Tested as part of Final Acceptance
072	Power supply characteristics	Testing
073	Power consumption	Testing
074	Power and cooling plant capacity	Tested as part of Final Acceptance
076	Uninterruptable power supply	Tested as part of Final Acceptance
077	Low voltage protection	Tested as part of Final Acceptance
078	Power cables	Inspection
	Routing 10 MHz Clock Cables	**(I.S1L.LFAA_INFRA-AUS.006)**
120	10 MHz clock cables routing	Tested as part of Final Acceptance
	Routing 1 PPS Cables	**(I.S1L.LFAA_INFRA-AUS.007)**
122	1 PPS cables routing	Tested as part of Final Acceptance
	Cabinet Cooling Fluid	**(I.S1L.LFAA_INFRA-AUS.008)**
079	Cooling water	Inspection
080	Cooling fluid characteristics	Inspected my measurements
083	Cooling capacity	Tested
	CPF and RPF Floor Space	**(I.S1L.LFAA_INFRA-AUS.009)**
086	RPF Cabinet positions	Inspection by measurement
111	RPF Shielding	Tested as part of INAU verification
085	Cabinet positions	
110	CPF Shielding	Tested as part of INAU verification

8 List of TBDs and TBCs

A summary of the unknowns is tabulated alongside the dataset owner and proposed date of completion (Table 8-1:):

Table 8-1: Summary of Outstanding Interface Definitions

No	Reference	Description	Owner	Due Date
TBC81		DDBH Cabinet average power consumption and thermal load		
TBC82		DDBH Muxponder RPF average power consumption and thermal load		
TBD93		Length of Fibre Cable Assembly required		
TBD94		Reference INAU document for length of Fibre Cable Assembly required		
TBC95		Number of FCAs per Splice Cabinet		
TBC98		MCCS Cabinet average power consumption and thermal load		

9 Known Issues

- The names of INAU products in Table 1-1, Table 4-1, Table 4-2, Table 4-3, and Table 4-4 should be replaced with the names according to the INAU PBS.
- Update Table 7-1: Verification List