Antenna Electronics Environmental Control System: Preliminary Technical Requirements

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1 Introduction

1.1 Purpose

This document aims to present a set of technical requirements for the reference design of the ngVLA Antenna Electronics Environmental Control System. These parameters determine the overall form and performance of the environmental control of the antenna electronics. Many requirements flow down from the preliminary ngVLA System Requirements [AD02], which in turn flow down from the preliminary ngVLA Science Requirements [AD01].

1.2 Scope

The scope of this document is the environmental control for the ngVLA antenna electronics. This consists of temperature control of all electronics enclosures as well as protecting electrical components at the antenna from the environment. It includes interface requirements that must be defined. This requirements document establishes the performance, functional, design, and test requirements applicable to the environmental control for the ngVLA antenna electronics.

2 Related Documents & Drawings

2.1 Applicable Documents

The following documents are applicable to this Technical Specification to the extent specified. In the event of conflict between the documents referenced herein and the content of this Technical Specification, the content of this Technical Specification shall be considered as a superseding requirement.

Ref. No.	Document Title	Rev/Doc. No.
AD01	ngVLA Science Requirements	020.10.15.00.00-0001-REQ
AD02	ngVLA Preliminary System Requirements	020.10.15.10.00-0003-REQ
AD03	ngVLA Electronics Environmental Control System: Reference Design Description	020.30.60.00.00-0002-DSN
AD04	Insulation Coordination for Equipment within Low-Voltage Systems	IEC-60664
AD05	Enclosures for Electrical Equipment (1000 Volts Maximum)	NEMA 250
AD06	System Environmental Specifications	020.10.15.10.00-0001-SPE

2.2 Reference Documents

The following references provide supporting context:

Reference No.	Document Title	Rev/Doc. No.
RD01	System EMC Compatibility and RFI Mitigation Requirements	020.10.15.10.00-0002-REQ
RD02	ngVLA Cryogenic Subsystem Requirements	020.30.10.00.00.0001-REQ
RD03	ngVLA Integrated Receivers and Downconverters: Preliminary Technical Requirements	020.30.15.00.00-0001-REQ
RD04	ngVLA Water Vapor Radiometer Preliminary Technical Requirements	020.45.00.00.00-0001-REQ
RD05	ngVLA Front End Technical Requirements	020.30.03.01.00-0001-REQ

3 Overview of Antenna Electronics Environmental Control System Technical Requirements

3.1 Document Outline

The functional and performance specifications, along with detailed explanatory notes, are found in Section 4. The notes contain elaborations regarding the meaning, intent, and scope of the requirements. These notes form an important part of the definition of the requirements and should guide the verification procedures.

In many cases, the notes contain an explanation or an analysis of how the numeric values of requirements were derived. Where numbers are not well substantiated, this is also documented in the notes. In this way, the required analysis and trade-space available is apparent to scientists and engineers who will guide the evolution of the ngVLA Antenna Electronics Environmental Control System.

Requirements pertinent to interfacing systems are described in Section 5. Initial requirements are noted by interface, along with identified parameters for Interface Control Documents (ICDs) that will fully define the interfaces as the design progresses. Subsystem requirements appear in Section 6.

Safety requirements applicable to both the design phase and the functional environmental control of the antenna electronics are described in Section 7. Additional requirements for the design phase are described in Section 8. Documentation requirements for both technical design documentation and software are provided in Section 9.

Requirements for Verification and Test, from the conceptual design through to prototype, are described in Section 10.

Section 11 identifies Key Performance Parameters (KPP) that should be estimated and monitored throughout the design phase. These are metrics to assist in the trade-off analysis of various concepts, and help identify and resolve tensions between requirements as the design progresses.

3.2 Project Background

The Next Generation Very Large Array (ngVLA) is a project of the National Radio Astronomy Observatory (NRAO) to design and build an astronomical observatory that will operate at centimeter wavelengths (25 to 0.26 centimeters, corresponding to a frequency range extending from 1.2 GHz to 116 GHz). The observatory will be a synthesis radio telescope constituted of reflector antennas of 18 meters diameter and 6 meters diameter, operating in a phased or interferometric mode.

The signal-processing center of the array will be located at the Very Large Array site, on the plains of San Agustin, New Mexico. The array will include stations in other locations throughout the state of New Mexico, west Texas, eastern Arizona, and northern Mexico.

Operations will be conducted from both the VLA Control Building and the Domenici Science Operations Center in Socorro, NM.

3.3 General Antenna Electronics Environmental Control System Description

Antenna electronics are located in various places around the antenna. Primary locations include, but are not limited to, the electronics rack in the pedestal room, front end enclosures on the feed arm, the WVR enclosure along the edge of the primary reflector, and the compressor platform at the top-rear of the pedestal. Environmental control of the antenna electronics involves temperature control of all electronics in these locations as well as protection from water, dust, animals, or other environmental hazards.

The primary temperature control system consists of a heated and cooled liquid loop, most likely glycol, which runs from the compressor at the top-rear of the pedestal to the WVR module and the front end enclosures. Liquid cold plates, made of copper tubing running through an aluminum block which components may be directly mounted to, will cool electronics in both the front end enclosures and the WVR, as well as heat or cool components on the compressor platform. The pedestal room electronics rack will be forced-air-cooled via a commercial air conditioning unit which will likely mount to the side of the rack and be purchased from the rack manufacturer.

Protection from water, dust, animals, or other environmental hazards will be accomplished with custom sealed enclosures for the front end, WVR, and Cryo M&C enclosure. The electronics rack in the pedestal room will be protected from such hazards by the antenna structure.

3.4 Summary: Antenna Electronics Environmental Control System Requirements

The following table provides a summary of the major requirements in order to provide the reader with a high-level view of the desired system. Should there be a conflict between the requirements listed here and the descriptions in Sections 4 through 10, the latter shall take precedence.

3.4.1 General Functional Specifications

Parameter	Summary of Requirement	Reference Reqs.
Front End Receiver Enclosure	NEMA 4X [AD05], Cooled per [RD05]	020.30.03.01.00-0001-REQ ngVLA Front End Technical Requirements
Front End Auxiliary Enclosure	NEMA 4X [AD05], Cooled per [RD02]	020.30.10.00.00-0001-REQ ngVLA Cryogenic Subsystem Requirements
WVR Receiver Enclosure	NEMA 4X [AD05], Cooled per [RD04]	020.10.15.10.00-0001-SPE System-Level Environmental Specifications
Compressor Platform	Cooled/heated per [RD02]	020.30.10.00.00-0001-REQ ngVLA Cryogenic Subsystem Requirements
Pedestal Room Rack	Cooled as required	020.10.15.10.00-0001-SPE System-Level Environmental Specifications

4 Environmental Control System Functional and Performance Requirements

These requirements apply to a properly functioning system, under normal operating environmental conditions, unless otherwise stated.

4.1 Functional Requirements

Parameter	Req. #	Value	Traceability
Front End Enclosure	EEC0100	The environmental control system shall provide a protective enclosure meeting NEMA 4X standards for the front end receivers and ancillary equipment mounted on the feed indexing mechanism.	020.30.03.01.00-0001-REQ Front End Technical Requirements
Front End Auxiliary Enclosure	EEC0101	The environmental control system shall provide a protective enclosure meeting NEMA 4X standards for the vacuum pump and ancillary equipment mounted adjacent to the feed indexing mechanism.	020.30.10.00.00-0001-REQ Cryogenic Subsystem Requirements
WVR Enclosure	EEC0102	The environmental control system shall provide a protective enclosure meeting NEMA 4X standards for the WVR front-end electronics mounted to the feed arm adjacent to the main reflector.	020.10.15.10.00-0001-SPE System-Level Environmental Specifications
Front End Enclosure Thermal Regulation	EEC0103	The front end enclosure shall provide an active heat exchanger service for heat-generating electronics within the enclosure.	020.30.03.01.00-0001-REQ ngVLA Front End Technical Requirements
Front End Auxiliary Enclosure Thermal Regulation	EEC0104	The front end auxiliary enclosure shall provide an active heat exchanger service for heat-generating electronics within the enclosure.	020.30.10.00.00-0001-REQ ngVLA Cryogenic Subsystem Requirements
WVR Enclosure Thermal Regulation	EEC0105	The WVR enclosure shall provide an active heat exchanger service for heat-generating electronics within the enclosure.	020.10.15.10.00-0001-SPE System-Level Environmental Specifications
Compressor Enclosure Thermal Regulation	EEC0106	The environmental control system shall provide an active heat exchanger service for heat-generating electronics within the compressor enclosure.	020.30.10.00.00-0001-REQ ngVLA Cryogenic Subsystem Requirements

Parameter	Req. #	Value	Traceability
Pedestal Room Rack Thermal Regulation	EEC0107	The environmental control system shall provide an active forced-air heat exchanger service for heat-generating electronics in the pedestal room rack.	020.10.15.10.00-0001-SPE System-Level Environmental Specifications

4.2 Additional Requirements

Parameter	Req. #	Value	Traceability
Vibration	EEC0152	All Antenna Electronics Environmental Control exposed equipment, including all equipment within the antenna, shall be designed to withstand persistent wind-induced vibration.	020.10.15.10.00-0001-SPE System-Level Environmental Specifications ENV0531
Dust	EEC0153	All Antenna Electronics Environmental Control exposed equipment shall be protected against windblown dust, ashes, and grit.	020.10.15.10.00-0001-SPE System-Level Environmental Specifications ENV0541
Rodents	EEC0154	All Antenna Electronics Environmental Control exposed equipment shall be designed to prevent rodent damage. At a minimum, this may involve protecting all cables with flexible or rigid conduit or equivalent. Any penetrations within enclosures and raceways shall mitigate the risk of rodent damage.	020.10.15.10.00-0001-SPE System-Level Environmental Specifications ENV0551

4.2.1 Operating Conditions

Parameter	Req.#	Value	Traceability
Solar Thermal Load	EEC0250	Antenna Electronics Environmental Control equipment shall provide needed environmental conditioning to the antenna electronics while meeting the condition: Exposed to full Sun.	020.10.15.10.00-0001-SPE System-Level Environmental Specifications ENV0321
Wind Speed	EEC0251	Antenna Electronics Environmental Control equipment shall provide needed environmental conditioning to the antenna electronics while meeting the condition: W ≤ 15 m/s average over 10 min. W ≤ 20 m/s gust.	020.10.15.10.00-0001-SPE System-Level Environmental Specifications ENV0322
Outdoor Temperature	EEC0252	Antenna Electronics Environmental Control equipment shall provide needed environmental conditioning to the antenna electronics while meeting the condition: –20 C ≤ T ≤ 45 C	020.10.15.10.00-0001-SPE System-Level Environmental Specifications ENV0323

Parameter	Req.#	Value	Traceability
Outdoor Temperature Rate of Change	EEC0253	Antenna Electronics Environmental Control equipment shall provide needed environmental conditioning to the antenna electronics while meeting the condition: $\Delta T = 3.6^{o}C/hr.$	020.10.15.10.00-0001-SPE System-Level Environmental Specifications ENV0324
Precipitation	EEC0254	Antenna Electronics Environmental Control equipment shall provide needed environmental conditioning to the antenna electronics while meeting the condition: 5 cm/hr. precipitation. (TBC)	020.10.15.10.00-0001-SPE System-Level Environmental Specifications
Cooling Temp Front End Enclosure	EEC0255	The Front End enclosure shall provide needed environmental conditioning to provide an internal operational temperature range of –15 to $35^{o}C$; with a temp gradient of less than $3.6^{o}C/hr.$	020.30.15.00.00-0001-REQ
Cooling Temp Front End Auxiliary Enclosure	EEC0256	The Front End Auxiliary enclosure shall provide needed environmental conditioning to provide an internal operational temperature range of 12 to $45^{o}C$	020.30.10.00.00.0001-REQ
Cooling Temp-Compressor Platform	EEC0257	Antenna Electronics Environmental Control components shall provide needed environmental conditioning to provide an internal operational temperature range, within the compressor enclosure, of –30 to $45^{o}C$	020.30.10.00.00.0001-REQ
Heat Exchanger Service Temperature	EEC0258	The Heat Exchanger Service provided to various locations around the antenna shall maintain an operational temperature >28 C; with a temp grad. Of less than $0.1^{o}C/hr.$	020.45.00.00.00-0001-REQ

This section describes the operating conditions under which the environmental control system is expected to meet its full specification. This environmental definition is consistent with the limit to the operating conditions in [AD06].

4.2.2 Survival Conditions

Parameter	Constraints	Value	
Wind	EEC0350	Antenna Electronics Environmental Control equipment shall survive wind speeds of 0 m/s ≤ W ≤ 50 m/s average	020.10.15.10.00-0001-SPE System-Level Environmental Specifications ENV0341
Temperature	EEC0351	Antenna Electronics Environmental Control equipment and the electronics they house shall survive outdoor temperatures of –30 C ≤ T ≤ 50 C	020.10.15.10.00-0001-SPE System-Level Environmental Specifications ENV0342
Radial Ice	EEC0352	Antenna Electronics Environmental Control equipment and the electronics they house shall survive radial ice of 2.5 cm	020.10.15.10.00-0001-SPE System-Level Environmental Specifications ENV0343
Snow Load – Equipment	EEC0354	Antenna Electronics Environmental Control equipment and the electronics they house shall survive snow loads of 100 kg/m^2 on horizontal surfaces.	020.10.15.10.00-0001-SPE System-Level Environmental Specifications ENV0345
Hail Stones	EEC0355	Antenna Electronics Environmental Control equipment and the electronics they house shall survive hail stones of 2.0 cm diameter	020.10.15.10.00-0001-SPE System-Level Environmental Specifications ENV0346

The survival conditions describe the environment that the antenna and all outside structures should be able to withstand without damage when placed in its least-vulnerable state. For the antenna, the designer will specify the orientation that will result in minimum stress to the structure at the maximum wind speed and maximum snow and ice loading. Systems housed within or on the antenna (including the environmental control system) shall assume this orientation.

The temperature limits, radial ice, snow load and hail stone requirements are based on experience at the VLA site and a survey of conditions throughout the extent of the array.

4.2.3 Solar Radiation

Parameter	Req. #	Value	Traceability
Solar Flux	EEC0360	All environmental control equipment exposed to outside environment shall be designed to allow normal operations given the condition: a maximum diurnal solar flux of 1200 W/m^2 from 0.3–60 μm.	020.10.15.10.00-0001-SPE ENV0561
UV Radiation	EEC0361	All environmental control equipment exposed to outside environment shall be designed to allow normal operations, over the full operating life of the array, given the condition: a maximum diurnal UV radiated flux of 100W/m^2 from 280–400 nm.	020.10.15.10.00-0001-SPE ENV0562

4.2.4 Rain/Water Infiltration

Parameter	Req. #	Value	Traceability
Rain/Water Infiltration	EEC0450	All environmental control exposed equipment shall be designed to withstand rainfall intensity up to 10 cm/hr., with droplets sized 0.5 to 4.5mm, at wind velocity of 18 m/s from the vertical to horizontal direction, while protecting any housed equipment.	020.10.15.10.00-0001-SPE ENV0571

4.2.5 Mechanical Shock

Parameter	Req. #	Value	Traceability
Transportation Environment	EEC0500	All environmental control equipment shall be designed to withstand typical loads and environments encountered during transportation as part of assembly or maintenance.	020.10.15.10.00-0001-SPE ENV0581
Mechanical Shocks	EEC0501	All environmental control equipment shall be designed to survive mechanical shock levels from handling as defined in Table 1 of AD06.	020.10.15.10.00-0001-SPE ENV0582

4.3 Maintenance and Reliability Requirements

Parameter	Req. #	Value	Traceability
Mean Time Between Failures	EEC0550	The Electronics Environmental Enclosures shall be designed to have a MTBF ≥ TBD hrs.	020.10.15.10.00-0003-REQ SYS2302

The maintenance and reliability requirements are in support of high-level requirements that limit the total operating cost of the array.

Monitor points/sensors should be included in the MTBF/MTTR analysis, but sensors and other components that can be reasonably deemed to be ancillary to operation may be removed from the determination of compliance with the MTBF requirement. "Failure" will be defined as a condition which places the system outside of its performance specifications or into an unsafe state, requiring repair.

4.4 Monitor and Control Requirements

Parameter	Req. #	Value	Traceability
Self-Monitoring	EEC0600	The Electronics Environmental Enclosures shall measure, report, and monitor a set of parameters that allow for determination of its status and may help predict or respond to failures.	020.10.15.10.00-0003-REQ SYS2701

The expectation with self-monitoring is that the monitor and control system expose lower-level sensors to the monitor and control system when queried. The cadence of access is flexible, and is not expected at high rates (typical access might be on second to minute scales). Any high-cadence monitoring should

generally be internal to the Antenna Electronics Environmental Control System with a summary output on the interface.

Other features of the M&C interface are to be specified in the Monitor and Control ICD.

4.5 Lifecycle Requirements

Parameter	Req. #	Value	Traceability
Design Life	EEC0650	The Electronics Environmental Enclosures shall be designed to be operated and supported for a period of 20 years.	020.10.15.10.00-0003-REQ SYS2801
Lifecycle Optimization	EEC0651	The Electronics Environmental Enclosures design shall minimize its lifecycle cost for 20 years of operation.	020.10.15.10.00-0003-REQ SYS2802

Lifecycle costs include manufacturing, transportation, construction/assembly, operation, and decommissioning.

5 Interface Requirements

This section provides information about the interfaces of the Antenna Electronics Environmental Control System. Interface Control Documents (ICDs) are required between the Antenna Electronics Environmental Control system and all connecting systems. In many cases, specifications for the interfaces are not yet available, but the broad scope of the ICD can be defined.

These interfaces shall be developed and documented by the Antenna Electronics Environmental Control system designer, and approved by ngVLA, as part of the Antenna Electronics Environmental Control system reference and conceptual design efforts, and updated throughout the design. Post CoDR, the ICD shall only be updated through formal project change control processes.

6 Subsystem Requirements

Derivation of any subsystem requirements will be included as part of the Antenna Electronics Environmental Control system conceptual design efforts, and updated throughout the design. Post CoDR, the subsystem requirements will only be updated through formal project change control processes.

7 Safety

7.1 General

7.2 Safety Design Requirements

7.2.1 Electrical Safety

Electrical equipment installed on the antenna shall comply with their relevant international or US product standard.

Electrical installations and equipment shall be specifically built and/or derated in order to safely perform their intended functions under the applicable environmental conditions. Insulation shall be coordinated in conformity with IEC 60664 while taking into account the altitude of up to 2500 m above sea level.

7.2.2 Handling, Transport, and Storage Safety

The design of the Antenna Electronics Environmental Control system shall incorporate all means necessary to preclude or limit hazards to personnel and equipment during assembly, disassembly, test, and operation. A safety hazard analysis shall be completed prior to the system CoDR.

8 Requirements for Design

8.1 Analyses and Design Requirements

8.1.1 Reliability, Availability, Maintainability Analysis

A Reliability, Availability, Maintainability analysis shall be performed in order to locate weak design points and to determine whether the design meets the Maintenance and Reliability requirements. ngVLA suggests to apply the Parts Count Method for predicting the reliability of the system as described in the MIL-HDBK-217F, but the designer may propose to use other methods. For non-electronic parts, the values of NPRD-95 may be used, or data from manufacturers or other databases may be used.

Another, but more time consuming (and considered more accurate) method, the Parts Stress Analysis Prediction, is also described in MIL-HDBK-217F. This may be used if the result of the Parts Count Method does not comply with the Maintenance and Reliability requirements.

The ngVLA equipment will typically operate at an elevation of 2200m above sea level, where temperature and pressure might decrease the MTBF relative to that at low elevations. These conditions shall be taken into specific account in the reliability prediction by using the environmental factor given in MIL-HDBK-217F.

The analysis shall result in estimates of the Mean Time Between Failures (MTBF), the Mean Time To Repair (MTTR), assuming that any scheduled preventive maintenance is performed.

8.2 Electromagnetic Compatibility Requirements

The ngVLA Antenna Electronics Environmental Control System elements shall exhibit complete electromagnetic compatibility (EMC) among components (intra-system electromagnetic compatibility).

8.3 Materials, Parts and Processes

8.3.1 Fasteners

All fasteners shall be metric where reasonably possible.

8.3.2 Paints

Any painted coatings shall be chosen to last at least 20 years without repainting.

8.3.3 Surface Treatment

Any unpainted surfaces shall be treated against corrosion.

8.3.4 Name Plates and Product Marking

As a general rule the main parts and all exchangeable units shall be equipped with nameplates which are visible after installation of the part/unit and which contain the following information:

- Part/unit name
- Drawing number including revision
- Serial number
- Manufacturing month and year
- Name of manufacturer

Alternatively, a system of marking based on barcodes or similar system may be used upon approval by ngVLA. For any Line Replaceable Units (LRUs; see Section 12.2), it is highly desirable that the serial number of the LRU be ascertainable over the monitor and control interface (see Section 4.4).

8.3.5 Labels

All cables and switches, junction boxes, sensors, and similar equipment shall be labeled using a marking based on barcodes.

9 Documentation Requirements

9.1 Technical Documentation

All documentation related to the antenna electronics environmental control system shall meet the following requirements:

- The language used for written documentation shall be English.
- Drawings shall be generated according to ISO standards and use dual metric and imperial units.
- Layouts of electronic circuits and printed circuit boards shall also be provided in electronically readable form. The ngVLA preferred formats are Altium Designer files for electronic circuit diagrams and printed circuit board layouts.
- The electronic document formats are Microsoft Word and Adobe PDF.
- The preferred CAD system used is AutoDesk Inventor and/or AutoCAD (discouraged).

Any deviation from the above shall be agreed to by the ngVLA project office.

9.2 Software and Software Documentation

The Antenna Electronics Environmental Control System software and any other specially developed software (SW), are deliverables. The SW shall be delivered in source and object form, together with all procedures and tests necessary for compilation, installation, testing, upgrades, and maintenance.

- Software must be tagged with suitable version numbers that allow identification (also on-line remotely) of a release.
- User manuals of software developed under this specification and of any other commercial software used (controllers embedded software, special tools, etc.) shall be provided.
- Software maintenance and installation upgrade documentation shall be provided.
- Full Test and Acceptance procedures shall be documented.

10 Verification and Quality Assurance

The design may be verified to meet the requirements by design (D), analysis (A) inspection (I), a factory acceptance test (FAT) or a site acceptance test (SAT). The definitions of each are given below.

Verification by Design: The performance shall be demonstrated by a proper design, which may be checked by the ngVLA project office during the design phase by review of the design documentation.

Verification by Analysis: The fulfillment of the specified performance shall be demonstrated by appropriate analysis (hand calculations, finite element analysis, thermal modeling, etc.), which will be checked by the ngVLA project office during the design phase.
Verification by Inspection: The compliance of the developed item is determined by a simple inspection or measurement.

Verification by Factory Acceptance Test: The compliance of the developed item/assembly/unit with the specified performance shall be demonstrated by tests. A FAT is performed w/o integration with interfacing systems.

Verification by Site Acceptance Test: The compliance of the developed item/assembly/unit with the specified performance shall be demonstrated by tests. SAT is performed on-site with the equipment as installed.

Multiple verification methods are allowed. The following table summarizes the expected verification method for each requirement.

Req. #	Parameter/Requirement	D	A	I	FAT	SAT
EEC0100	Front End Enclosure	X				
EEC0101	Front End Auxiliary Enclosure	X				
EEC0102	WVR Enclosure	X				
EEC0103	Front End Enclosure Thermal Regulation	X				
EEC0104	Front End Auxiliary Enclosure Thermal Regulation	X				
EEC0105	WVR Enclosure Thermal Regulation	X				
EEC0106	Compressor Enclosure Thermal Regulation	X				
EEC0107	Pedestal Room Rack Thermal Regulation	X				
EEC0152	Vibration	X				
EEC0153	Dust	X				
EEC0154	Rodents	X				
EEC0250	Solar Thermal Load		X			
EEC0251	Wind Speed	X				
EEC0252	Outdoor Temperature		X			
EEC0253	Outdoor Temperature Rate of Change		X			
EEC0254	Precipitation	X				
EEC0255	Cooling Temp Front End Enclosure		X			
EEC0256	Cooling Temp Front End Auxiliary Enclosure		X			
EEC0257	Cooling Temp-Compressor Platform		X			
EEC0258	Heat Exchanger Service Temperature		X		X	X

Req. #	Parameter/Requirement	D	A	I	FAT	SAT
EEC0350	Wind	X				
EEC0351	Temperature	X				
EEC0352	Radial Ice	X	X			
EEC0354	Snow Load – Equipment		X			
EEC0355	Hail Stones		X			
EEC0360	Solar Flux		X			
EEC0361	UV Radiation		X			
EEC0450	Rain Infiltration				X	
EEC0500	Transportation Environment		X			
EEC0501	Mechanical Shocks		X			
EEC0550	Mean Time Between Failures		X			
EEC0600	Self-Monitoring			X		
EEC0650	Design Life	X				
EEC0651	Life Cycle Optimization		X			

Table 1 - Expected requirements verification method.

11 Key Performance Parameters

This section provides Key Performance Parameters that should be estimated by the designer and monitored by NRAO throughout the design phase of the project. These are parameters that have a large influence on the eventual effectiveness of the facility, and are useful high-level metrics for trade-off decisions.

The technical requirements are generally specified as *minimum* values. The goal is to give the designer some latitude in optimization for a balanced design. Understanding the anticipated performance of the Antenna Electronics Environmental Control System (not just its specified minimum) on these parameters is of value for system-level analysis and performance estimation.

These parameters may also be useful for determining the relative priority of the requirements documented in Section 4 and can assist in the required analysis should tensions be identified between requirements, or reductions in capability be required to fit within cost constraints.

The Key Performance Parameters that have been identified for monitoring are described in Table 9. Note that the order in the table reflects the order in the document, and is not indicative of relative importance or priority.

Key Performance Parameter	Req. #
Front End Receiver Enclosure Temp. Reg.	EEC0255
Heat Exchanger Service Temperature Reg.	EEC0258
Mean Time Between Failures	EEC0550

Table 2 - Key Performance Parameters for monitoring during design.

12 Appendix

12.1 Abbreviations and Acronyms

Acronym	Description
AD	Applicable Document
CoDR	Conceptual Design Review
CFD	Computational Fluid Dynamics
EM	Electro-Magnetic
EMC	Electro-Magnetic Compatibility
EMP	Electro-Magnetic Pulse
HVAC	Heating, Ventilation & Air Conditioning
ICD	Interface Control Document
IF	Intermediate Frequency
KPP	Key Performance Parameters
LRU	Line Replaceable Unit
MTBF	Mean Time Between Failure
MTTF	Mean Time To Failure
MTTR	Mean Time To Repair
ngVLA	Next Generation VLA
RD	Reference Document
RFI	Radio Frequency Interference
SAC	Science Advisory Council
SWG	Science Working Group
TAC	Technical Advisory Council
TBD	To Be Determined
VLA	Jansky Very Large Array

12.2 Maintenance Definitions

12.2.1 Maintenance Approach

Required maintenance tasks shall be minimized.

Maintenance shall be mainly performed at assembly and subassembly level by exchange of Line Replaceable Units (LRUs). LRUs are defined as units that can be easily exchanged (without extensive calibration, of sufficient low mass and dimension for easiness of handling, etc.) by maintenance staff of technician level.

LRU exchange shall be possible by two trained people within four working hours. It is desirable that LRU replacement be possible using only standard tools identified in a maintenance manual for the Electronics Environmental Enclosures.

A step-by-step procedure for safe exchange of every LRU shall be provided in the Maintenance Manual.

LRUs shall be defined by the Antenna Electronics Environmental Control System designer, depending on the design. The LRUs will be maintained by the ngVLA project (with or without industrial support).

12.2.2 Periodic Preventive Maintenance

Preventive maintenance may be performed at planned intervals in order to keep the Antenna Electronics Environmental Control System operational and within its specified performance. Any required preventive maintenance should be documented in the Maintenance Manual.