Bins, Modules, and Racks Work Package: 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 Bins, Modules, and Racks work package. Many requirements flow down from the preliminary ngVLA System Requirements [AD02], which in turn flow-down from the preliminary ngVLA Science Requirements [AD01].

The Science goals are presently being elaborated by the Science Advisory Council (SAC) and Science Working Groups (SWGs), and are captured in a series of draft use cases. A preliminary analysis of these use cases, and the flow down recursively to the science, system and subsystem requirements, are reflected in this draft.

1.2 Scope

The scope of this document is the ngVLA Bins, Modules, and Racks work package. This consists of any modular unit housing electronic components within the Antenna and the bins in which they are mounted.

This requirements document establishes the performance, functional, design, and test requirements applicable to the ngVLA Bins, Modules, and Racks. It also includes interface requirements that must be defined.

2 Related Documents and 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.

Reference 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 Operations Concept	020.10.05.00.00-0002-PLA
AD04	ngVLA System Electromagnetic Compatibility and Radio Frequency Interference Mitigation Requirements	020.10.15.10.00-0002-REQ
AD07	Insulation Coordination for Equipment within Low-Voltage Systems	IEC 60664
AD08	Occupational Safety and Health Standards for General Industry	29 CFR Part 1910
AD10	Military Handbook, Reliability Prediction of Electronic Equipment	MIL-HDBK-217F
AD11	Non-electronic Parts Reliability Data	NPRD-95
AD12	Electromagnetic Compatibility	IEC 61000-3-5

2.2 Reference Documents

The following references provide supporting context:

Reference No.	Document Title	Rev / Doc. No.
RD01	Cabinets, Racks, Panels, and Associated Equipment	EIA/ECA-310 Rev. E

3 Overview of the Bins, Modules, and Racks Technical Requirements

3.1 Document Outline

This document presents the technical requirements of the ngVLA Bins, Modules, and Racks work package. These parameters determine the overall form and performance of the Bins, Modules, and Racks work package.

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 Bins, Modules, and Racks Work Package concept.

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.

Safety requirements applicable to both the design phase and the functional Bins, Modules, and Racks 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 the 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 array's signal processing center 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 New Mexico, west Texas, eastern Arizona, and northern Mexico. Long baseline stations are located in Hawaii, Washington, California, Iowa, Massachusetts, New Hampshire, Puerto Rico, the US Virgin Islands, and Canada.

3.3 General Bins, Modules, and Racks Description

The Bins, Modules, and Racks work package consists of individual modules (LRUs) housed in a number of bins all inside of an EIA standard electronics rack located in the pedestal room of the antenna. The work package may also include a number of modules and bins in other locations as well. Its key function is to

modularize the electronics, and make assembly and maintenance of the antenna electronics as simple as possible, while providing adequate RFI shielding for the antenna and any other sensitive equipment.

3.4 Summary of Bins, Modules, and Racks Requirements

The following table summarizes major requirements to give the reader a high-level view of the subsystem. Should a conflict arise between requirements listed here and descriptions in Sections 4–10, the latter shall take precedence.

3.4.1 General Functional Specifications

Parameter	Req. #	Summary of Requirement	Traceability
Ease of Access	BMR0001	Must be simple and quick to access contained components.	SYS2403
Ease of Installation	BMR0002	Must be simple and quick to install and uninstall.	SYS2403
RFI Shielding	BMR0003	Must provide RFI shielding where needed.	SYS2106
Heat Dissipation	BMR0004	Must provide a means of expelling heat where needed.	
Volume	BMR0005	Must be configurable to different volumes of electronic components.	SYS2403
Mass	BMR0006	Must be low enough for a single person to lift and manipulate.	SYS2403

3.4.2 Other General Requirements

Parameter	Req. #	Summary of Requirement	Traceability
Corrosion resistance	BMR0101	Must have adequate corrosion prevention.	SYS2801
Hardware	BMR0102	Metric hardware, whenever possible.	
Standardized Components	BMR0103	Modules must be made up of standardized components requiring little alteration to accommodate different systems' needs.	
Minimize External Connectors	BMR0104	The use of as few external connectors as possible is encouraged.	SYS2106
Shielded Connectors	BMR0105	Any connectors entering/exiting any modules or racks must maintain RFI shielding levels.	SYS2106
Meet Specified General Dimensions	BMR0106	General dimensions of machined parts must fit the tolerances outlined in manufacturing drawing of the parts to ensure everything fits together correctly and mounting properly.	
Meet Specified Surface Flatness and Finish	BMR0107	Surface flatness and finish of machined parts must fit those outlined in manufacturing drawing to ensure surface contact for heat transfer spec. RFI is mitigated properly, and parts are kept safe from corrosion.	

4 Functional and Performance Requirements

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

4.1 RF Shielding

Parameter	Req. #	Value	Traceability
Module RF Shielding	BMR0401	>50 dB from 1–30 GHz	SYS2106
Rack RF Shielding	BMR0402	>80 dB from 1–30 GHz	SYS2106

Module and rack required RF shielding levels are not presently defined, and dependent on emission levels within the enclosures, so starting at a conservative level is prudent.

4.2 Environmental Conditions

4.2.1 Normal Operating Conditions

The modules, bins, and racks are not designed to withstand outside environmental conditions. The cost of an outdoor RFI-shielded rack is expected to be significantly higher compared to an indoor shielded rack. Each module, bin, or rack located outside of the pedestal room will reside inside of a separate, environmentally-sealed enclosure.

4.2.2 Specific Environmental Requirements

Parameter	Req. #	Value	Traceability
Rack Cooling	BMR0501	Must be forced-air cooled	
Bins and Module Cooling	BMR0502	Forced air must be directed to only flow through the bins and past the modules and not in the space between the doors or walls of the rack and the modules/bins.	
Rack air inlet temperature	BMR0503	4 ± 2°C	
Maximum air temperature difference from inlet to exit	BMR0504	10°C	

Any rack with heat generating modules contained within it must be able to be cooled with forced air. Typically this means honeycomb filters top and bottom and forced air flows from bottom to top. The forced air system may be an open or closed system.

4.3 Lifecycle Requirements

Parameter	Req. #	Value	Traceability
Design Life	BMR0601	The Bins, Modules, and Racks shall be designed to be operated and supported for a period of 20 years.	SYS2701
Lifecycle Optimization	BMR0602	The Bins, Modules, and Racks design shall minimize its lifecycle cost for 20 years of operation.	SYS2702

Lifecycle costs include manufacture, transport, construction/assembly, operation, and decommissioning.

5 Interface Requirements

This section provides information about the interfaces of the Bins, Modules, and Racks. Interface Control Documents (ICDs) are required between the Bins, Modules, and Racks 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 Bins, Modules, and Racks Designer, and approved by ngVLA, as part of the Bins, Modules, and Racks reference and conceptual design efforts, and updated throughout the design. Post CoDR, the ICD shall only be updated through formal project change control processes.

5.1 Interface between Modules and Bins

The module shall slide into the bin and be secured in such a manner that it is easy and quick to install or remove with minimal hand tools.

5.2 Interface between Bins and Rack

The bins will mount to the standard EIA rack mounting rails and will conform to EIA rack mount standards [RD01].

5.3 Interface between Racks and Antenna

5.3.1 Electrical Interface

The ICD should describe both the mechanical and electrical specifications of the electrical interfaces.

5.3.2 Mechanical Interface

The rack base will be bolted to the floor, and at least one point at the top of the rack will be anchored to a point on a wall or other secure mounting point.

5.3.3 HVAC

The rack will have an HVAC interface at both the top and bottom, for a closed system. This will effectively prevent the ingress of dust and other contaminants, and allow a much longer service interval.

5.4 Interface to the Monitor and Control System

The rack air inlet and exit temperature should be monitored.

6 Safety

6.1 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 [AD07] while taking into account the altitude of up to 2500 m above sea level.

6.2 Handling, Transport, and Storage Safety

The design of the Bins, Modules, and Racks shall incorporate all means necessary to preclude or limit hazards to personnel and equipment during assembly, disassembly, test, and operation.

7 Requirements for Design

7.1 Materials, Parts and Processes

7.1.1 Fasteners

Where reasonably possible, all fasteners shall be metric.

7.1.2 Paints

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

7.1.3 Surface Treatment

Any unpainted surfaces shall be treated against corrosion.

7.1.4 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.

7.1.5 Labels

Racks, bins and modules, and all associated electrical interconnects shall be labeled.

8 Documentation Requirements

8.1 Technical Documentation

All documentation related to the Bins, Modules, and Racks shall meet the following requirements:

- The language used for written documentation shall be English.
- Drawings shall be generated according to ISO standards and use both metric and imperial units.
- Drawings will be archived in Adobe PDF format.
- All CAD source files will be provided.
- The CAD system used is AutoDesk Inventor and/or AutoCAD (not preferred).
- The electronic document formats are Microsoft Word and Adobe PDF.

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

9 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
BMR0313	Machined Part Dimensions	X		X		
BMR0314	Machined Part Surface Flatness/Finish	X		X		
BMR0401	Module RF Shielding				X	
BMR0402	Rack RF Shielding				X	

Table 1 - Expected requirements verification method.

10 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.

These parameters are of higher importance to NRAO. Improved performance above the requirement is desirable on these parameters. The impact on system-level performance is often discussed in the narrative in Section 4.

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 Bins, Modules, and Racks (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 2. 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. #
Module RF Shielding	BMR0401
Rack RF Shielding	BMR0402

Table 2 - Key performance parameters for monitoring during design.

11 Appendix

11.1 Abbreviations and Acronyms

Acronym	Description
AD	Applicable Document
CDR	Critical Design Review
CoDR	Conceptual Design Review
FDR	Final Design Review
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
TAC	Technical Advisory Council
TBD	To Be Determined
VLA	Jansky Very Large Array

11.2 Maintenance Definitions

11.2.1 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 which can be easily exchanged (without extensive calibration, of sufficient low mass and dimension for easiness of handling, etc.) by maintenance staff of technician level. In the context of this subsystem, an LRU is defined as any ARCS module.

LRU exchange shall be possible by 2 trained people within 4 working hours. It is desirable that LRU replacement be possible using only standard tools identified in a maintenance manual for the Bins, Modules, and Racks.

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

11.2.2 Periodic Preventive Maintenance

The ARCS modules require no preventive maintenance. The shielded racks will periodically require replacement of air filters at the HVAC inlet or outlet, where used.