System Environmental Specifications

020.10.15.10.00-0001-SPE

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Change Record

Version	Date	Author	Affected Section(s)	Reason
01	2017-10-02	R. Selina	All	Started first draft; used 020.25.00.00.00-0001-SPE-A as a template; pulling heavily from ALMA-80.05.02.00-001-B-SPE too
02	2017-10-12	R. Selina	1, 3, 4.	Incorporating suggestions from R. Treacy
03	2018-04-12	R. Selina	3.4	Clarified survival rain rate
04	2018-04-18	R. Selina	3.3	Clarified solar loads
04	2018-05-09	R. Selina	2, 3.4, 4.7	Updated survival rain rates
05	2018-05-11	R. Selina		Minor typos
06	2018-09-27	R. Selina	1.3, 3.1	Revised wind in Precision Environment to better reflect San Agustin Plains vs eastern NM used in initial analysis; updated introduction to match Ref. Design
07	2018-10-02	R. Selina	3.1	Revised Normal Environment wind conditions to better reflect San Agustin Plains
A	2019-07-09	A. Lear	All	Prepared document for review & approvals

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1 Introduction

1.1 Purpose

This document aims to present the system-level environmental specification, incorporating a set of definitions and requirements. This specification is a subsection of the preliminary ngVLA System Requirements [AD01], which in turn flow down from the preliminary ngVLA Science Requirements and ngVLA Stakeholder Requirements.

The environmental specification has been broken out into a separate document for ease of reference, since the environmental definitions and requirements shall be incorporated into the requirement specifications of multiple subsystems.

1.2 Scope

The scope of this document is all buildings, infrastructure and equipment that are located at the ngVLA core, as well as outlying stations. All related ngVLA system elements shall be specified to comply with this specification.

1.3 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 approximately 244 reflector antennas each of 18 meters diameter, and 19 reflector antennas each of 6 meters diameter, operating in a phased or interferometric mode.

The facility will be operated as a proposal-driven instrument with the science program determined by Principal Investigator (PI)-led proposals. Data will generally be delivered to PIs and the broader scientific community as Science Ready Data Products; automated pipelines will calibrate raw data and create higher level data products (typically image cubes). Data and quality assured data products will be available through an Observatory science archive. Data exploration tools will allow users to analyze the data directly from the archive, reducing the need for data transmission and reprocessing at the user's institution.

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 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.

Array Operations will be conducted from both the VLA Site and the Array Operations and Repair Centers in Socorro, NM. A Science Operations Center and Data Center will likely be collocated in a large metropolitan area and will be the base for science operations and support staff, software operations, and related administration. Research and development activities will be split amongst these centers as appropriate.

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 the Technical Specification shall be considered as a superseding requirement.

Reference No.	Document Title	Rev/Doc. No.
AD01	ngVLA Preliminary System Requirements	020.10.15.10.00-0003-REQ
AD02	International Standard: Protection Against Lightning	IEC 62305:2010

2.2 Reference Documents

The following references provide supporting context:

Reference No.	Document Title	Rev/Doc. No.
RD01	USGS Coterminous US Seismic Hazard Map – PGA 2% in 50 Years	ftp://hazards.cr.usgs.gov/web/nshm/conterminous/2014/2014pga2pct.pdf
RD02	NOAA ATLAS 14 Point Precipitation Frequency Estimates: NM	https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=nm

3 Definitions of External Environmental Conditions

Based on historical weather data of the VLA site and other public weather databases, the following definitions of environmental conditions are adopted.

3.1 Precision Operating Conditions

Parameter	Req. #	Value
Solar Thermal Load	ENV0311	Nighttime only; no solar thermal load within last 2 hours.
Wind Speed	ENV0312	0 ≤ W ≤ 5 m/s average over 10 mins. 7 m/s peak gusts.
Temperature	ENV0313	–15 C ≤ T ≤ 25 C
Temperature Rate of Change	ENV0314	1.8°C/Hr.
Precipitation	ENV0315	No precipitation.

The precision operating environment defines the conditions under which the system is expected to meet the most stringent requirements and provide optimal system performance. The solar thermal load requirement limits this environment to two hours after sunset through sunrise, so long as the other requirements of this section are met. The two-hour restriction is intended to allow sufficient time for the system to equilibrate.

3.2 Normal Operating Conditions

Parameter	Req. #	Value
Solar Thermal Load	ENV0321	Exposed to full sun, 1200W/m^2.
Wind Speed	ENV0322	W ≤ 7 m/s average over 10 mins. 10 m/s peak gusts.
Temperature	ENV0323	–15 C ≤ T ≤ 35 C
Temperature Rate of Change	ENV0324	3.6°C/Hr.
Precipitation	ENV0325	No precipitation.

When the environment meets the constraints of the normal operating conditions, system performance requirements are relaxed but are still expected to provide adequate performance for operation below 50 GHz. The relevant performance specifications are discussed in [AD01].

3.3 Limits to Operating Conditions

Parameter	Req. #	Value
Solar Thermal Load	ENV0330	Exposed to full sun, 1200W/m^2
Wind	ENV0331	W ≤15 m/s average over 10 mins W ≤20 m/s gust
Temperature	ENV0332	–20 C ≤ T ≤ 45 C
Precipitation	ENV0333	5 cm/hr over 10 mins
Ice	ENV0334	No ice accumulation on structure

A third categorization will establish hard limits to the operating conditions. While outside the bounds of the normal operating environment but within this regime, no performance guarantees are expected, but the system shall still be capable of safe operation. Once these limits are exceeded, the antenna will be moved to its "stow-survival" orientation to prevent damage.

3.4 Survival Conditions

Parameter	Req. #	Value
Wind	ENV0341	0 m/s ≤ W ≤ 50 m/s average
Temperature	ENV0342	–30 C ≤ T ≤ 50 C
Radial Ice	ENV0343	2.5 cm
Rain Rate	ENV0344	16 cm/hr over 10 mins
Snow Load, Antenna	ENV0345	25 cm
Snow Load, Equipment & Bldgs.	ENV0346	100 kg/m^2 on horizontal surfaces
Hail Stones	ENV0347	2.0 cm
Antenna Orientation	ENV0348	Stow-survival, as defined by antenna designer

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. The designer must specify the antenna 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 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.

3.5 Site Elevation

Parameter	Req. #	Value
Altitude Range	ENV0351	All system elements shall be designed for operation and survival at altitudes ranging from sea level to 2500m.

4 Environmental Protection Requirements

4.1 Lightning

Parameter	Req. #	Value
Lightning Protection, Structure	ENV0511	The antenna, buildings, and housed equipment shall be protected from both direct and nearby lightning strikes, achieving Protection Level I as defined in IEC 62305-1/3. [AD02]
Lightning Protection, Electronics Systems	ENV0512	The building and antenna electrical and electronics systems shall be protected against Lightning Electromagnetic Impulse (LEMP) in accordance with IEC 62305-4. [AD02]
Lightning Protection, Personnel	ENV0513	A safety hazard analysis shall be performed for anticipated preventive maintenance tasks that may place personnel at risk in the event of direct or nearby lightning strikes.

Given the extent of the array and the prevailing environmental conditions, direct and nearby lightning strikes, causing a lightning electromagnetic pulse (LEMP), should be anticipated and mitigated in the antenna design. The antenna and housed equipment shall be protected in any antenna orientation. All antenna bearings shall have bypass grounding connections. Grounding systems shall be designed to minimize ground loops. Multi-point grounding is a necessity imposed by the need for RFI shielding, but the effects should be minimized in signal paths wherever possible.

The lightning protection system shall be designed to achieve Protection Level I as defined by [AD02] IEC 62305-1—Protection Against Lightning. This level assures protection against 99% of strikes, with a residual risk of damage for strikes with parameters outside the defined range.

4.2 Seismic

Parameter	Req. #	Value
Seismic Protection	ENV0521	The system shall be designed to withstand a low-probability earthquake with up to 0.2g peak acceleration in either the vertical or the horizontal axis.

Low probability has been defined as a 2% probability of an event exceeding this magnitude over a 50-year period, consistent with data available from the USGS Seismic Hazard Model [RD01]. Equipment shall be designed to survive this standard in any operational condition and orientation.

4.3 Vibration

Parameter	Req. #	Value
Wind Vibration	ENV0531	Exposed equipment, including all equipment within the antenna, shall be designed to withstand persistent wind-induced vibration.
Transport Vibration	ENV0532	All line-replaceable units shall be designed to withstand transportation vibration.

The vibration mitigation requirement is especially applicable to all mechanical connectors. All cables shall be mechanically supported to mitigate vibration loosening of connectors (see Figure 1).

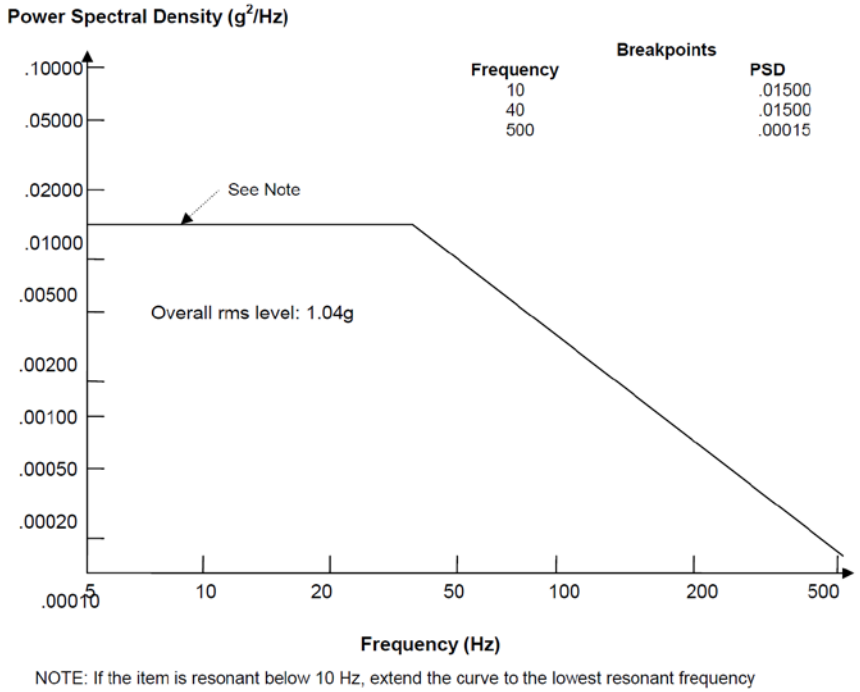

Figure 1 - Power spectral density of design spectra for vibration mitigation. Adopted from ALMA-80.05.02.00-001-B-SPE.

4.4 Dust

Parameter	Req. #	Value
Equipment Protection	ENV0541	Exposed equipment shall be protected against windblown dust, ashes, and grit.
Building Protection	ENV0542	Building envelopes shall be tight enough to mitigate penetration of dust. All air circulation penetrations shall be filtered.

4.5 Fauna

Parameter	Req. #	Value
Rodent Protection	ENV0551	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 penetration within enclosures and raceways shall mitigate the risk of rodent damage.
Large Mammal Protection	ENV0552	Exposed equipment shall be protected against damage by large mammals such as cows.

Note that the large mammal protection requirement needn't be met by all exposed equipment directly. For example, if a fence is provided around each antenna, equipment within the fence envelope can be built assuming that the fence provides adequate large mammal protection.

4.6 Solar Radiation

Parameter	Req. #	Value
Maximum Solar Flux	ENV0561	All equipment exposed to outside environment shall be designed for a maximum diurnal solar flux of 1200 W/m² from 0.3–60 μm.
Maximum UV Radiation	ENV0562	All equipment exposed to outside environment shall be designed for a maximum diurnal UV radiated flux of 100 W/m² from 280–400 nm.

4.7 Rain/Water Infiltration

Parameter	Req. #	Value
Rain/Water Infiltration	ENV0571	Exposed equipment enclosures shall be designed to withstand rainfall intensity up to 16 cm/hr., with droplets sized 0.5 to 4.5mm, at wind velocity of 15 m/s from the vertical to horizontal direction.

Survival rain rates correspond to 50-year events as defined in RD 02.

4.8 Mechanical Shock

Parameter	Req. #	Value
Transportation Environment	ENV0581	Equipment shall be designed to withstand typical loads and environments encountered during transportation as part of assembly or maintenance.
Mechanical Shocks	ENV0582	Equipment shall be designed to survive mechanical shock levels from handling as defined in Table 1.

Determination of typical loads will be the responsibility of the IPT lead and may be unique to each LRU.

Mass of Package	Type of Handling	Drop Height [cm]
0 to 9.1 kg	Manual Handling	76
9.2 to 18.2 kg	Manual Handling	66
18.3 to 27.2 kg	Manual Handling	61
27.4 to 36.3 kg	Manual Handling	46
36.4 to 45.5 kg	Manual Handling	38
45.5 to 68.1 kg	Mechanical Handling	31
68.2 to 113.5 kg	Mechanical Handling	26
>113.5 kg	Mechanical Handling	20

Table 1 - Shock levels during handling. Adopted from ALMA-80.05.02.00-001-B-SPE.

5 Appendix

5.1 Abbreviations and Acronyms

Acronym	Description
AD	Applicable Document
CFD	Computational Fluid Dynamics
HVAC	Heating, Ventilation & Air Conditioning
LRU	Line Replaceable Unit
ngVLA	Next Generation VLA
RD	Reference Document
SAC	Science Advisory Council
TAC	Technical Advisory Council
TBD	To Be Determined
VLA	Jansky Very Large Array