Computing and Software: Preliminary Requirements

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Change Record

Version	Date	Author	Notes/Changes
01	2018-04-09	Hiriart	Initial draft
02	2019-07-19	Hiriart	Updated for reference design.
03	2019-07-22	Selina	Minor updates for release.
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1 Introduction

1.1 Purpose

This document defines L2 requirements for the elements belonging to the ngVLA Computing and Software system. The main inputs for the derivation of these requirements are the ngVLA Science Requirements [AD01], the ngVLA System Requirements [AD02], and the ngVLA Operations Concept [AD03]. The requirements defined in this document are preliminary, and will be completed and refined as the project advances to more detailed design stages.

1.2 Scope

The scope of this document is the system elements belonging to the ngVLA Computing and Software subsystem. Following the Computing and Software architecture [RD01], this document has been structured in sections that classify requirements according to the following areas:

- **Proposal Management:** Requirements related to the process of proposal submission, evaluation, time allocation and the generation of observing instructions (scheduling blocks).
- **Online Subsystem:** Requirements related to the execution of telescope observations, up to the point where raw data is stored persistently into the Science Archive.
- **Offline Subsystem:** Requirements related to all the post-observation operations performed on the collected science data.
- **Maintenance and Support:** Requirements related to the system elements that provide support for engineering and maintenance activities.
- **Development Operations:** Requirements related to system elements that support software development activities.

The requirements defined for the Online Subsystem include the Monitoring & Control requirements, with the exception of requirements pertaining to the hardware interface between Computing & Software and the antenna electronics systems, the Module Interface Board (MIB). These requirements are defined in [RD02].

2 Related Documents

2.1 Applicable Documents

The following documents may not be directly referenced herein, but provide necessary context or supporting material.

Ref. No.	Document Title	Rev / Doc. No.
AD01	ngVLA Science Requirements	020.10.15.00.00-0001-REQ
AD02	System Requirements	020.10.15.10.00-0003-SPE
AD03	Operations Concept	020.10.05.00.00-0002-PLA

2.2 Reference Documents

The following documents are referenced within this text.

Ref. No.	Document Title	Rev / Doc. No.
RD01	Computing & Software Architecture: Reference Design	020.50.00.00.01-002-REP
RD02	Monitor and Control Hardware Interface Layer: Preliminary Technical Requirements	020.30.45.00.00-0002-REQ

3 Proposal Management Requirements

Parameter	Req. #	Value	Traceability
NRAO Proposal System Integration	CSW0075	The ngVLA Proposal Management Subsystem shall be integrated with the NRAO Proposal Management System, which currently supports the VLA, GBT, and VLBA telescopes, and supports the proposal submission, review, and time allocation use cases.	SYS2201, STK2502
ngVLA Resources Model	CSW0076	The Proposal Management Subsystem shall incorporate the ngVLA Resource Model.	SYS2221
Sub-Array Management Support	CSW0077	The ngVLA Resource Model shall incorporate the necessary data elements to support sub-array management.	SYS2302
Post-Processing Support	CSW0078	The ngVLA Resource Model shall incorporate the necessary data elements to support automatic post-processing, for the supported Standard Observing Modes.	SYS0703, SYS0721, STK0800
Expert Mode Support	CSW0079	The ngVLA Proposal Management Subsystem shall support expert modes, allowing the specification of non-standard instrument configurations and data processing.	
Scheduling Block Generation	CSW0080	The ngVLA Proposal Management Subsystem shall generate observing instructions (scheduling blocks) from the information entered in the submitted proposals.	SYS2222

4 Online Subsystem Requirements

4.1 Scheduling Requirements

Parameter	Req. #	Value	Traceability
Automatic Scheduling Block Selection	CSW0070	The Online Subsystem shall dynamically select the Scheduling Block to be executed in a sub-array, based on a pool of candidate Scheduling Blocks, and the current conditions of the sub-array and its environment, including the weather conditions.	SYS2302
Manual Scheduling Block Selection	CSW0071	The Online Subsystem shall provide an interface for the Operator to select the Scheduling Block to be executed in a sub-array.	SYS2223
VLBI Observations	CSW0072	The Online Subsystem shall provide an interface to execute VLBI observations in a sub-array. A VLBI observation shall be specified in VEX format, and the system shall provide a way to synchronize the observation with other participating observatories.	SYS0006
Observation Execution Abortion	CSW0073	The Online Subsystem shall provide a way for the Array Operator to abort a running observation in a sub-array. The observations running in other sub-arrays shall not be affected by this abort operation.	SYS2224, SYS3004, STK0902
Manual Sub-Array Management	CSW0074	The Online Subsystem shall provide an interface for the Array Operator to create and destroy sub-arrays.	SYS2302

4.2 Observation Control Requirements

Parameter	Req. #	Value	Traceability
Antenna Pointing	CSW0048	The Online Subsystem shall control the pointing of antennas belonging to a sub-array during an observation. The subsystem shall allow to partition the sub-array in portions that point to different directions (this is necessary for calibration observations such as interferometric pointing and sky holography).	
Online Antenna Pointing Calibration	CSW0049	The Online Subsystem shall compute pointing calibration coefficients from the data acquired in pointing scans and apply these coefficients on subsequent antenna movements.	SYS2303
Delay Tracking	CSW0050	The Online Subsystem shall command the sub-array electronic systems to perform delay tracking during an observation.	
Frequency Tuning	CSW0051	The Online Subsystem shall command the sub-array electronic system to down-convert and process the specified observation frequency range(s).	SYS0801, SYS0806

Parameter	Req. #	Value	Traceability
Doppler Tracking	CSW0052	The Online Subsystem shall shift the observing frequency to account for Doppler effects. This function shall be an observation option; i.e. it should be possible to turn this function on or off.	
Signal Path Attenuation	CSW0053	The Online Subsystem shall command the sub-array electronic system to set optimal attenuator gains.	SYS1203
Online Antenna Focus Calibration	CSW0054	The Online Subsystem shall compute focus calibration coefficients from the data acquired in focus scans and apply these coefficients on subsequent antenna sub-reflector settings.	
CSP Antenna Input Distribution	CSW0055	The Online Subsystem shall manage the distribution of antenna inputs into the CSP, mapping antenna streams to CSP tridents, both for the direct-connected antennas and the ISP-connected antennas.	
Unconnected Antennas Data Transmission	CSW0056	The Online Subsystem shall manage the data transmission for the ISP-connected antennas, starting and stopping the transmission of data packets from the antennas.	
Fringe Rotation	CSW0057	The Online Subsystem shall issue the necessary commands to the sub-array electronic system to perform fringe rotation during an observation.	
LO Offsetting	CSW0058	The Online Subsystem shall command the sub-array electronic systems to perform LO offsetting.	
Timing Synchronization	CSW0059	The Online Subsystem shall command the sub-array electronic systems so their local clocks are synchronized in time.	
Return to Phase	CSW0060	The Online Subsystem shall issue the necessary commands to the sub-array electronic systems to return to phase; i.e. when returning to a given frequency after observing in a different frequency the visibility phase should be as if the system had been observing in the first frequency all the time.	
Beam-forming weights	CSW0061	The Online Subsystem shall compute beam-forming weights and pass them to the CSP during an observation.	

4.3 Observing Mode Requirements

Parameter	Req. #	Value	Traceability
Continuum Interferometry Observing Mode	CSW0062	The Online Subsystem shall support the Continuum Interferometry Observing Mode.	SYS0002
Spectral Line Interferometry Observing Mode	CSW0063	The Online Subsystem shall support the Spectral Line Interferometry Observing Mode.	SYS0002
Total Power Observing Mode	CSW0064	The Online Subsystem shall support the Total Power Observing Mode.	SYS0007
Pulsar Timing Observing Mode	CSW0065	The Online Subsystem shall support the Pulsar Timing Observing Mode.	SYS0004
Pulsar Search Observing Mode	CSW0066	The Online Subsystem shall support the Pulsar Search Observing Mode.	SYS0005
Very Long Baseline Interferometry Observing Mode	CSW0067	The Online Subsystem shall support the Very Long Baseline Interferometry Observing Mode.	SYS0006, SYS0201, SYS0203
On-the-Fly Mosaicking Observing Mode	CSW0068	The Online Subsystem shall support the On-the-Fly Mosaicking Observing Mode.	SYS0008
Solar Observing Mode	CSW0069	The Online Subsystem shall support the Solar Observing Mode.	SYS0009

4.4 Calibration Requirements

Parameter	Req. #	Value	Traceability
Array Calibration Tools	CSW0016	The Online Subsystem shall provide tools to compute calibration models, store them, and apply them into the system.	SYS1063
Amplitude Calibration	CSW0017	The Online Subsystem shall compute complex amplitude calibration tables and include them in the output data product.	SYS1068
Flux Calibration	CSW0018	The Online Subsystem shall compute flux calibration tables and include them in the output data product.	SYS1064, SYS1801, SYS4801
Bandpass Calibration	CSW0019	The Online Subsystem shall compute bandpass calibration tables and include them in the output data product.	SYS1066
Polarization Calibration	CSW0020	The Online Subsystem shall compute polarization calibration tables and include them in the output data product.	SYS1065, SYS1901
Pointing Calibration	CSW0021	The Online Subsystem shall compute pointing calibration tables and include them in the output data product.	
Focus Calibration	CSW0022	The Online Subsystem shall compute focus calibration tables and include them in the output data product.	

Parameter	Req. #	Value	Traceability
Delay Calibration	CSW0023	The Online Subsystem shall compute delay calibration tables and include them in the output data product.	
WVR Calibration	CSW0024	The Online Subsystem shall compute WVR calibration tables and include them in the output data product.	
Offline Calibration Tools	CSW0025	The Online Subsystem shall provide tools to calculate the calibration tables generated during an observation (amplitude, flux, bandpass, polarization, pointing, focus, delay, and WVR) offline from saved datasets.	

4.5 Configuration Requirements

Parameter	Req. #	Value	Traceability
Persistent Configuration Data	CSW0026	The Online Subsystem shall persistently store system configuration data. This configuration data includes the array center position, the antenna locations, the cable and electronic delay model, alarm thresholds, and other parameters. Configuration data shall be kept under version control.	SYS2406, STK1300
System Reconfiguration	CSW0027	The Online Subsystem shall allow an Operator to change configuration parameters and apply these changes in the affected systems automatically.	STK1704

4.6 Data Product Requirements

Parameter	Req. #	Value	Traceability
Visibility Data Format	CSW0028	The Online Subsystem shall output visibility data in the same format as required for processing (calibration and imaging).	SYS0701, SYS0702
Pulsar Timing Profile Data Format	CSW0029	The Online Subsystem shall output pulsar timing profile data in PSRFITS format.	SYS0741
Offline Pulsar Search Data Format	CSW0030	The Online Subsystem shall output offline pulsar search data in PSRFITS format.	SYS0742
VLBI Data Format	CSW0031	The Online Subsystem shall output VLBI data in VDIF format.	

4.7 Interface Requirements

Parameter	Req. #	Value	Traceability
Antenna Electronics M&C Interface	CSW0032	The Online Subsystem shall interface with the antenna electronic systems for M&C through the MIB boards, using the Ethernet protocol.	
LO Reference M&C Interface	CSW0033	The Online Subsystem shall interface with the LO Reference equipment for M&C using the Ethernet protocol.	
Time Synchronization M&C Interface	CSW0034	The Online Subsystem shall interface with the Time Synchronization equipment for M&C using the Ethernet protocol.	
CSP M&C Interface	CSW0035	The Online Subsystem shall interface with the CSP for M&C using the Ethernet protocol.	
CSP Output Interface	CSW0036	The Online Subsystem shall interface with the CSP to receive its output using the Ethernet protocol.	
Operations Interface	CSW0037	The Online Subsystem shall provide an interface for array operations.	SYS2407, SYS2305, SYS2306, SYS2307, SYS2223, STK1703
Engineering Support Interface	CSW0038	The Online Subsystem shall provide an interface for engineering support.	SYS2407
Quality Assurance Interface	CSW0039	The Online Subsystem shall provide an interface for observation quality assurance.	

4.8 Monitoring and Control Requirements

Parameter	Req. #	Value	Traceability
Autonomous Operations	CSW0040	The Monitor and Control systems shall initialize and configure themselves and their connected elements to become operationally ready autonomously. Monitoring shall start as soon as possible, also autonomously.	STK1506
Line Replaceable Unit Serial Number	CSW0041	Each Line Replaceable Unit (LRU) shall be identified by a unique serial number.	SYS2403
Ethernet M&C Protocol	CSW0042	The Monitoring and Control protocol shall be based on Ethernet.	
Automatic Reconfiguration	CSW0043	The system shall detect when an LRU has been replaced and reconfigure itself automatically.	STK1506
Low-Level Access to MIB Boards	CSW0044	The system shall provide low-level access to the MIB boards in order to support effective troubleshooting operations.	
Self-Diagnostic Operations	CSW0045	The system shall incorporate self-diagnostic operations.	SYS2405

Parameter	Req. #	Value	Traceability
Safety-Critical Operations	CSW0046	The Monitor and Control system shall not be responsible for safety-critical operations involving possible damage to personnel and equipment.	SYS2700
Oscilloscope Function	CSW0047	The system shall provide an oscilloscope function, which allows sampling a monitor point with high frequency for an interval of time. The system shall provide the capability to trigger this function both manually and automatically.	

5 Offline Subsystem Requirements

Parameter	Req. #	Value	Traceability
Visibility Data Rate	CSW0006	The Offline Subsystem shall support an input data rate for interferometric data of 6,714.5 GVis per hour, 7.46 GB/s in average, with a peak of 119,342 GVis per hour, 132.6 GB/s. This is estimated to require 322.9 PFLOPs/s of processing.	SYS0752
Pulsar Timing Data Rate	CSW0007	The Offline Subsystem shall support an input data rate for pulsar timing data of 130MB/s.	SYS0301, SYS0302, SYS0303, SYS0304, SYS0305, SYS0306, SYS0307
Pulsar Search Data Rate	CSW0008	The Offline Subsystem shall support an input data rate for pulsar search data of 820 MB/s.	SYS0401, SYS0402, SYS0403, SYS0404, SYS0405
Synthesis Imaging Performance	CSW0009	The Offline Subsystem shall be able to calibrate and produce imaging data products from interferometric data with a throughput that matches or exceeds the input data rate (CSW0006).	SYS1062, SYS0752
Pipeline Reliability	CSW0010	The Offline Subsystem shall tolerate failure of 10% (TBC) of computing nodes and associated storage involved in a pipeline execution without losing data computed so far.	SYS0752
SRDP Integration	CSW0011	The ngVLA Offline Subsystem shall be based on the architecture developed by the SRDP project.	STK2500
External Processing	CSW0012	The Offline Subsystem shall support the capability of using external (i.e. non-Observatory) computing resources in order to support Large and Legacy scale projects.	
Visibility Processing Software Package	CSW0013	The Offline Subsystem shall provide a software package for visibility processing.	STK1202
Data Analysis Software Package	CSW0014	The Offline Subsystem shall provide a software package for data analysis.	SYS0761, SYS2201, STK1201
Reprocessing capacity	CSW0015	The Offline Subsystem shall incorporate enough processing capacity to service reprocessing requests. Total capacity shall be 1.5 times the processing power necessary to generate the standard data products.	SYS0736, SYS0734

6 Maintenance and Support Subsystem Requirements

Parameter	Req. #	Value	Traceability
Concurrent Software Versions	CSW0003	It shall be possible to run multiple software versions in all systems with multiple instances concurrently, for testing and commissioning purposes.	STK1501, STK1402
Automatic Maintenance Scheduler	CSW0004	The system shall continuously analyze the array status, automatically generate maintenance activity tickets, and maintain the maintenance schedule.	SYS2405, STK1700
Autonomous Antennas	CSW0005	The system shall include a supervisory system for controlling the antennas, evaluating its performance, calibrating the antennas, and solving routine problems.	SYS2304, STK1506, STK1704

7 Development Operations Requirements

Parameter	Req. #	Value	Traceability
Simulation Support	CSW0001	The ngVLA development infrastructure shall incorporate telescope simulation capabilities in order to support development, testing, integration, and verification activities.	
Consistent Deployment	CSW0002	The ngVLA development infrastructure shall keep all the necessary artifacts to deploy a consistent system under version control. This includes the source code, configuration data for both software and hardware, and external libraries.	