# Stakeholder Requirements

020.10.15.01.00-0001-REQ

Status: **RELEASED**

| PREPARED BY | ORGANIZATION | DATE |
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## Change Record

| Version | Date | Author | Notes/Changes |
| --- | --- | --- | --- |
| 01 | 2018-06-01 | Treacy | Initial version for preliminary Stakeholder Requirements Review (StRR) |
| 02 | 2018-11-05 | Treacy | In-progress draft addressing RIDS from preliminary StRR |
| 03 | 2018-11-19 | Zuckerberg, Selina, Hiriart | Addressed gap analysis, updates from RIDs, and major edits throughout for requirements quality. Reformatted to doc. |
| 04 | 2018-11-26 | Zuckerberg, Selina, Hiriart | Added new categories of requirements for organization. Finished major edits from preliminary StRR and team review. |
| 05 | 2018-12-05 | Selina, Hiriart, Zuckerberg | Updated numbering scheme for consistency with Requirements Management Plan. Updated traceability column entries. Minor updates to requirements flow-down strategy narrative. |
| 06 | 2019-05-30 | Lear | Prepared document for review. |
| 07 | 2019-05-31 | Selina | Minor edits for release. |
| 08 | 2019-07-08 | Selina | Addressing comments from MM review. |
| A | 2019-07-09 | Lear | Prepared document for approvals & release. |
| A.01 | 2019-08-22 | Leyba-Newton, Selina | Fixed template for StRR. Updated throughout with requirements capture from the AIV and CSV Concepts. |
| A.02 | 2019-08-27 | Lear | Finalized template for document update and release. |
| A.03 | 2019-08-27 | Selina | Clarifications to the introduction and scope of the document. Updated Abbreviations & Acronyms. |
| A.04 | 2019-08-29 | Hiriart, Selina | Updates to template code. Typographical corrections in a few requirements. |
| B | 2019-09-04 | Selina, Murphy | Incorporated comments from EJM and MM. Release for StRR. |
| B.01 | 2020-01-16 | Selina | Addressing RIDs from StRR. Updates in both template and MagicDraw database. |
| B.02 | 2020-01-23 | Selina | Additional updates to template. |
| B.03 | 2020-02-03 | Selina | Incorporated feedback from EJM, LLN and SL before release. |
| C | 2020-02-05 | Lear | Minor copyedits; prepared PDF for approvals & release |

# Table of Contents

# 1 Introduction

## 1.1 Purpose

This document aims to present a set of L0 stakeholder requirements for the ngVLA that should guide the development of the facility. Stakeholders, in this context, are people with a stake in the form and fit of the delivered facility, such as those who will eventually operate and maintain the array. This document is complementary to the ngVLA Science Requirements [AD01], which are documented separately. Level-0 stakeholder requirements are expressed in terms applicable to their needs or use cases, and are generally implementation agnostic.

Many requirements flow from the system lifecycle concept [AD02] documents, especially the Operations and Maintenance Concept [AD07]. Input from the Assembly, Integration, and Verification (AIV) Concept [AD08] and the Commissioning and Science Validation (CSV) Concept [AD09] is reflected when appropriate, especially as these concepts inform the development and commissioning of new modes and capabilities in the operations phase.

An attempt has also been made to capture other stakeholder requirements from representatives of various stakeholder groups (safety, regulatory compliance, local citizens, etc.) Where possible, traceability for these requirements is provided to a source, but this document should be considered a primary reference for stakeholder-level requirements.

## 1.2 Scope

The scope of this document is the ngVLA facility over its full lifecycle. This includes not just the scientific instrument but the supporting infrastructure necessary for full operations.

The emphasis in this document is on requirements that will inform the technical development of the facility. Programmatic and schedule constraints that influence the design and final deliverable are noted, but requirements that primarily pertain to project scope and the conduct of the project are not considered in scope.

For relevant requirements that inform the conduct of the project, please consult the Project Execution Plan [RD01] and its references including AUI/NRAO policies, the NSF Major Facilities Guide [RD02], and the Systems Engineering Management Plan [RD03].

# 2 Related Documents

## 2.1 Applicable Documents

The following documents are applicable to this Requirements Specification to the extent specified. An understanding of these documents is necessary to fully comprehend the scope of this Requirements Specification. In the event of conflict between the documents referenced herein and the content of this Requirements Specification, the content of the *highest* level specification (in the requirements flow-down) shall be considered the superseding requirement.

| Ref. No. | Document Title | Rev/Doc. No. |
| --- | --- | --- |
| AD01 | ngVLA Science Requirements (L0) | 020.10.15.05.00-0001-REQ |
| AD02 | ngVLA Lifecycle Stages & Concepts | 020.10.05.00.00-0001-PLA |
| AD03 | ngVLA Requirements Management Plan | 020.10.15.00.00-0001-PLA |
| AD04 | A Notional Reference Observing Program | 020.10.15.05.10-0001-REP |
| AD05 | ngVLA Safety Requirements (L0) | 020.10.15.10.00-0004-REQ |
| AD06 | ngVLA Land Acquisition and Regulatory Compliance Requirements (L0) | 020.70.00.00.00-0001-REQ |
| AD07 | ngVLA Operations Concept | 020.10.05.00.00-0002-PLA |
| AD08 | Assembly, Integration & Verification Concept | 020.10.05.00.00-0005-PLA |
| AD09 | Commissioning & Science Validation Concept | 020.10.05.00.00-0006-PLA |

## 2.2 Reference Documents

The following documents provide additional supporting context or are referenced in the text, but reading these documents is not necessary to understand the scope of this document.

| Ref. No. | Document Title | Rev/Doc. No. |
| --- | --- | --- |
| RD01 | ngVLA Project Execution Plan | 020.05.00.00.00-0003-PLA |
| RD02 | NSF Major Facilities Guide, Sept. 2019 | NSF 19-68 |
| RD03 | ngVLA Systems Engineering Management Plan | 020.10.00.00.00-0001-PLA |

# 3 Overview of the Stakeholder Requirements

The L0 Stakeholder Requirements along with any explanatory notes are found in Section 6. The system safety and regulatory compliance requirements are documented separately and incorporated by reference:

| | | |
| --- | --- | --- |
| [AD05] | *ngVLA Safety Requirements (L0)* | 020.10.15.10.00-0004-REQ |
| [AD06] | *ngVLA Land Acquisition and Regulatory Compliance Requirements (L0)* | 020.70.00.00.00-0001-REQ |

As noted in Section 4.2, this document includes a number of L0 requirements captured from the lifecycle concept documents including the Assembly, Integration, and Verification Concept [AD08], the Commissioning and Science Validation Concept [AD09], and the Operations and Maintenance Concept [AD07].

The Operations and Maintenance Concept is considered a stakeholder document that feeds directly into the design of the facility. The AIV and CSV concepts are solutions to reaching this deployment, and therefore largely provide lower-level requirement input (at the L1 or L2 levels). However, these concepts have proven useful in informing the development and commissioning of new modes and capabilities in the operations phase. Input from this perspective has been captured at the L0 level within the Stakeholder Requirements.

The lifecycle concepts are a tool for requirements elicitation. The goal is to capture the *need* expressed in the concept, but not necessarily the *solution*. For example, the maintenance concept may describe tracking the configuration of the system through barcodes on line replaceable units (LRUs). The *needs* expressed in this statement are (1) packing of serviceable hardware systems into interchangeable LRUs, and (2) the need for a system for tracking the location and configuration of these LRUs throughout the array. The barcode system is a solution to satisfying this need. In this L0 requirements capture, we aim to capture the need only, leaving the solution space open for the detailed design phase.

This approach requires a degree of abstraction in the L0 requirements capture, with detail added at subsequent requirements refinement and derivation at the L1 or L2 level. It may be appropriate to revisit the lifecycle concept documents in the L1 and L2 requirements derivation to ensure the full expressed need is satisfied in context (i.e., requirements validation).

The lifecycle concept documents also establish a number of scope and process requirements. While necessary for implementation of the concept, these choices do not directly influence the delivered facility and system design, and are therefore not captured as part of this requirements specification. Instead, these decisions are captured in relevant scope and process-oriented documents such as the Project Execution Plan [RD01] (in particular, the scope statement for each Integrated Product Team [IPT] and Work Package [WP]), and the Systems Engineering Management Plan [RD03].

Since the stakeholder requirements are written in the stakeholder's language (i.e., non-technical), they are typically not verifiable. The verification and validation strategy for ngVLA aims to capture the broad intent or need with stakeholder requirements, with sufficient specificity in the subsequent derivation of system-level L1 requirements to enable their verification. ngVLA performance to the L0 stakeholder requirements will be validated as part of the commissioning effort and the handover to operations.

# 4 Requirements Management

## 4.1 Requirement Definitions

Consistent with the Requirements Management Plan [AD03], the following definitions of requirement "levels" are used in this document.

| Requirement Level | Definition |
| --- | --- |
| L0 | User requirements expressed in terms applicable to their needs or use cases ("Science Requirements" or "Stakeholder Requirements") |
| L1 | Requirements expressed in technical functional or performance terms, but still implementation agnostic ("System Level Requirements") |
| L2 | Requirements that define a specification for an element of the system, presuming an architecture ("Sub System Requirements") |

## 4.2 Requirements Flow-Down

The L0 Requirements are fully captured in the following set of documents:

| | | |
| --- | --- | --- |
| [AD01] | *ngVLA Science Requirements (L0)* | 020.10.15.05.00-0001-REQ |
| | *ngVLA Stakeholder Requirements (L0)* | 020.10.15.01.00-0001-REQ |
| [AD05] | *ngVLA Safety Requirements (L0)* | 020.10.15.10.00-0004-REQ |
| [AD06] | *ngVLA Land Acquisition and Regulatory Compliance Requirements (L0)* | 020.70.00.00.00-0001-REQ |

The functional and performance requirements necessary to support the key science goals of the facility are captured in the L0 Science Requirements [AD01]. Other Stakeholder Requirements also influence or dictate design choices. Examples include programmatic requirements, regulatory compliance requirements, and the lifecycle concepts (e.g., the operations and maintenance concept [AD07]) for the facility, and these requirements are captured here.

The Science Requirements and Stakeholder Requirements, including the Safety and Regulatory requirements incorporated by reference, fully encapsulate all known L0 requirements. The System requirements and subordinate specifications fully encapsulate all known L1 requirements. L0 requirements may be directly passed to the L1 level if the requirement is expressed in appropriate functional or performance terms.

Specifications for individual subsystems (L2) flow from the L1 System Requirements, and may not always be directly attributable to a single system requirement (e.g., phase drift specifications at the system level may be apportioned to multiple subsystems, or a subsystem spec may be in support of multiple higher-level requirements). Completeness of the L2 requirements is assessed at the requirements review of each subsystem.

Maintaining complete, enumerated, and traceable science requirements, system requirements, and subsystem specifications ensures this trade-off process is complete and well understood by the project team. The effect of a change in a subsystem specification can be analyzed at the system level, and thereafter the impact on a specific scientific program can be ascertained.

The details of the requirements management strategy can be found in [AD03].

# 5 Constraints

## *5.1 Programmatic Constraints*

The project shall be designed and constructed within the following constraints:

1. *CON001: Construction Budget*: The construction point estimate shall not exceed $1.7B (2018 USD, TBC.)
2. *CON002: Operations Budget*: The annual operations post estimate shall not exceed $80M/yr. (2018 USD, TBC.)
3. *CON003: Community Engagement*: The project and system architecture shall be structured to permit community development and partner contributions.
4. *CON004: Broader Impacts*: Efforts to leverage, measure, and document the Broader Impacts of the program shall be included in the scope of the design and construction effort.
5. *CON005: Site/Location*: It is a goal to center the array near the existing VLA, on the plains of San Agustin, NM.
6. *CON006: VLA Reuse*: It is a goal to reuse infrastructure and buildings built as part of the VLA or EVLA effort.
7. *CON007: Design & Development Timeline*: It is a goal to conclude design and development activities in a seven-year period ending in 2024.
8. *CON008: Construction Timeline*: It is a goal to begin construction by 2025, and conclude within a ten-year period in 2034.
9. *CON009: AIV Scope*: The project shall include necessary assembly and integration facilities in the project scope. It is a goal to have dual use assembly/integration facilities that fulfill a necessary operations role (e.g., an assembly space in AIV transitions in to the Operations Warehouse or Repair Facility).
10. *CON010: Commissioning Scope*: The commissioning of the observatory shall be within the scope of the construction project, not operations.
11. *CON011: Concurrent Construction & Operations*: The transition from the construction phase to the operations phase will be staged, with a progressive and incremental set of capabilities and infrastructure delivered to Operations. It is a goal to begin early science operations by 2028.

# 6 Stakeholder Requirements

## 6.1 Science Operations

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| Operations Concept | STK0200 | The system shall be a proposal-driven, pointed, general purpose instrument. | [020.10.05.00.00-0002-PLA-C, Sec 1, Para 2]; [020.10.05.00.00-0002-PLA-C, Sec 12.2, Table] |

## 6.2 System Life Cycle

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| Material Selection and Sustainability | STK0302 | The environmental sustainability of materials, and the environmental impact from the construction through to the disposal phase, shall be evaluated in the system lifecycle cost analysis and trade studies. | [020.10.05.00.00-0001-PLA-A, Sec 3.4.3, Para 3]; [020.10.05.00.00-0001-PLA-A, Sec 3.6, Para 2] |
| Design Life | STK0303 | The system shall be designed for an initial operations campaign of 20 years, beginning at the start of full operations (i.e., post system commissioning). | [Directors Office, 2016] |
| Projected Environment | STK0304 | The system shall be designed to survive the environmental conditions expected over the Design Life of the instrument, and shall survive 50-year events (extreme weather, seismic, etc.) without damage in excess of 1% of construction cost. | [020.10.05.00.00-0001-PLA-A, Sec 3.4.2, Para 2] |
| Part Selection and Obsolescence | STK0310 | The project shall predict elements prone to early obsolescence, and identify plans for replacement. This plan will apply to both the construction and operations phases of the life cycle. | [020.10.05.00.00-0001-PLA-A, Sec 3.4.3, Para 3] |

## 6.3 Integration and Verification

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| Provision of Assembly Verification Tools | STK0400 | Test frameworks (unit tests, hardware simulators, and test racks) for the standalone verification of line replaceable units and subsystems shall be provided. | [020.10.05.00.00-0005-PLA-B, Sec 5.2.5, Para 1] |
| Provision of System Verification Software Tools | STK0402 | The system shall provide engineering interfaces to test system functional status without the use of the full end-to-end software system (e.g., tools to generate and execute test scripts for fringe tests; tools to see fringes on a baseline in near real-time). | [020.10.05.00.00-0005-PLA-B, Sec 5.2.2, Para 3] |

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| Spare Parts | STK0403 | The project shall deliver critical spares (those likely to become obsolete, too expensive to replace within the operations budget, single points of failure, or sole-source supply) for the operating life of the facility within the scope of construction. | [020.10.05.00.00-0002-PLA-C, Sec 7.1, Para 2] |
| Testing: Software and Firmware | STK0427 | All software and firmware delivered by the project shall be delivered with automated unit, integration, and regression testing suites. | [020.10.05.00.00-0005-PLA-B, Sec 5.2.2, Para 1] |
| AIV Software Tools | STK0431 | Development tools, compilers, source code, and the build system shall be delivered for all project software to enable maintenance over the life of the facility. | [020.10.05.00.00-0005-PLA-B, Sec 5.2.2, Para 3] |
| ICD: API and Software Definition | STK0432 | All Application Program Interfaces (API) or other software interfaces shall be defined in ICDs. | [020.10.05.00.00-0005-PLA-B, Sec 5.2.2, Para 4] |
| ICD: Automated Conformance Testing | STK0433 | Automated test results demonstrating conformance to API ICDs shall be delivered with the product. | [020.10.05.00.00-0005-PLA-B, Sec 5.2.2, Para 4] |
| ICD: LRUs | STK0434 | ICDs shall be delivered for each Line Replaceable Unit in the system. | [STRR RID #33] |

## *6.4 Commissioning and Science Validation*

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| First Look Science Products | STK0500 | The project shall prepare and release a set of First Look Science Products, obtained as part of Science Validation activities, before of the start of proposal-driven observations with the array. | [020.10.05.00.00-0002-PLA-C, Sec 5.5, Para2]; [020.10.05.00.00-0006-PLA-B, Sec 2.4.1, Para 4] |
| Availability for Early Science | STK0501 | Proposal-driven observations, or Early Science, shall commence as soon as a commissioned observing mode is available with capabilities in excess of the current VLA. | [020.10.05.00.00-0001-PLA-A, Sec 3.4.1, Para 3], [020.10.05.00.00-0002-PLA-C, Sect 5.0, Para 4; Sect 5.5, Para 3.] |
| Provision of Commissioning Tools | STK0502 | The system shall include software interfaces and diagnostic tools to quantify system performance and status (e.g., tools to plot real time calibration coefficients). | [020.10.05.00.00-0006-PLA-B, Sec 5.1, Para 1] |
| Transition to Ops: Capabilities and Observing Modes | STK0511 | Operational capabilities and observing modes must be made available in stages during the transition from construction through to the commencement of full operations. | [020.10.05.00.00-0006-PLA-B, Sec 2.4.1, Para 2] |

| Parameter | Req. # | Value | Traceability |
|---|---|---|---|
| Commissioning: Observing Mode SRDP Pipeline | STK0512 | Delivery of a commissioned standard observing mode shall include an operational SRDP pipeline before it is offered for regular use through PI proposals. | [020.10.05.00.00-0006-PLA-B, Sec 2.4.1, Para 3], [020.10.05.00.00-0002-PLA-C, Sec 5.3, Para 3] |
| API and Scheduling Blocks | STK0516 | A science-oriented API (scripting interface) for calling high-level array functions, prior to the widespread use of Scheduling Blocks (SBs), shall be delivered. | [020.10.05.00.00-0006-PLA-B, Sec 5, # 5] |
| Simulators: Development of Observing Scripts | STK0517 | Simulators to enable the development of observing scripts without the real system shall be delivered. | [020.10.05.00.00-0006-PLA-B, Sec 5, # 6] |
| Interactive Shell Access | STK0518 | The system shall provide interactive shell access to the calibration and imaging software, running on an observatory-supported OS. | [020.10.05.00.00-0006-PLA-B, Sec 5, # 7] |
| Contemporaneous Calibrator Data | STK0520 | It is a goal for the system to provide interfaces to make use of any contemporaneous flux densities, spectra, and polarization of calibrators in the various ngVLA bands that are already provided by the VLA and/or ALMA. | [020.10.05.00.00-0006-PLA-B, Sec 5, # 9] |
| Data Access: Visibility Data | STK0523 | The system shall provide interfaces to, and tools to process, the visibility data outside of the automatic, non-interactive processing model that is needed for Standard Observing Modes in Full Operations. | [020.10.05.00.00-0006-PLA-B, Sec 5.2.4, Para 2] |

## *6.5 Observing Modes*

| Parameter | Req. # | Value | Traceability |
|---|---|---|---|
| Standard Modes: Time-Phased Availability | STK0700 | By Full Operations the project shall provide a set of standard observing modes that can achieve the ngVLA Key Science Goals. | [020.10.05.00.00-0002-PLA-C, Sec 5, Para 4] |
| Standard Modes: Generation of Scheduling Blocks | STK0701 | For standard observing modes, observing instructions (e.g., scheduling blocks) shall be generated based on the scientific and technical requirements specified by the PI in their submitted proposal. | [020.10.05.00.00-0002-PLA-C, Sec 5, Para 4] |
| Non-Standard Observing Modes | STK0702 | The system, starting with the proposal submission system, shall support non-standard observing modes, when programs require other instrument configurations and/or non-standard and non-automated data processing. | [020.10.05.00.00-0002-PLA-C, Sec 5, Para 5] |

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| Observing Awards: Array Time on Source | STK0703 | The observation execution process shall manage allocated time by subarray to an observation. Successful PIs will be awarded array time on source rather than guaranteed satisfaction of a scientific objective such as sensitivity. | [020.10.05.00.00-0002-PLA-C, Sec 5.2, Para 4] |
| Standard Modes: Observing Strategy | STK0704 | The Observatory shall provide a defined observing strategy (including array characterization and quantitatively known calibration overheads within an acceptable margin of error) for all standard modes and capabilities. | [020.10.05.00.00-0002-PLA-C, Sec 5.2, Para 4] |
| Standard Modes: Flexibility | STK0705 | Interfaces for PIs to make changes to the standard observing strategy, when required to meet the scientific objectives, shall be available. | [020.10.05.00.00-0002-PLA-C, Sec 5.2, Para 4] |

## *6.6 Proposal Submission*

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| Proposal Submission Criteria | STK0800 | The proposal submission system shall capture the information necessary for scheduling the telescope, configuring the instrument, and collecting the data appropriate to address the scientific goals. For Standard Operating Modes, it shall also capture sufficient information to automatically generate the appropriate Science Ready Data Products (SRDPs). | [020.10.05.00.00-0002-PLA-C, Sec 5, Para 3] |
| Proposal Submission Tool | STK0801 | A proposal tool shall be supplied to allow users to specify the scientific and technical requirements for their projects. Projects can request both telescope time and/or compute resources (i.e., archive reprocessing). | [020.10.05.00.00-0002-PLA-C, Sec 5.1, Para 1] |
| Proposal Assessment | STK0802 | The proposal management system shall provide interfaces for (1) scientific review by science review panels made up of experts from the broad astronomy research community, and (2) technical review by facility experts. | [020.10.05.00.00-0002-PLA-C, Sec 5.1, Para 1] |
| Mitigating Bias in Proposal Peer Review | STK0803 | The ngVLA proposal review interface shall anonymize the proposal for scientific and technical review, with a goal of minimizing reviewer bias in the time allocation process. | [020.10.05.00.00-0002-PLA-C, Sec 5.1, Para 1] |

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| Proposal Attributes | STK0804 | The system shall support proposal attributes such as regular, triggered, monitoring, large and legacy (see 020.10.05.00.00-0004-PLA), and joint (with other observatories). | [020.10.05.00.00-0002-PLA-C, Sec 5.1, Para 3] |
| Proposal Submission Concept | STK0805 | The proposal submission process shall minimize the need for PIs to have expert knowledge of the hardware, calibration and data processing issues specific to the ngVLA. | [020.10.05.00.00-0002-PLA-C, Sec 5.1, Para 1] |

## 6.7 Scheduling

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| Priority in Scheduling Observations | STK0900 | The system shall schedule observations based on the scientific rankings of proposals, taking into consideration array status and observing conditions. | [020.10.05.00.00-0002-PLA-C, Sec 5.1, Para 4] |
| Priority for Triggered Observations | STK0901 | A capability to interrupt the execution of the observing program in order to respond to a triggered observation with a higher scientific rank shall be provided. | [020.10.05.00.00-0002-PLA-C, Sec 5.2, Para 3] |
| Concurrent Maintenance and Observation | STK0902 | In order to support concurrent maintenance and observations, it shall be possible to dynamically remove/add antennas from/to an active observation without interrupting the execution of the project. | [020.10.05.00.00-0002-PLA-C, Sec 6.1, Para1] |

## 6.8 Data Processing

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| Pipeline Use for Standard Observing Modes | STK1000 | The system should, in Full Operations, support 80% or more of the awarded proposals with the delivered set of standard observing modes, for which the calibration and data processing will be undertaken through an automated pipeline developed and run by the Observatory. | [020.10.05.00.00-0002-PLA-C, Sec 5, Para 3] |
| Computing Resources for Standard Modes: Reprocessing | STK1001 | The system shall provide computing resources for data reprocessing, requested by PIs, with capacity to reprocess no less than 20% of recorded observations each year. | [020.10.05.00.00-0002-PLA-C, Sec 5.3, Para 2] |

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| Computing Resources for Standard Modes | STK1002 | The system shall provide the necessary computing resources for the data processing associated with normal operations using standard modes and capabilities (including the delivery of Science Ready Data Products to PIs). | [020.10.05.00.00-0002-PLA-C, Sec 5.3, Para 2] |
| Support for Legacy Programs | STK1004 | The system shall include interfaces to support generating some or all SRDP for Large and Legacy scale projects, if the project SRDPs can be generated within available compute resources. Large and Legacy scale projects will identify data processing requirements and resources, and may require additional computing resources to be made available from non-Observatory sources in order to be scheduled. | [020.10.05.00.00-0002-PLA-C, Sec 5.3, Para 5] |
| Data Delivery: Process in Place | STK1005 | User interface tools to ngVLA data shall permit processing the data in place rather than transferring the data across the Internet for processing and analysis by users. | [020.10.05.00.00-0002-PLA-C, Sec 5.4, Para 5] |

## *6.9 Data Archive*

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| Data Product Types to Archive | STK1100 | Raw visibilities, calibration tables, and SRDPs shall be stored and made available to PIs and archival researchers through the Data Archive. | [020.10.05.00.00-0002-PLA-C, Sec 5.3, Para 4] |
| ngVLA Data Archive Functionality: Image Selection and Download | STK1101 | The Archive user interface shall allow users to inspect and select image data for download. | [020.10.05.00.00-0002-PLA-C, Sec 5.4, Para 1] |
| Reprocessing and Automated QA via Archive | STK1102 | The Data Archive shall provide an interface to allow scientists to initiate reprocessing of ngVLA archived data using Observatory-provided techniques and tools, and shall include automated quality assurance processes. | [020.10.05.00.00-0002-PLA-C, Sec 5.4, Para 1] |
| Proprietary Period for PI Data | STK1103 | PI access to data shall be protected by a proprietary period (nominally a year, but determined by Observatory policy), after which the data and data products are fully and publicly accessible. The proprietary period shall be granular to the level of a scan, and begin when the data products are made available to PIs. | [020.10.05.00.00-0002-PLA-C, Sec 5.4, Para 2] |

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| User Produced Data Products | STK1104 | The Data Archive shall have provisions for accepting user-produced data products where those products can be quality assured by the Observatory (such as products from Large projects or Legacy projects). In such circumstances the Observatory will approve the user QA process, not the individual products. | [020.10.05.00.00-0002-PLA-C, Sec 5.4, Para 3] |
| Proprietary Period for Legacy Program Data | STK1105 | It shall be possible to adjust the proprietary period by project and project class. Large and Legacy projects and some other special cases may have a different proprietary period, subject to Observatory-level proprietary policy changes. | [020.10.05.00.00-0002-PLA-C, Sec 5.4, Para 4] |
| Data Delivery via Observatory Archive | STK1106 | Data products shall be delivered to the Principal Investigators through an Internet-accessible Observatory Science Data Archive. | [020.10.05.00.00-0002-PLA-C, Sec 5, Para 3] |
| Data Provenance | STK9950 | The system shall include all the necessary tools and data stores for scientific operations staff to be able to retroactively associate any recorded data with the full state of the system (inclusive of hardware and software versions across subsystems) used to generate the data set. | [STRR RID #25] |

## *6.10 Support Datastores*

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| System Calibration Database | STK1150 | A System Calibration database shall be provided to store antenna-based calibration parameters such as gain curves and polarization D-terms. | [020.10.05.00.00-0006-PLA-B, Sec 2.4.3, Para 1] |
| Astronomical Calibrator Database | STK9943 | An Astronomical Calibrator database shall be provided to store calibrator flux density histories and image models. | [020.10.05.00.00-0006-PLA-B, Sec 5.1, List Item 9] |

## *6.11 Calibration*

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| Storage and Retrieval of Calibration Coefficients | STK1300 | The system shall provide for automatic storage and retrieval of system parameters determined by calibration, such as delays or bandpass gains. | [020.10.05.00.00-0002-PLA-C, Sec 5.8, Para1] |

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| Automated Re-Measurement of Calibration Coefficients | STK1301 | Remeasurement of calibration and related scientific performance characteristics of the array, as required to support the Standard Observing Modes, shall be automated and performed as an Observatory function. | [020.10.05.00.00-0002-PLA-C, Sec 5.8, Para1] |
| Inclusion of Calibration Pipelines and Supporting Systems | STK1302 | The design of online and offline calibration strategies to support standard observing modes, including any supporting hardware and software, shall be a construction project deliverable. | [020.10.05.00.00-0006-PLA-B, Sec 2.4.3, Para1] |

## *6.12 Observational Efficiency*

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| Subarrays for Scheduling | STK1401 | The proposal tools and scheduling system shall support, at a minimum, a limited number of predefined science subarrays. | [020.10.05.00.00-0002-PLA-C, Sec 5.2, Para 1] |
| Observational Efficiency | STK1402 | The system shall be designed to maximize the array's resources and time spent on scientific observations (vs maintenance, testing, and development efforts.) Greater than 90% of antennas shall be available for scientific observations 80% of the time. Goal of system availability for scientific observations of 95% of time, with at least 70% of antennas. | [020.10.05.00.00-0002-PLA-C, Sec 6.1, Para 2] |
| Calibration Efficiency | STK1403 | Within the portion of time spent on science observations, the system shall be optimized for time spent on the science target, with consideration given to minimizing operational overheads and calibration level. | [020.10.05.00.00-0002-PLA-C, Sec 5.1, Para 4] |

## *6.13 User Support*

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| Operational User Support | STK1200 | The project shall provide tools and interfaces for user support for all aspect of ngVLA use related to proposing, observing, data quality, processing and data analysis. | [020.10.05.00.00-0002-PLA-C, Sec 5.6, Para1] |
| Software Packages Available to User Community: Data Analysis | STK1201 | The project shall provide software tools for data analysis by users. The package shall be executable on Observatory compute resources and on external computers. | [020.10.05.00.00-0002-PLA-C, Sec 5.3, Para 6] |

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| Software Packages Available to User Community: Data Processing | STK1202 | The project shall provide software tools to the user community for processing ngVLA visibilities. The package shall be executable on Observatory compute resources and on external computers. | [020.10.05.00.00-0002-PLA-C, Sec 5.3, Para 6] |
| Open Source Software | STK9947 | The ngVLA data processing and analysis software shall be developed under an open source license and the source code shall be made available to the community in order to foster community experimentation. | [STRR RID #49] |

## *6.14 Array Operations*

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| Array Operations: Subarray Use | STK1501 | The automatic scheduling of array time shall incorporate the use of concurrent subarrays, allowing a more continuous concurrent implementation of scientific observations, maintenance, and testing. | [020.10.05.00.00-0002-PLA-C, Sec 6.1, Para 2] |
| Operator Interface | STK1502 | The system shall include interfaces for human operator(s) to oversee the array. The operator interface shall enable the supervision of array scheduling and observation execution, while also reporting array status and system health. | [020.10.05.00.00-0002-PLA-C, Sec 6.2, Para1] |
| Array Operations: Remote and Automated Functions | STK1506 | Functions leveraging remote operations and automation of antenna functions shall be implemented when supported by lifecycle cost analysis. | [020.10.05.00.00-0002-PLA-C, Sec 6.2, Para3] |
| Operator Interface Location | STK9944 | It shall be possible for authorized personnel to access the operator interface software from any approved workstation in the observatory. | [STRR RID #52] |

## *6.15 Configuration Management*

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| Remote Access of System Configuration | STK1600 | The system configuration shall be remotely ascertainable for each major element (Line Replaceable Unit, Software Module, or equivalent) of the system, even those that do not typically have integrated diagnostic monitoring (e.g., cryogenic refrigerators), so that the facility configuration can be queried and tracked using automated tools. | [020.10.05.00.00-0002-PLA-C, Sec 7.2, Para 3] |

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| Identification by Serial Numbers | STK1602 | Individual LRUs, and all other configurable items, shall be uniquely identifiable to facilitate status and location tracking across the Observatory. | [020.10.05.00.00-0006-PLA-B, Sec 5, # 4] |
| Packaging as LRUs | STK1603 | Electronics shall be packaged as Line Replaceable Units (LRUs), where LRU modules are interchanged at the antenna. | [020.10.05.00.00-0002-PLA-C, Sec 7, Para 5] |
| Configuration Management Tools | STK1604 | The project shall provide configuration management tools for tracking the design versions of construction deliverables throughout the system lifecycle. | [020.10.05.00.00-0005-PLA-B, Sec 3, Bullet 7] |
| Version Control: Software and Firmware | STK1606 | All software and firmware delivered to the project shall be version controlled via a configuration management process. | [020.10.05.00.00-0005-PLA-B, Sec 5.2.2, Para 1] |
| Configuration Retrieval | STK9945 | All configurable LRUs shall retrieve their hardware parameter configuration automatically after replacement, and upon a change in the parameter in the System Calibration database. | [STRR RID #35] |

## *6.16 Quality Assurance and Quality Control*

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| Quality Control Database | STK1900 | A quality control database shall be provided to record repairs, test data, and associated information on each LRU. The database should be globally visible to all authorized personnel from any ngVLA location, even out in the field at remote antennas. | [020.10.05.00.00-0002-PLA-C, Sec 9.3, Para 3] |
| Quality Control | STK1902 | Stand-alone acceptance testing of software and hardware deliverables (based on a qualification matrix unique to each deliverable) must occur before delivery to, or installation on, the array. | [020.10.05.00.00-0002-PLA-C, Sec 9.3, Para 3] |
| Automated QA of Data Products | STK9948 | The system shall include an automated quality control check of low-level and high-level data products generated using standard operating modes. | [STRR RID #53] |
| QA Tools for Data Products | STK9949 | The system shall include tools for human inspection when the automated QA system identifies faults, or when data products were generated with non-standard modes. | [STRR RID #53] |

### *6.17 Facilities*

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| Inclusion of a Visitor Center | STK2000 | An ngVLA Visitor Center shall be provided for public outreach and shall be located near the array, but at some distance from the center of the core to mitigate RFI. It is a goal to renovate and reuse the VLA Cafeteria for this purpose. | [020.10.05.00.00-0002-PLA-C, Sec 8.4, Para 1], [Director's Office, 2018.] |
| Inclusion of a Maintenance Operations Center | STK2001 | A Maintenance Operations center shall be provided as the duty station for safety, security, and maintenance personnel. This center shall serve as the node for maintenance activities and the storage of LRUs, field tools and equipment. | [020.10.05.00.00-0002-PLA-C, Sec 8.5, Para 1] |
| Inclusion of a Warehouse | STK2002 | A central warehouse shall be provided for controlled inventory of all components used for preventive and corrective maintenance. | [020.10.05.00.00-0002-PLA-C, Sec 8.5, Para 3] |
| Inclusion of a Repair Center | STK2003 | A Repair Center shall be provided to host staff and equipment necessary for the transfer, diagnosis, repair, and test of electronic LRUs and other equipment. | [020.10.05.00.00-0002-PLA-C, Sec 8.6, Para 1-2] |
| Inclusion of an Array Operations Center | STK2004 | An Array Operations Center (AOC) shall provide sufficient space to host off-site array operations and a comparable complement of office space, laboratory space, storage and transfer capabilities, and computing infrastructure as in the existing DSOC. | [020.10.05.00.00-0002-PLA-C, Sec 8.6, Para 1-2] |
| Inclusion of a Science Operations Center | STK2005 | A Science Operations Center (SOC) shall be provided to house the scientific operations staff constituted of scientists, data analysts, computing, software, and IT positions, and some administrative and management staff. The facility shall primarily consist of office space and supporting computing infrastructure. | [020.10.05.00.00-0002-PLA-C, Sec 8.7, Para 1-2] |
| Inclusion of Remote Support Stations | STK2006 | Remote Support Stations (RSS) shall be provided and located to support operations across the array extent. Each RSS shall have a footprint to support workbenches, organized tools, supplies, and inventory including spare LRUs required for routine maintenance of a group of antennas. | [020.10.05.00.00-0002-PLA-C, Sec 8.8, Para 1-3] |
| Location of the Maintenance Operations Center | STK2007 | The Maintenance Operations Center shall be located near the array site in order to facilitate logistics, but sufficiently far away to mitigate RFI at the Array Core. | [020.10.05.00.00-0002-PLA-C, Sec 8.5] |

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| Location of the Array Operations Center | STK2008 | The Array Operations Center shall be located within a two hour drive of the array site in order to facilitate logistics while providing an attractive location to recruit array operations personnel. | [020.10.05.00.00-0002-PLA-C, Sec 8.6] |
| Location of the Science Operations Center | STK2009 | The Science Operations Center shall be located at a site that facilitates personnel recruitment, such as an attractive metropolitan area. | [020.10.05.00.00-0002-PLA-C, Sec 8.7] |
| Location of the Repair Center | STK2010 | The Repair Center shall be located within a two hour drive of the array site in order to facilitate logistics while providing an attractive location to recruit array operations personnel. It may be co-located with the Array Operations Center. | [020.10.05.00.00-0002-PLA-C, Sec 8.6] |
| Location of the Warehouse | STK2011 | The Warehouse shall be located near the array site in order to facilitate logistics, but sufficiently far away to mitigate RFI at the Array Core. It may be co-located with the Maintenance Operations Center. | [020.10.05.00.00-0002-PLA-C, Sec 8.5] |
| Inclusion of a Guard Booth | STK2012 | To maintain site security at the additional buildings near the core of the array, a guard booth shall be provided to support a constant security presence by security staff. | [020.10.05.00.00-0002-PLA-C, Sec 8.2 Para 1] |
| Inclusion of Central Support Buildings | STK2013 | As required, additional buildings near the array core shall provide for the storage and maintenance of heavy equipment that cannot be easily delivered or driven from the nearby Maintenance Center and to support the maintenance and repair staff temporarily on-site. | [020.10.05.00.00-0002-PLA-C, Sec 8.2, Para 1] |

## *6.18 Logistics*

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| Inventory Tracking System | STK2100 | A system shall be provided to electronically track inventory to determine usage rate and location of spare assemblies, component level spares, and consumables. | [020.10.05.00.00-0002-PLA-C, Sec 9.2, Para 1] |
| Shipping and Receiving Logistics | STK2102 | Each facility shall have central shipping and receiving and be integrated with a shipping system between sites. | [020.10.05.00.00-0002-PLA-C, Sec 9.2, Para 2] |
| Repair and Tracking of LRUs | STK2103 | Provisions shall be provided for centralized management, testing, and repair of LRUs from the Repair Center. Repaired LRUs may be stored near the point of service at the Maintenance Center and RSS locations. | [020.10.05.00.00-0002-PLA-C, Sec 9.3, Para 1] |

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| Observatory-Controlled Logistics | STK2105 | Observatory-controlled shipping resources shall be provided to enable prioritization, possession, and safe-handling of items during transit (i.e., to be used rather than commercial carriers, when practical). | [020.10.05.00.00-0002-PLA-C, Sec 9.2, Para 2] |
| Packaging Used for Shipping | STK2106 | Shipping cases and packaging shall be provided with ESD protection and mechanical shock absorption. | [020.10.05.00.00-0002-PLA-C, Sec 9.2, Para 2] |

## *6.19 Security*

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| Physical Security Plans | STK2201 | Physical security and monitoring for the ngVLA central site and remote sites shall be provided. | [020.10.05.00.00-0002-PLA-C, Sec 9.5, Para 1-2] |
| Cybersecurity | STK2202 | ngVLA IT systems shall be hardened against intrusion consistent with existing NRAO CIS policies. | [020.10.05.00.00-0002-PLA-C, Sec 9.6, Para 1] |

## *6.20 Local Stakeholders*

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| Grassland & Water | STK2400 | The project shall minimize the impact on grasslands and water within the plains of San Agustin. Special care will be necessary in the array core given the degree of disturbance. | [J&S Bruton, 09/25/2018 visit by PD. ] |
| Roads | STK2401 | Road widths and lengths shall be minimized to reduce the destruction of top soil. The road design shall aim to avoid the collection of water into new ditches or arroyos that will exacerbate soil erosion. | [J&S Bruton, 09/25/2018 visit by PD. ] |
| Existing Roads | STK2402 | Existing ranch roads shall be assessed for suitability in both construction and operations. It is a goal to reuse existing roads where possible. | [J&S Bruton, 09/25/2018 visit by PD. ] |
| Fences | STK2403 | Any fences shall not impede the flow of cattle and wildlife within and between neighboring ranches, or significantly increase the travel distance to water sources. | [J&S Bruton, 09/25/2018 visit by PD. ] |
| Ranching Impact | STK2404 | The project shall aim to reduce the environmental impact to cattle ranching as well as hunting/outfitting, which are both mainstays of local ranches. | [J&S Bruton, 09/25/2018 visit by PD. ] |
| Core Site | STK2405 | The specific location of the array core shall consider the differences in the quality of lands on the plains for other beneficial uses including ranching. | [J&S Bruton, 09/25/2018 visit by PD. ] |

## 6.21 NRAO and Other Facility Integration

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| SRDP Integration | STK2500 | The ngVLA project should extend and reuse the SRDP Observatory-User interfacing architecture for ngVLA. | [SRDP AD, 2018. Director's Office, 2018.] |
| Facility Integration | STK2501 | It is desirable for ngVLA to support joint (e.g., VLB) observations with other NRAO facilities, as well as other global flagship facilities. | [ngVLA PD] |
| DMS Integration | STK2502 | The ngVLA project shall adopt existing NRAO Data Management & Software (DMS) policies, with facility integration into Observatory infrastructure and standards, in order to promote reuse and maintainability. | [DMS AD, 2016] |

## 6.22 Radio Frequency Interference

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| Self-Interference | STK2600 | The system shall be designed to prevent self-interference that will be detrimental to science operations. | [ngVLA PD] |
| RFI Survival | STK2601 | The system shall be designed to withstand, without damage or long-term degradation, the projected RFI environment over the life of the instrument. | [ngVLA PD] |
| RFI Mitigation | STK2602 | The system shall be designed to operate in the projected RFI environment while still achieving the Key Science Goals and the desired operational efficiencies. | [ngVLA PD] |
| VLA Interference | STK2603 | It is a goal to minimize interference with VLA operations during the construction/transition phase. | [ngVLA PD] |

## 6.23 Non-Traditional Use Cases

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| SSA Support | STK2800 | It is a goal for the ngVLA to support non-traditional use cases related to space situational awareness, such as imaging of geostationary objects. | [Directors Office, 2016] |
| DSN Support | STK2801 | It is a goal for the ngVLA to support non-traditional use cases related to spacecraft operation, such as Deep Space Network (DSN) downlink support for critical NASA missions. | [Directors Office, 2016] |

### *6.24 Future Commensal Systems*

| Parameter | Req. # | Value | Traceability |
| --- | --- | --- | --- |
| Commensal Front-Ends | STK2900 | The system shall be designed for but not with commensal front-ends (e.g., ngLOBO), with interfaces for future commensal receivers and data processing systems incorporated into the design. | [NRL, LWA, 2016] |
| Commensal Back-Ends | STK2901 | The system shall be designed for but not with commensal back-ends (e.g., RealFast, SETI), with interfaces for future commensal back-ends incorporated into the design. | [ngVLA PD] |

# 7 Appendix

## 7.1 Abbreviations and Acronyms

| Acronym | Description |
| --- | --- |
| AD | Applicable Document |
| AIV | Assembly, Integration and Verification |
| ALMA | Atacama Large Millimeter/submillimeter Array |
| AOC | Array Operations Center |
| API | Application Programming Interface |
| APM | Atmospheric Phase Monitor |
| AST | Division of Astronomical Sciences (NSF) |
| AUI | Associated Universities Inc. |
| CASA | Common Astronomy Software Applications |
| CDL | Central Development Laboratory |
| CSV | Commissioning & Science Validation |
| DMS | Data Management & Software |
| DSN | Deep Space Network |
| EMC | Electro-Magnetic Compatibility |
| ESD | Electro-Static Discharge |
| EVLA | Expanded Very Large Array Project |
| FOV | Field of View |
| FWHM | Full Width Half Max |
| HPC | High Performance Computing |
| ICD | Interface Control Document/Definition |
| IF | Intermediate Frequency |
| IPT | Integrated Product Team |
| IT | Information Technology |
| KPP | Key Performance Parameters |
| KSG | Key Science Goals |
| LFM | Large Facilities Manual |
| LO | Local Oscillator |
| LRU | Line Replaceable Unit |
| LSST | Large Synoptic Survey Telescope |
| MOC | Maintenance Operations Center |
| MoE | Measure of Effectiveness |
| MoP | Measure of Performance |
| MREFC | Major Research Equipment and Facilities Construction (NSF) |
| MTBF | Mean Time Between Failure |
| MTTF | Mean Time To Failure |
| NES | Near Earth Sensing |
| ngLOBO | Next Generation LOw-Band Observatory |

| | |
| --- | --- |
| ngVLA | Next Generation VLA |
| NMTO | New Mode Test Observation |
| NRAO | National Radio Astronomy Observatory |
| NSDR | Non-Standard Data Reduction |
| NSF | National Science Foundation |
| OS | Operating System |
| PD | Project Director |
| PI | Principal Investigator |
| PM | Preventive Maintenance |
| PWV | Precipitable Water Vapor |
| RID | Review Item Discrepancy |
| RD | Reference Document |
| RFI | Radio Frequency Interference |
| rms | Root Mean Square |
| RSS | Root of Sum of Squares; Remote Support Station |
| SAC | Science Advisory Council |
| SB | Scheduling Block |
| SKA | Square Kilometer Array |
| SMDR | Standard Mode Data Reduction |
| SNR | Signal to Noise Ratio |
| SOC | Science Operations Center |
| SRDP | Science Ready Data Products |
| SRO | Shared Risk Observing |
| STRR | Stakeholder Requirements Review |
| SWG | Science Working Group |
| TBC | To Be Confirmed |
| TBD | To Be Determined |
| VLA | Jansky Very Large Array |
| VLASS | Very Large Array Sky Survey |
| VLB | Very Long Baseline (Interferometry) |
| VLBI | Very Long Baseline Interferometry |
| WFIRST | Wide Field InfraRed Survey Telescope |
| WP | Work Package |
| WVR | Water Vapor Radiometer |