Requirements Verification Traceability Matrix

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Change Log

Version	Date	Author	Description of Change(s)
1	2019-03-29	S. Leff	Draft formatted & uploaded to EDMS
2	2019-04-08	S. Leff	Updated to reflect latest information
A	2019-07-09	A. Lear	Prepared document for approvals and release
A.1	2020-05-06	S. Leff	Revisions for external review
B	2020-05-06	A. Lear	Prepared document for approvals and release

Key Science Goals - RVTM

#	Id	Name	Text	Derived
1	KSG1	Unveiling the Formation of Solar System Analogues on Terrestrial Scales	The ngVLA shall be able to measure the planet initial mass function down to a mass of 5−10 Earth masses and unveil the formation of planetary systems similar to our own Solar System by probing the presence of planets on orbital radii as small as 0.5 AU at the distance of 140 pc. The ngVLA shall also be able to reveal circumplanetary disks and sub-structures in the distribution of mm-size dust particles created by close-in planets and measure the orbital motion of these features on monthly timescales.	SCI0001 Frequency Coverage SCI0006 Observing Modes SCI0019 Accessible Sky
2	KSG1.1		Continuum observations for center frequencies between 20−110 GHz with angular resolution better than 5 mas at 100 GHz are required to study the formation of planets in the innermost 10 AU of nearby (<140 pc) proto-planetary disks.	SCI0003 Frequency Selection SCI0103 Angular Resolution SCI0108 Imaging Fidelity SCI0109 Snapshot Image Fidelity
3	KSG1.2		Extensive simulations of the disks perturbed by planets suggest that a sensitivity of 0.5 uJy/bm in the continuum at 100 GHz is required to map structures in the dust distribution created by planets of mass down to 10 Earth-masses and orbital radius of 2.5 AU in a couple hundred systems out to a distance of 400 pc. There is a desire to reach 0.3 uJy/bm to extend this work to several hundred systems out to a distance of 700 pc.	SCI0100 Continuum Sensitivity
4	KSG1.3		Matching resolution (i.e. 5 mas) and achieving a continuum rms noise of order 0.07 uJy/bm at 30 GHz will map the planet–disk interactions where the disk emission is expected to be optically thin. There is a desire to reach 0.04 uJy/bm to extend this work to a couple hundred systems out to a distance of 400 pc.	SCI0100 Continuum Sensitivity SCI0103 Angular Resolution
5	KSG1.4		Observations would benefit from the largest possible aggregate bandwidth to maximize continuum sensitivity, and from full polarization capabilities to better constrain the properties of the dust grains.	SCI0003 Frequency Selection SCI0015 Polarization Products
6	KSG1.5		A field of view larger than 2” is required to map the entire disk in a single pointing.	
7	KSG1.6		A maximum recoverable scale of at least 1”−2” is required to minimize the effects of spatial filtering.	SCI0104 Largest Recoverable Scale
8	KSG2	Probing the Initial Conditions for Planetary Systems and Life with Astrochemistry	The ngVLA shall be able to detect predicted, but as yet unobserved, complex prebiotic species towards planet and star-forming regions that are the basis of our understanding of chemical evolution toward amino acids and other biogenic molecules. It shall also allow us to detect and study chiral molecules, testing ideas on the origins of homochirality in biological systems. The detection of such complex organic molecules will provide the chemical initial conditions of forming solar systems and individual planets.	SCI0001 Frequency Coverage SCI0006 Observing Modes SCI0019 Accessible Sky
9	KSG2.1		An angular resolution on the order of 50 mas is needed near 30 GHz.	SCI0103 Angular Resolution
10	KSG2.2		An rms of 30 uJy/bm/km/s for frequencies between 16−50 GHz is required.	SCI0102 Line Sensitivity
11	KSG2.3		A spectral resolution of 0.1 km/s is required, preferably concurrent with broadband (4+ GHz) observations.	SCI0002 Observing Bands SCI0003 Frequency Selection SCI0105 Spectral Resolution
12	KSG2.4		Recovery of angular scales up to the expected range of 2”–10” to allow for proper abundance studies using line ratios.	SCI0104 Largest Recoverable Scale
13	KSG2.5		At the desired sensitivity, the spectra must not be corrupted by spurious self-generated signals or changes in bandpass structure that cannot be removed through calibration.	SCI0116 Spurious Spectral Features
14	KSG2.6		An emissive spectral dynamic range better than 50 db is required to enable imaging of faint prebiotic molecules in the presence of bright line emission within the field of view.	SCI0107 Quality of the Synthesized Beam SCI0115 Spectral Dynamic Range (Emissive)
15	KSG3	Charting the Assembly, Structure, and Evolution of Galaxies from the First Billion Years to the Present	The ngVLA shall have the sensitivity to survey cold gas in thousands of galaxies back to early cosmic epochs, while simultaneously enabling routine sub-kiloparsec scale resolution imaging of their gas reservoirs. In doing so, the ngVLA will afford a unique view into how galaxies accrete, process, and expel their gas through detailed imaging of their extended atomic reservoirs and	SCI0001 Frequency Coverage SCI0006 Observing Modes SCI0019 Accessible Sky

			circumgalactic regions. The ngVLA shall also have enough sensitivity to map the physical and chemical properties of molecular gas over the entire local galaxy population. These studies will reveal the detailed physical conditions for galaxy assembly and evolution throughout the history of the universe.	
16	KSG3.1	R	A line sensitivity of ~46 uJy/bm/km/s at 0.1” and 1” angular resolution between 10–50 GHz with a spectral resolution of 5 km/s is required for detailed studies of CO kinematics of high-z galaxies and blind CO searches of >1000 galaxies, respectively.	R SCI0102 Line Sensitivity
17	KSG3.2	R	A large instantaneous bandwidth (minimum 1.6:1 BW ratio, up to 20 GHz instantaneous bandwidth) to conduct wideband observations at 5 km/s resolution is required to efficiently perform blind surveys of large cosmic volumes in a single observation to provide routine access molecular species in addition to CO (e.g., HCN, HCO+, or N2H+).	R SCI0003 Frequency Selection
18	KSG3.3	R	Frequency coverage to access the transitions of formaldehyde (5 GHz and 14 GHz), ammonia (23–27 GHz), methanol (particularly the 36 GHz masers), deuterated molecules (~70 GHz), and a host of dense gas tracers (~90 GHz) besides CO (115 GHz) and H1 (1.4 GHz) are required.	R SCI0002 Observing Bands R SCI0003 Frequency Selection
19	KSG3.4	R	Thermal line imaging of CO (115 GHz) with an rms noise of 0.75 K at 0.1” angular resolution and 1 km/s spectral resolution is required for detailed studies of CO in the nearby universe. A spectral dynamic range of 30 dB is also required, while 40 dB is desired.	R SCI0102 Line Sensitivity R SCI0107 Quality of the Synthesized Beam R SCI0108 Imaging Fidelity
20	KSG3.5	R	Thermal imaging with an rms noise of 1–5 mK between 70 and 116 GHz at 1–5” angular resolution, and 1–5 km/s spectral resolution is required to support studies of gas density across the local universe. A spectral dynamic range of 30 dB is also required, while 40 dB is desired.	R SCI0102 Line Sensitivity R SCI0107 Quality of the Synthesized Beam R SCI0108 Imaging Fidelity R SCI0109 Snapshot Image Fidelity
21	KSG3.6	R	Full 1.2–116 GHz frequency coverage is required to obtain accurate, simultaneous measurements of star formation rates from free-free continuum and radio recombination line (RRL) emission. A spectral dynamic range of better than 40 db is required for accurate RRL line-to-continuum ratios.	R SCI0109 Snapshot Image Fidelity R SCI0110 Photometric Error
22	KSG3.7	R	Angular resolutions of 0.1–1” for continuum imaging at all available frequencies are required.	R SCI0107 Quality of the Synthesized Beam R SCI0108 Imaging Fidelity
23	KSG3.8	R	A continuum rms noise of ~0.18 uJy/bm at 27 GHz for a 1” synthesized beam is required for robustly studying star formation within nearby, star-forming galaxies. Given the expected 27 GHz peak brightnesses within such galaxies, the resulting dynamic range requirement is ~35 dB.	R SCI0100 Continuum Sensitivity R SCI0113 Brightness Dynamic Range
24	KSG3.9	R	Accurate recovery of flux density for extended objects on arcminute scales at all frequencies is required.	R SCI0104 Largest Recoverable Scale R SCI0108 Imaging Fidelity
25	KSG3.10	R	The ability is needed to make large mosaics or conduct on-the-fly line and/or continuum mappings of galaxies that extend beyond the area of a single primary beam.	R SCI0004 Mosaics and On-the-Fly Mapping
26	KSG3.11	R	A brightness dynamic range of 45 and 35 dB is required at 8 GHz for deep-field continuum studies of MW-like galaxies at “cosmic noon” to not be dynamic-range-limited in total and polarized intensity, respectively.	R SCI0015 Polarization Products R SCI0113 Brightness Dynamic Range R SCI0114 Polarization Dynamic Range
27	KSG3.12	R	An absorptive dynamic range of 40 dB to measure the physical properties of Galactic neutral Hydrogen for ~1000 sight lines with a velocity resolution of 0.4 km/s and +/- 150 km/s velocity range at an angular resolution of 0.1”.	R SCI0119 Spectral Dynamic Range (Absorptive)
28	KSG4	R Using Pulsars in the Galactic Center to Make a Fundamental Test of Gravity	The ngVLA shall achieve a combination of sensitivity and frequency range, enabling it to probe much deeper into the likely Galactic Center pulsar population to address fundamental questions in relativity and stellar evolution. Pulsars in the Galactic Center represent clocks moving in the space-time potential of a super-massive black hole and would enable qualitatively new tests of theories of gravity. More generally, they offer the opportunity to constrain the history of star formation, stellar dynamics, stellar evolution, and the magneto-ionic medium in the Galactic Center.	R SCI0001 Frequency Coverage R SCI0006 Observing Modes R SCI0019 Accessible Sky
29	KSG4.1	R	The ngVLA shall support pulsar search and timing observations from ~1 to 30 GHz for Galactic Center pulsars. Pulsar searching requires 100 us scales (20 us scales desired), while timing requires 1 us resolution. While there are uncertainties and the distribution could be inhomogeneous, mitigating radio wave scattering is likely to require a frequency range that includes the lower range anticipated for the ngVLA (≥3 GHz).	R SCI0012 Pulsar Timing Capabilities R SCI0013 Time Domain Search Capabilities

30	KSG4.2	R	A continuum rms noise of order 50 nJy/bm is desired at 20 GHz. This is a significant improvement compared to existing 100 m class radio telescopes that have found few pulsars, indicating that substantial additional sensitivity is necessary.	R SCI0100 Continuum Sensitivity
31	KSG4.3	R	The system timing accuracy shall be better than 10 ns (1 ns desired) over periods correctable to a known standard from 30 minutes to ten years.	R SCI0112 Timing Error
32	KSG4.4	R	The array shall have the ability to make multiple (minimum ten) beams (i.e. phase centers within the primary beam) within a single sub-array, or distributed amongst multiple sub-arrays.	R SCI0007 Phased Array Capability R SCI0008 Beam Forming
33	KSG4.5	R	Timing multiple pulsars within a single primary beam is desirable. Support for five or more independent de-dispersion and folding threads is desired.	R SCI0012 Pulsar Timing Capabilities
34	KSG5	R Understanding the Formation and Evolution of Stellar and Supermassive Black Holes in the Era of Multi-Messenger Astronomy	The ngVLA shall be able to survey everything from the remnants of massive stars to the supermassive black holes that lurk in the centers of galaxies, making it the ultimate black hole hunting machine. High-resolution imaging abilities are required to separate low-luminosity black hole systems in our local Universe from background sources, thereby providing critical constraints on the formation and growth of black holes of all sizes and mergers of black hole–black hole binaries. The ngVLA shall also be able to identify the radio counterparts to transient sources discovered by gravitational wave, neutrino, and optical observatories. This requires high-resolution, fast-mapping capabilities to make it the preferred instrument to pinpoint transients associated with violent phenomena such as supermassive black hole mergers and blast waves.	R SCI0001 Frequency Coverage R SCI0006 Observing Modes R SCI0019 Accessible Sky
35	KSG5.1	R	High-resolution (mas − μas) imaging with relative astrometric accuracy that is <1% of the synthesized beam FWHM or equal to the positional uncertainty in the reference frame, for a bright (SNR ≥100) point source, is required for surveying black holes. Such high-resolution (mas − μas) imaging will enable proper motion separation of local black holes (both Galactic and in nearby galaxies, out to 15 Mpc) from background sources.	R SCI0103 Angular Resolution R SCI0107 Quality of the Synthesized Beam R SCI0111 Relative Astrometric Error
36	KSG5.2	R	Long baselines are required to enable imaging the SMBH binaries that will be detected in gravitational waves by LISA and pulsar timing arrays. These astrometric science goals benefit from the implementation of very long baselines (≥1000 km for mas−uas accuracy). Associated VLBI recording capabilities shall be available for three or more beams (two calibrators and the science target).	R SCI0017 VLBI Capabilities R SCI0107 Quality of the Synthesized Beam R SCI0111 Relative Astrometric Error
37	KSG5.3	R	While the key frequency range is 5−20 GHz, the availability of higher (20−50 GHz) frequencies are required for regions with high interstellar scatter broadening.	
38	KSG5.4	R	Multiple (i.e. a minimum of ten) sub-arrays with independent beams and pulsar timing support are desired. Precision timing of pulsars may not be sensitivity limited, but require long observations to oversample the pulse period and remove pulse jitter.	R SCI0007 Phased Array Capability R SCI0008 Beam Forming R SCI0009 Sub-Array Capabilities R SCI0012 Pulsar Timing Capabilities
39	KSG5.5	R	Pulsar timing will require 1 us resolution and frequency coverage down to 1–2 GHz.	R SCI0012 Pulsar Timing Capabilities
40	KSG5.6	R	Mapping a ~7 square degree region (i.e. the localization uncertainty expected by gravitational wave detectors when ngVLA is operational) to a depth of ~1 uJy/bm at 2.5 GHz for detection of Advanced LIGO-detected NS-NS and NS-BH mergers is required. Completing the on-the-fly mapping of each epoch within ~10 hr is desirable.	R SCI0004 Mosaics and On-the-Fly Mapping R SCI0106 Survey Speed
41	KSG5.7	R	Mapping a ~10 square degree region (i.e. the localization uncertainty expected by LISA) at 28 GHz to a depth of ~10 uJy/bm with on-the-fly mapping is required for localization of LISA-detected SMBH mergers. Completing the on-the-fly mapping of each epoch within ~10 hr is desirable.	R SCI0004 Mosaics and On-the-Fly Mapping R SCI0106 Survey Speed
42	KSG5.8	R	The ability to receive and respond to external triggers rapidly is also an essential requirement to enable multi-messenger science. Triggered response time not to exceed ten minutes is required, while response time of better than three minutes is desired.	R SCI0005 Triggered Observations R SCI0020 Data Delivery Latency
43	KSG5.9	R	The ability to perform time-domain transient searches requires a search capability on 100 us scales, with 20 us scales desired. Interfaces for future high time-resolution imaging capabilities (e.g., for fast radio burst localization) are desired.	R SCI0013 Time Domain Search Capabilities
44	KSG5.10	R	An rms noise of 0.23 uJy/bm at 10 GHz is required for a 0.7 mas beam to detect a source like GW170817 with a SNR ~10 at the Advanced LIGO horizon distance of 200 Mpc and allow for the measurement of its expansion at the 5-sigma level.	R SCI0017 VLBI Capabilities R SCI0117 VLB Continuum Sensitivity R SCI0118 VLB Angular Resolution

45	KSG5.11	R		To inform follow-up observations of sub-(stellar) systems and accreting/merging compact objects, the ngVLA shall be capable of delivering “quick-look” continuum images to PI’s within 1 hr of completing (triggered) observations of integration times up to 1 hr to inform/trigger follow-up observations using the ngVLA and/or other telescopes across the electromagnetic spectrum.	R SCI0020 Data Delivery Latency

L0 Science Requirements - RVTM

#	Id	Name	Text	Derived	Derived From
1	SCI0001	Frequency Coverage	The ngVLA should be able to observe in all atmospheric windows between 1.2 and 116 GHz. These frequency limits are bracketed by spectral line emission from H1 and CO (J=1-->0) respectively.	SYS0801 System Frequency Range SYS0806 Continuity of Frequency Coverage EMC0328 EMC Test Frequencies	KSG1 Unveiling the Formation of Solar System Analogues on Terrestrial Scales KSG5 Understanding the Formation and Evolution of Stellar and Supermassive Black Holes in the Era of Multi-Messenger Astronomy KSG4 Using Pulsars in the Galactic Center to Make a Fundamental Test of Gravity KSG3 Charting the Assembly, Structure, and Evolution of Galaxies from the First Billion Years to the Present KSG2 Probing the Initial Conditions for Planetary Systems and Life with Astrochemistry
2	SCI0002	Observing Bands	ngVLA observing band edges should in all possible cases avoid astronomically interesting spectral lines for redshifts between z=0 and z=0.1. Overlap of 1% in band edges is therefore desirable.	SYS0806 Continuity of Frequency Coverage	KSG2.3 KSG3.3
3	SCI0003	Frequency Selection	The system shall support full bandwidth selection of the front end(s) without gaps in frequency coverage that is instantaneously available. Selectable bandwidth steps may be discrete if necessary. Observing multiple line diagnostics within a single band is also desirable.	SYS0806 Continuity of Frequency Coverage SYS0902 Instantaneous Digitized Bandwidth SYS0904 Sub-Bands SYS0905 Frequency Tunability SYS0907 Sub-Band Step Size SYS0909 Contiguous Bandwidth	KSG1.1 KSG1.4 KSG2.3 KSG3.2 KSG3.3
4	SCI0004	Mosaics and On-the-Fly Mapping	The system shall support both mosaicking and on-the-fly mapping of larger fields of view with full spectral capabilities in support of the survey speed requirement (SCI0106).	SYS0008 On The Fly Mapping Mode SYS0106 On-The-Fly Mapping – Data & Control Rates SYS0107 On-The-Fly Mapping – Antenna Tracking Rate SYS1104 Tracking Rates SYS2001 Temporal Resolution SYS5700 Variable Slew Rates SYS5701 Phase Center Update Rates	KSG3.10 KSG5.6 KSG5.7
5	SCI0005	Triggered Observations	The array shall have a mechanism to receive and rapidly respond to external triggers. Triggered response times not to exceed 10 minutes are required for transient science, while response times of 3 minutes are desired.	SYS1103 Slew Rates SYS3004 Triggered Observations SYS3005 Triggered Observation Response SYS3006 Trigger Override SYS5901 Trigger Subscriptions	KSG5.8

				E SYS4302 Calibration of Triggered Observations	
6	SCI0006	R Observing Modes	The system shall observe in both narrow (spectral line) and wide-band (continuum) modes simultaneously. The goal is to maximize flexibility and sensitivity of both modes. This does not preclude a single configurable ‘mode’ that meets the requirements of both general use cases.	E SYS0001 Functional Modes E SYS0002 Interferometric Mode E SYS1403 Flexible Spectral Resolution	R KSG1 Unveiling the Formation of Solar System Analogues on Terrestrial Scales R KSG2 Probing the Initial Conditions for Planetary Systems and Life with Astrochemistry R KSG3 Charting the Assembly, Structure, and Evolution of Galaxies from the First Billion Years to the Present R KSG4 Using Pulsars in the Galactic Center to Make a Fundamental Test of Gravity R KSG5 Understanding the Formation and Evolution of Stellar and Supermassive Black Holes in the Era of Multi-Messenger Astronomy
7	SCI0007	R Phased Array Capability	The system shall operate both as an interferometer and phased-array simultaneously.	E SYS0003 Phased Array Mode E SYS0201 Phased Aperture E SYS0202 Concurrent Interferometric Visibilities E SYS4310 Real Time Atmospheric Delay Calibration	R KSG4.4 R KSG5.4
8	SCI0008	R Beam Forming	The array shall have the ability to make multiple (minimum 10) beams (phase centers within the primary beam) within a single sub-array, or distributed amongst multiple sub-arrays, in the phased array mode.	E SYS0203 Number of Beams	R KSG4.4 R KSG5.4
9	SCI0009	R Sub-Array Capabilities	The system shall be divisible into multiple (i.e. at least 10) sub-arrays for operation and calibration purposes. It is desirable that all functional capabilities listed above should be available in any combination of sub-arrays.	E SYS0203 Number of Beams E SYS0601 Sub-Array Capabilities E SYS0603 Sub-Array Composition E SYS0604 Sub-Array Operating Modes	R KSG5.4
10	SCI0010	R Sub-Array Commensality	Sub-arrays must concurrently function in different observing modes and should be supported at their full specification. In particular, full-bandwidth cross-correlation must be supported in a sub-array, concurrent with phased array and time-domain search capabilities in a separate sub-array.	E SYS0604 Sub-Array Operating Modes E SYS0605 Sub-Array Operating Mode Commensality	
11	SCI0012	R Pulsar Timing Capabilities	Timing multiple pulsars within a single primary beam is required. Support for independent de-dispersion and folding of 5 or more astronomical objects is desired. The system shall provide pulsar timing capabilities with 1 us resolution.	E SYS0003 Phased Array Mode E SYS0004 Pulsar Timing Mode E SYS0301 Timing Capabilities E SYS0302 Timing Sys. Bandwidth E SYS0303 Timing Sys. Frequency Resolution E SYS0304 Pulse Profile Bins E SYS0305 Polarization E SYS0306 Pulse Period E SYS0307 Dump Rate E SYS0741 Pulsar Timing Data Product	R KSG4.1 R KSG4.5 R KSG5.4 R KSG5.5

				E SYS2002 Temporal Accuracy E SYS0308 Pulse Period Resolution	
12	SCI0013	R Time Domain Search Capabilities	The system shall provide time-domain transient search capabilities on 100 us scales in the phased array mode, with 20 us scales desired. Interfaces for future high time-resolution imaging capabilities (e.g., FRB localization) are desired.	E SYS0003 Phased Array Mode E SYS0005 Pulsar and Transient Search Mode E SYS5600 Commensal Processing E SYS0401 Search Capabilities E SYS0402 Search Sys. Bandwidth E SYS0403 Search Sys. Frequency Resolution E SYS0404 Search Sys. Time Resolution E SYS0405 Polarization E SYS0742 Pulsar Search Data Product	R KSG4.1 R KSG5.9
13	SCI0015	R Polarization Products	The system shall measure all polarization products simultaneously.	E SYS0102 Polarization Products E SYS1900 Full Stokes	R KSG1.4 R KSG3.11
14	SCI0016	R Solar Observation Capabilities	It shall be possible to observe the sun at all available frequencies.	E SYS0009 Solar Mode E SYS1201 Input Dynamic Range E SYS5800 Direct Solar Observations E SYS1205 High-Noise Path E SYS1203 Provision of Variable Attenuators E SYS1202 Gain Calibration System Dynamic Range	
15	SCI0017	R VLBI Capabilities	It shall be possible to use the system for VLBI observations with a single element, or phased array output, at all available frequencies. Recording capabilities shall be included for a minimum of 3 beams (10 beams desired). The format should be compatible with expected VLBI arrays.	E SYS0006 VLBI Mode E SYS0501 VLBI Recording Capabilities	R KSG5.2 R KSG5.10
16	SCI0018	R Multi-Frequency Observations	The system shall support either multi-frequency observations or rapid switching between bands. Switching time of the order of 10–20 sec is desired.	E SYS0908 Band Switching Time	
17	SCI0019	R Accessible Sky	The system shall be capable of observations from -40° declination to 90° declination, ensuring adequate overlap with planned southern hemisphere arrays.	E SYS1102 Accessible Field of View	R KSG1 Unveiling the Formation of Solar System Analogues on Terrestrial Scales R KSG2 Probing the Initial Conditions for Planetary Systems and Life with Astrochemistry R KSG3 Charting the Assembly, Structure, and Evolution of Galaxies from the First Billion Years to the Present R KSG4 Using Pulsars in the Galactic Center to Make a Fundamental Test of Gravity R KSG5 Understanding the Formation and Evolution of Stellar and Supermassive Black Holes in the Era of Multi-Messenger Astronomy
18	SCI0020	Data	The ngVLA shall be capable of delivering “quick-look” continuum images to PI’s within 1 hr of completing (triggered) observations of	SYS0754 Processing	KSG5.8

		Delivery Latency	integration times up to 1 hr to inform/trigger follow-up observations using the ngVLA and/or other telescopes across the electromagnetic spectrum	Triggers E SYS0755 Processing Priorities E SYS0721 Imaging Pipeline E SYS0751 Data Processing Resources E SYS0722 Quick Look Image Pipeline	R KSG5.11
19	SCI0100	R Continuum Sensitivity	An rms noise of ~0.07 uJy/bm @30 GHz and 0.5 uJy/bm @100 GHz is required for studying protoplanetary disks. See SCI0117 for corresponding VLB continuum sensitivity requirement.	E SYS0802 Optimized Frequency Range E SYS0901 Front End Bandwidth Ratio E SYS0902 Instantaneous Digitized Bandwidth E SYS0903 Total Instantaneous Processed Bandwidth E SYS1001 Effective Area / Tsys Ratio E SYS1061 Calibration Efficiency E SYS1308 Distribution and Weighting of Visibilities E SYS1501 Delay/Phase Variations Magnitude E SYS1502 SNR Loss to Delay/Phase Variations	R KSG1.2 R KSG1.3 R KSG3.8 R KSG4.2
20	SCI0102	R Line Sensitivity	A line rms noise of 30 uJy/bm/km/s for frequencies between 10–50 GHz is required to support both astrochemistry studies and deep/blind spectral line surveys. A line rms noise of 1 – 750 mK at 5” – 0.1” angular resolution and 1 – 5 km/s spectral resolution between 70 and 116 GHz is required to simultaneously support detailed studies of CO and variations in gas density across the local universe.	E SYS0802 Optimized Frequency Range E SYS0901 Front End Bandwidth Ratio E SYS1001 Effective Area / Tsys Ratio E SYS1061 Calibration Efficiency E SYS1308 Distribution and Weighting of Visibilities	R KSG2.2 R KSG3.1 R KSG3.4 R KSG3.5
21	SCI0103	R Angular Resolution	A synthesized beam having a FWHM ~5 mas with uniform weights is required at both 30 and 100 GHz. See SCI0118 for corresponding VLB angular resolution requirement.	E SYS1301 Longest Baseline E SYS1308 Distribution and Weighting of Visibilities E SYS2001 Temporal Resolution	R KSG1.1 R KSG1.3 R KSG2.1 R KSG5.1
22	SCI0104	R Largest Recoverable Scale	Angular scales of >20” x (116 GHz/v) must be recovered at frequencies v<116 GHz. A more stringent desire is accurate flux density recovery on arcminute scales at all frequencies.	E SYS0007 Total Power Mode E SYS1101 Instantaneous Field of View E SYS1302 Shortest Baseline E SYS1303 Zero Spacing / Single Dish Total Power E SYS1601 TP Antennas: Gain Stability E SYS1603 TP Antennas: Gain Variations with Antenna Pointing Angle E SYS1604 TP Antennas: System Temperature Stability over Time	R KSG1.6 R KSG2.4 R KSG3.9

				E SYS1605 TP Antennas: System Temperature Variations with Antenna Pointing Angle E SYS1801 TP Antennas: Gain Calibration Reference E SYS4401 Flux Scale E SYS4402 Autocorrelation Integration Intervals E SYS4403 PSD Differencing	
23	SCI0105	R Spectral Resolution	A spectral resolution of at least 0.1 km/s is required. It is desirable that this spectral resolution be available over a broad (4+ GHz) bandwidth.	E SYS1401 Highest Spectral Resolution E SYS1402 Number of Spectral Channels E SYS1403 Flexible Spectral Resolution E SYS1404 Doppler Corrections	R KSG2.3
24	SCI0106	R Survey Speed	The array shall be able to map a ~7 square degree region to a depth of ~1 uJy/bm @ 2.5 GHz and a depth of ~10 uJy/bm @ 28 GHz within a 10 hr epoch.	E SYS0106 On-The-Fly Mapping – Data & Control Rates E SYS0107 On-The-Fly Mapping – Antenna Tracking Rate E SYS1001 Effective Area / Tsys Ratio E SYS1061 Calibration Efficiency E SYS1101 Instantaneous Field of View E SYS1306 Fraction of Occupied Cells	R KSG5.6 R KSG5.7
25	SCI0107	R Quality of the Synthesized Beam	The (sculpted) synthesized beam shall be elliptical down to the attenuation level of the first side lobe and display a beam efficiency of >90% at all angular scales and frequencies, while still meeting continuum sensitivity requirements (SCI0100).	E SYS1308 Distribution and Weighting of Visibilities E SYS1306 Fraction of Occupied Cells E SYS0105 Visibility Weighting	R KSG2.6 R KSG3.4 R KSG3.5 R KSG3.7 R KSG5.1 R KSG5.2
26	SCI0108	R Imaging Fidelity	The ngVLA should produce high fidelity imaging (>0.9) over a wide range of scales, spanning from a few arcmin to a few mas.	E SYS1306 Fraction of Occupied Cells E SYS1308 Distribution and Weighting of Visibilities E SYS2105 LO Frequency and Sampler Clock Offsets	R KSG1.1 R KSG3.4 R KSG3.5 R KSG3.7 R KSG3.9
27	SCI0109	R Snapshot Image Fidelity	The ngVLA snapshot performance should yield high fidelity imaging on angular scales >100mas at 20 GHz for strong sources.	E SYS1306 Fraction of Occupied Cells	R KSG1.1 R KSG3.5 R KSG3.6
28	SCI0110	R Photometric Error	The photometric error for point sources shall be less than 1% at frequencies where a sufficiently accurate flux density scale is known for programs requiring highly accurate photometry.	E SYS1603 TP Antennas: Gain Variations with Antenna Pointing Angle E SYS1604 TP Antennas: System Temperature Stability over Time E SYS1605 TP Antennas: System Temperature Variations with Antenna	R KSG3.6

				Pointing Angle E SYS1801 TP Antennas: Gain Calibration Reference E SYS4603 Gain Variations with Antenna Pointing Angle E SYS4801 Gain Calibration Reference E SYS4401 Flux Scale	
29	SCI0111	R Relative Astrometric Error	The instrument shall achieve an astrometric error that is <1% of the synthesized beam FWHM or the positional uncertainty in the reference frame, for a bright (SNR≥100) point source.	E SYS1504 Phase Drift Residual E SYS1505 Absolute Phase Drift E SYS2501 Weather Monitoring	R KSG5.1 R KSG5.2
30	SCI0112	R Timing Error	The system timing error shall be less than 10 ns (1 ns desired) over pulsar periods correctable to a known standard from 30 min to 10 yr.	E SYS2002 Temporal Accuracy	R KSG4.3
31	SCI0113	R Brightness Dynamic Range	The system brightness dynamic range shall be >45 dB to support deep field studies at 8 GHz and >35 dB to support deep continuum imaging of nearby galaxies at 27 GHz.	E SYS2105 LO Frequency and Sampler Clock Offsets E SYS4601 Interferometric Antennas: Gain Stability E SYS4801 Gain Calibration Reference	R KSG3.11 R KSG3.8
32	SCI0114	R Polarization Dynamic Range	The polarization dynamic range shall be >35 dB at the center of the field of view to support deep field studies at 8 GHz and >25 dB to support deep continuum imaging of nearby galaxies at 27 GHz.	E SYS1901 Polarization Purity E SYS4601 Interferometric Antennas: Gain Stability E SYS4602 Interferometric Antennas: Relative Gain Stability E SYS4801 Gain Calibration Reference	R KSG3.11
33	SCI0115	R Spectral Dynamic Range (Emissive)	The emissive spectral dynamic range shall be >50 dB to enable imaging of faint prebiotic molecules in the presence of bright emission lines within the field of view.	E SYS2105 LO Frequency and Sampler Clock Offsets E SYS4601 Interferometric Antennas: Gain Stability	R KSG2.6
34	SCI0116	R Spurious Spectral Features	Self-generated spurious spectral feature flux density must be below ~95 µJy/bm in any 0.1 km/s channel, post calibration between 16 – 50 GHz.	E SYS2104 Self-Generated Spurious Signal Power Level E SYS2106 Shielding & Emission Limits E EMC0310 Spurious Signal Level	R KSG2.5
35	SCI0117	R VLB Continuum Sensitivity	The continuum rms noise shall be less than ~0.23 uJy/bm at 10 GHz to detect GW events at a distance of 200 Mpc.	E SYS1309 Collecting Area on VLB Baselines	R KSG5.10
36	SCI0118	R VLB Angular Resolution	A 0.7 mas synthesized beam at 10 GHz is required to support measurement of proper motions for GW events at a distance of 200 Mpc.	E SYS1301 Longest Baseline E SYS1308 Distribution and Weighting of Visibilities	R KSG5.10
37	SCI0119	R Spectral Dynamic Range (Absorptive)	The absorptive spectral dynamic range shall be better than 40 dB to measure the physical properties of Galactic neutral Hydrogen.	E SYS2105 LO Frequency and Sampler Clock Offsets E SYS4601	R KSG3.12

L0 Stakeholders Requirements - RVTM

#	Id	Name	Text	Derived	Copied By	Source
1		Integration and Verification				
2	STK0400	Provision of Assembly Verification Tools	Test frameworks (unit tests, hardware simulators, and test racks) for the stand-alone verification of line replaceable units and sub-systems shall be provided.	SYS2811 Test Fixtures SYS2817 ICD Automated Conformance Testing SYS2820 AIV Concept SYS2816 ICD API and software Definition SYS2813 System Verification Tools SYS2814 Testing of Software and Firmware SYS2815 AIV Software Tools SYS2818 ICD LRUs		[020.10.05.00.00-0005-PLA-B, Sec 5.2.5, Para 1]
3	STK0402	Provision of System Verification Software Tools	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.)	SYS2222 Observation Preparation – Non-Standard Observing modes SYS2305 Single Baseline Data Display SYS2306 Calibration Data Display SYS2407 Engineering Console SYS2408 Monitor Data Stream SYS2813 System Verification Tools		[020.10.05.00.00-0005-PLA-B, Sec 5.2.2, Para 3]
4	STK0403	Spare Parts	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.	SYS2812 Critical Spares		[020.10.05.00.00-0002-PLA-C, Sec 7.1, Para 2]
5	STK0427	Testing-Software and Firmware	All software and firmware delivered by the project shall be delivered with automated unit, integration, and regression testing suites.		SYS2814 Testing of Software and Firmware	[020.10.05.00.00-0005-PLA-B, Sec 5.2.2, Para 1]
6	STK0431	AIV Software Tools	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.		SYS2815 AIV Software Tools	[020.10.05.00.00-0005-PLA-B, Sec 5.2.2, Para 3]
7	STK0432	ICD-API and Software Definition	All Application Program Interfaces (API) or other software interfaces shall be defined in ICDs.		SYS2816 ICD API and software Definition	[020.10.05.00.00-0005-PLA-B, Sec 5.2.2, Para 4]
8	STK0433	ICD-Automated	Automated test results demonstrating conformance to API ICDs shall be delivered with the product.		SYS2817	[020.10.05.00.00-0005-PLA-B,

		Conformance Testing			ICD Automated Conformance Testing	Sec 5.2.2, Para 4]
9	STK0434	ICD-LRUs	ICDs shall be delivered for each Line Replaceable Unit in the system.		SYS2818 ICD LRUs	[STRR RID #33]
10	STK0435	Project Documentation	Documentation necessary to support the training of operations and maintenance staff, and to execute preventive and corrective maintenance for the operations phase of the facility, shall be delivered prior to the transition to full operations.	SYS6001 As-Built Drawings SYS6002 Operations and Maintenance Manuals SYS6003 Units SYS6004 Language SYS6005 Electronic Document Format		020.10.10.05.00.00-0002-PLA
11	STK0536	Assembly, Integration and Verification Concept	An Assembly, Integration and Verification Concept shall be documented and approved by the Observatory. The concept shall describe the overall approach of the project to deploy, test and verify instrument capabilities. Any requirements to fulfill the Assembly, Integration and Verification Concept shall be a construction project responsibility.	SYS2820 AIV Concept		020.10.05.00.00-0001-PLA
12		NRAO & Other Facility Integration				
13	STK2500	SRDP Integration	The ngVLA project should extend and reuse the SRDP Observatory-User interfacing architecture for ngVLA.	CSW0011 SRDP Integration	SYS2401 SRDP Integration	SRDP AD, 2018. Director's Office, 2018.
14	STK2501	Facility Integration	It is desirable for ngVLA to support joint (e.g., VLB) observations with other NRAO facilities, as well as other global flagship facilities.	SYS0502 eVLBI Capabilities SYS5900 External eVLBI Elements		ngVLA PD
15	STK2502	DMS Integration	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.	CSW0075 NRAO Proposal System Integration	SYS4201 DMS Integration	DMS AD, 2016
16		Security				
17	STK2201	Physical Security Plans	Physical security and monitoring for the ngVLA central site and remote sites shall be provided.	SYS2704 Physical Security SYS3880 Provision of a Guard Booth		[020.10.05.00.00-0002-PLA-C, Sec 9.5, Para 1-2]
18	STK2202	Cybersecurity	ngVLA IT systems shall be hardened against intrusion consistent with existing NRAO CIS policies.	SYS2702 IT Security		[020.10.05.00.00-0002-PLA-C, Sec 9.6, Para 1]
19		Future Commensal Systems				
20	STK2900	Commensal Front-Ends	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.	SYS5602 Commensal Low-Frequency System		NRL, LWA, 2016
21	STK2901	Commensal Back-Ends	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.	SYS5600 Commensal Processing SYS5601 Commensal Voltage Streams		ngVLA PD

22		Decommissioning and Disposal				
23	STK0600	Disposal Costs	Disposal costs shall be accounted for in any life cycle optimization for the project.	SYS2802 Cost Optimization		[020.10.05.00.00-0001-PLA-A, Sec 3.6, Para 2]
24		Local Stakeholders				
25	STK2400	Grassland & Water	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.	SYS4000 Grassland Impact		J&S Bruton, 09/25/2018 visit by PD.
26	STK2401	Roads	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.		SYS4001 Sustainable Roads	J&S Bruton, 09/25/2018 visit by PD.
27	STK2402	Existing Roads	Existing ranch roads shall be assessed for suitability in both construction and operations. It is a goal to reuse existing roads where possible.	SYS4000 Grassland Impact	SYS4002 Existing Roads	J&S Bruton, 09/25/2018 visit by PD.
28	STK2403	Fences	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.		SYS4003 Fences	J&S Bruton, 09/25/2018 visit by PD.
29	STK2404	Ranching Impact	The project shall aim to reduce the environmental impact to cattle ranching as well as hunting/outfitting, which are both mainstays of local ranches.		SYS4004 Ranching Impact	J&S Bruton, 09/25/2018 visit by PD.
30	STK2405	Core Site	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.		SYS4500 Array Core Location	J&S Bruton, 09/25/2018 visit by PD.
31		Observational Efficiency				
32	STK1401	Subarrays for Scheduling	The proposal tools and scheduling system shall support, at a minimum, a limited number of predefined science subarrays.		SYS2217 Subarray Support	[020.10.05.00.00-0002-PLA-C, Sec 5.2, Para 1]
33	STK1402	Observational Efficiency	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.	CSW0003 Concurrent software versions SYS1501 Delay/Phase Variations Magnitude SYS2601 Antenna System Availability SYS2602 Centralized Systems Availability ENV0311 Solar Thermal Load ENV0312 Wind Speed ENV0313 Temperature ENV0314 Temperature Rate of Change ENV0315 Precipitation ENV0321 Solar Thermal Load ENV0322 Wind Speed		[020.10.05.00.00-0002-PLA-C, Sec 6.1, Para 2]

				ENV0323 Temperature ENV0324 Temperature Rate of Change ENV0325 Precipitation ENV0330 Solar Thermal Load ENV0331 Wind ENV0332 Temperature ENV0333 Precipitation ENV0334 Ice SYS2504 Atmospheric Phase Monitor	
34	STK1403	Calibration Efficiency	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.	SYS0602 Phase Preservation SYS0906 Fixed Analog Tunings SYS1061 Calibration Efficiency SYS1062 Calibration Parallelization SYS1063 Calibration Recall SYS1064 Relative Flux Scale Calibration Efficiency SYS1065 Polarization Calibration Efficiency SYS1066 Bandpass Calibration Efficiency SYS1067 Gain Calibration Efficiency SYS1068 Phase Calibration Efficiency SYS1304 Integration Time Ratios SYS1501 Delay/Phase Variations Magnitude SYS1502 SNR Loss to Delay/Phase Variations SYS2503 Weather Archive ENV0311 Solar Thermal Load ENV0312 Wind Speed ENV0313 Temperature ENV0314 Temperature Rate of Change ENV0315 Precipitation	[020.10.05.00.00-0002-PLA-C, Sec 5.1, Para 4]

				ENV0321 Solar Thermal Load ENV0322 Wind Speed ENV0323 Temperature ENV0324 Temperature Rate of Change ENV0325 Precipitation	
35		Science Operations			
36	STK0200	Operations Concept	The system shall be a proposal-driven, pointed, general purpose instrument.	SYS0001 Functional Modes SYS2201 Provision of Software Tools	[020.10.05.00.00-0002-PLA-C, Sec 1, Para 2]; [020.10.05.00.00-0002-PLA-C, Sec 12.2, Table]
37		Radio Frequency Interference			
38	STK2600	Self-Interference	The system shall be designed to prevent self-interference that will be detrimental to science operations.	SYS3301 Equipment Screening for RFI SYS3302 Equipment RFI Standard EMC0310 Spurious Signal Level EMC0320 Drive System Shielding EMC0321 Relay Contact Arcing EMC0322 Amplifiers & Oscillators EMC0323 Silicone Controlled Rectifiers EMC0324 Gaseous Discharge Devices EMC0325 Static Discharge Mitigation EMC0326 Display Shielding EMC0327 Digital Equipment Shielding EMC0328 EMC Test Frequencies SYS2104 Self-Generated Spurious Signal Power Level SYS2105 LO Frequency and Sampler Clock Offsets SYS2106 Shielding & Emission Limits	ngVLA PD
39	STK2601	RFI Survival	The system shall be designed to withstand, without damage or long-term degradation, the projected RFI environment over the life of the instrument.	SYS1204 Input Protection	ngVLA PD

40	STK2602	RFI Mitigation	The system shall be designed to operate in the projected RFI environment while still achieving the Key Science Goals and the desired operational efficiencies.	SYS3403 RFI Database SYS4100 RFI Flagging		ngVLA PD
41	STK2603	VLA Interference	It is a goal to minimize interference with VLA operations during the construction/transition phase.		SYS2819 VLA Interference	ngVLA PD
42		Non-traditional Use Cases				
43	STK2800	SSA Support	It is a goal for the ngVLA to support non-traditional use cases related to space situational awareness, such as imaging of geostationary objects.	SYS1309 Collecting Area on VLB Baselines SYS1308 Distribution and Weighting of Visibilities		Directors Office, 2016
44	STK2801	DSN Support	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.	SYS0802 Optimized Frequency Range SYS0003 Phased Array Mode		Directors Office, 2016
45		System Life Cycle				
46	STK0302	Material Selection & Sustainability	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.	SYS2803 Sustainability SYS3801 Facility Sustainability		[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]
47	STK0303	Design Life	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).	SYS2801 Design Life SYS2802 Cost Optimization		Directors Office, 2016
48	STK0304	Projected Environment	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.	SYS2502 Safety Weather Monitoring ENV0341 Wind ENV0342 Temperature ENV0343 Radial Ice ENV0344 Rain Rate ENV0345 Snow Load, Antenna ENV0346 Snow Load, Equipment & Bldgs ENV0347 Hail Stones ENV0348 Antenna Orientation ENV0351 Altitude Range ENV0511 Lightning Protection, Structure ENV0512 Lightning Protection, Electronics Systems		[020.10.05.00.00-0001-PLA-A, Sec 3.4.2, Para 2]

				ENV0521 Seismic Protection ENV0531 Wind Vibration ENV0532 Transport Vibration ENV0541 Equipment Protection ENV0542 Building Protection ENV0551 Rodent Protection ENV0552 Large Mammal Protection ENV0561 Maximum Solar Flux ENV0562 Maximum UV Radiation ENV0571 Rain/Water Infiltration ENV0581 Transportation Environment ENV0582 Mechanical	
49	STK0310	Part Selection and Obsolescence	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.	SYS2805 Part Selection for Maintainability SYS2812 Critical Spares		[020.10.05.00.00-0001-PLA-A, Sec 3.4.3, Para 3]
50		Commissioning and Science Validation				
51	STK0500	First Look Science Products	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.		SYS2837 First Look Science Products	[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]
52	STK0501	Availability for Early Science	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.		SYS2836 Availability for Early Science	[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.]
53	STK0502	Provision of Commissioning Tools	The system shall include software interfaces and diagnostic tools to quantify system performance and status. (e.g., tools to plot real time calibration coefficients.)	SYS2222 Observation Preparation – Non-Standard Observing modes SYS2305 Single Baseline Data Display SYS2306 Calibration Data Display SYS2407 Engineering Console SYS2408 Monitor Data Stream		[020.10.05.00.00-0006-PLA-B, Sec 5.1, Para 1]
54	STK0511	Transition to Ops-Capabilities	Operational capabilities and observing modes must be made available in stages during the transition from construction through to the commencement of full operations.		SYS2830 Incremental	[020.10.05.00.00-0006-PLA-B, Sec 2.4.1, Para 2]

		and Observing Modes			Delivery to Operations	
55	STK0512	Commissioning-Observing Mode SRDP Pipeline	Delivery of a commissioned standard observing mode shall include an operational SRDP pipeline before it is offered for regular use through PI proposals.	SYS0721 Imaging Pipeline SYS0750 Data Processing for Standard Observing Modes SYS0751 Data Processing Resources	SYS2831 Delivery with SRDP Pipeline	[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]
56	STK0516	API and Scheduling Blocks	A science-oriented API (scripting interface) for calling high-level array functions, prior to the widespread use of Scheduling Blocks (SBs), shall be delivered.		SYS2832 Science Operations API	[020.10.05.00.00-0006-PLA-B, Sec 5, # 5]
57	STK0517	Simulators-Development of Observing Scripts	Simulators to enable the development of observing scripts without the real system shall be delivered.		SYS2833 Observing Simulator	[020.10.05.00.00-0006-PLA-B, Sec 5, # 6]
58	STK0518	Interactive Shell Access	The system shall provide interactive shell access to the calibration and imaging software, running on an observatory-supported OS.		SYS2834 Interactive Shell Access	[020.10.05.00.00-0006-PLA-B, Sec 5, # 7]
59	STK0520	Contemporaneous Calibrator Data	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.		SYS2835 External Calibrator Data Interface	[020.10.05.00.00-0006-PLA-B, Sec 5, # 9]
60	STK0523	Data Access-Visibility Data	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.		SYS0760 Interactive Processing	[020.10.05.00.00-0006-PLA-B, Sec 5.2.4, Para 2]
61	STK0524	Commissioning and Science Validation Concept	A Commissioning and Science Validation Concept shall be documented by the project and approved by the Observatory. The concept shall describe the overall approach of the project to commission the instrument capabilities and transition to full operations. Any requirements to fulfill the Commissioning and Science Validation Concept shall be a construction project responsibility.	SYS2838 CSV Concept		020.10.05.00.00-0001-PLA
62		Observing Modes				
63	STK0700	Standard Modes: Time-Phased Availability	By Full Operations the project shall provide a set of standard observing modes that can achieve the ngVLA Key Science Goals.	SYS3001 Standard Observing Modes SYS3002 Number of Standard Observing Modes		[020.10.05.00.00-0002-PLA-C, Sec 5, Para 4]
64	STK0701	Standard Modes: Generation of Scheduling Blocks	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.	SYS2221 Observation Preparation – Standard Observing Modes SYS3001 Standard Observing Modes SYS3002 Number of Standard Observing Modes		[020.10.05.00.00-0002-PLA-C, Sec 5, Para 4]
65	STK0702	Non-Standard Observing Modes	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.	SYS2212 Proposal Submission – non-standard observing modes. SYS3003 Non-Standard Observing Modes		[020.10.05.00.00-0002-PLA-C, Sec 5, Para 5]

66	STK0703	Observing Awards: Array Time on Source	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.	SYS2215 Observing Time Calculator SYS2302 Observation Scheduling SYS2216 Proposal Award Model SYS2226 Observation Time Model	[020.10.05.00.00-0002-PLA-C, Sec 5.2, Para 4]
67	STK0704	Standard Modes: Observing Strategy	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.	SYS1061 Calibration Efficiency SYS1064 Relative Flux Scale Calibration Efficiency SYS1065 Polarization Calibration Efficiency SYS1066 Bandpass Calibration Efficiency SYS2221 Observation Preparation – Standard Observing Modes SYS4301 Standard Observing Mode Calibration	[020.10.05.00.00-0002-PLA-C, Sec 5.2, Para 4]
68	STK0705	Standard Modes: Flexibility	Interfaces for PIs to make changes to the standard observing strategy, when required to meet the scientific objectives, shall be available.	SYS2225 Observation Preparation – Standard Observing Mode Flexibility	[020.10.05.00.00-0002-PLA-C, Sec 5.2, Para 4]
69		Proposal Submission			
70	STK0800	Proposal Submission Criteria	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).	CSW0078 Post-processing Support SYS2211 Proposal Submission – standard observing modes SYS2212 Proposal Submission – non-standard observing modes.	[020.10.05.00.00-0002-PLA-C, Sec 5, Para 3]
71	STK0801	Proposal Submission Tool	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).	SYS2201 Provision of Software Tools SYS2211 Proposal Submission – standard observing modes SYS2212 Proposal Submission – non-standard observing modes. SYS3500 Proposal Preparation Tool	[020.10.05.00.00-0002-PLA-C, Sec 5.1, Para 1]

72	STK0802	Proposal Assessment	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.	SYS2213 Scientific Proposal Evaluation SYS2214 Technical Proposal Evaluation		[020.10.05.00.00-0002-PLA-C, Sec 5.1, Para 1]
73	STK0803	Mitigating Bias in Proposal Peer Review	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.	SYS2213 Scientific Proposal Evaluation		[020.10.05.00.00-0002-PLA-C, Sec 5.1, Para 1]
74	STK0804	Proposal Attributes	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).		SYS2218 Proposal Attributes	[020.10.05.00.00-0002-PLA-C, Sec 5.1, Para 3]
75	STK0805	Proposal Submission Concept	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.	SYS2201 Provision of Software Tools SYS2211 Proposal Submission – standard observing modes SYS2221 Observation Preparation – Standard Observing Modes SYS2215 Observing Time Calculator		[020.10.05.00.00-0002-PLA-C, Sec 5.1, Para 1]
76		Scheduling				
77	STK0900	Priority in Scheduling Observations	The system shall schedule observations based on the scientific rankings of proposals, taking into consideration array status and observing conditions.	SYS2302 Observation Scheduling SYS2501 Weather Monitoring SYS2227 Observation Scheduling Criteria		[020.10.05.00.00-0002-PLA-C, Sec 5, Para 4]
78	STK0901	Priority for Triggered Observations	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.	SYS2223 Observation Scheduling GUI SYS2224 Observation Interrupt SYS2302 Observation Scheduling		[020.10.05.00.00-0002-PLA-C, Sec 5.2, Para 3]
79	STK0902	Concurrent Maintenance and Observation	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.	CSW0073 Observation Execution Abortion SYS0602 Phase Preservation SYS0607 Sub-Array Modification		[020.10.05.00.00-0002-PLA-C, Sec 6.1, Para1]
80		Data Processing				
81	STK1000	Pipeline Use for Standard Observing Modes	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.	SYS0703 Calibration Pipeline SYS0751 Data Processing Resources		[020.10.05.00.00-0002-PLA-C, Sec 5, Para 3]

				SYS3002 Number of Standard Observing Modes		
82	STK1001	Computing Resources for Standard Modes: Reprocessing	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.	SYS0752 Throughput & Latency SYS0751 Data Processing Resources		[020.10.05.00.00-0002-PLA-C, Sec 5.3, Para 2]
83	STK1002	Computing Resources for Standard Modes	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).	SYS0752 Throughput & Latency SYS0753 Heterogeneous Arrays SYS0751 Data Processing Resources		[020.10.05.00.00-0002-PLA-C, Sec 5.3, Para 2]
84	STK1004	Support for Legacy Programs	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.	SYS0752 Throughput & Latency SYS2206 Quality Assurance Tool Extensibility	SYS0757 Support for Legacy Programs	[020.10.05.00.00-0002-PLA-C, Sec 5.3, Para 5]
85	STK1005	Data Delivery: Process in Place	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.		SYS0756 Processing in Place	[020.10.05.00.00-0002-PLA-C, Sec 5.4, Para 5]
86		User Support				
87	STK1200	Operational User Support	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.	SYS3500 Proposal Preparation Tool SYS3501 Observation Preparation Tool SYS3502 Data Quality Inspection Tool SYS3503 Data Processing Inspection Tool SYS3504 Data Analysis Package SYS3505 User Support Tool SYS0762 Data Quality Assurance		[020.10.05.00.00-0002-PLA-C, Sec 5.6, Para1]
88	STK1201	Software Packages Available to User Community: Data Analysis	The project shall provide software tools for data analysis by users. The package shall be executable on Observatory compute resources and on external computers.	CSW0014 Data Analysis Software Package SYS0761 Data Analysis Resources SYS2201 Provision of Software Tools		[020.10.05.00.00-0002-PLA-C, Sec 5.3, Para 6]
89	STK1202	Software Packages Available to User Community: Data Processing	The project shall provide software tools to the user community for processing ngVLA visibilities. The package shall be executable on Observatory computational resources and on external computers.	CSW0013 Visibility Processing Software Package SYS0751 Data Processing Resources SYS2201		[020.10.05.00.00-0002-PLA-C, Sec 5.3, Para 6]

				Provision of Software Tools SYS3506 Data Processing Package		
90	STK9947	Open Source Software	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.		SYS4200 Open Source Software	[STRR RID #49]
91		Configuration Management				
92	STK1600	Remote Access of System Configuration	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.	SYS2406 Configuration Monitoring SYS3601 Configuration Management Tools SYS3602 Version Control for Software and Firmware SYS3603 Configuration Retrieval		[020.10.05.00.00-0002-PLA-C, Sec 7.2, Para 3]
93	STK1602	Identification by Serial Numbers	Individual LRUs, and all other configurable items, shall be uniquely identifiable to facilitate status and location tracking across the Observatory.		SYS3600 Identification by Serial Numbers	[020.10.05.00.00-0006-PLA-B, Sec 5, # 4]
94	STK1603	Packaging as LRUs	Electronics shall be packaged as Line Replaceable Units (LRUs), where LRU modules are interchanged at the antenna.	SYS2403 Modularization		[020.10.05.00.00-0002-PLA-C, Sec 7, Para 5]
95	STK1604	Configuration Management Tools	The project shall provide configuration management tools for tracking the design versions of construction deliverables throughout the system life cycle.		SYS3601 Configuration Management Tools	[020.10.05.00.00-0005-PLA-B, Sec 3, Bullet 7]
96	STK1606	Version Control-Software and Firmware	All software and firmware delivered to the project shall be version controlled via a configuration management process.	SYS3602 Version Control for Software and Firmware		[020.10.05.00.00-0005-PLA-B, Sec 5.2.2, Para 1]
97	STK9945	Configuration Retrieval	All configurable LRUs shall retrieve their hardware parameter configuration automatically after replacement, and upon a change in the parameter in the System Calibration database.		SYS3603 Configuration Retrieval	[STRR RID #35]
98		Facilities				
99	STK2000	Inclusion of a Visitor Center	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.	SYS3802 Provision of a Visitor Center SYS3803 Controlled Visitor Access		[020.10.05.00.00-0002-PLA-C, Sec 8.4, Para 1], Director's Office, 2018.
100	STK2001	Inclusion of a Maintenance Operations Center	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.	SYS3800 Outfitted Facilities SYS3810 Provision of a Maintenance Operations Center SYS3811 Maintenance Center - Support Equipment SYS3812 Maintenance Center - Ready Spares		[020.10.05.00.00-0002-PLA-C, Sec 8.5, Para 1]

101	STK2002	Inclusion of a Warehouse	A central warehouse shall be provided for controlled inventory of all components used for preventive and corrective maintenance.	SYS3800 Outfitted Facilities SYS3820 Provision of a Warehouse SYS3821 Warehouse Inventory System SYS3822 Warehouse Space - AIV		[020.10.05.00.00-0002-PLA-C, Sec 8.5, Para 3]
102	STK2003	Inclusion of a Repair Center	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.	SYS3800 Outfitted Facilities	SYS3830 Provision of a Repair Center	[020.10.05.00.00-0002-PLA-C, Sec 8.6, Para 1-2]
103	STK2004	Inclusion of an Array Operations Center	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.	SYS3800 Outfitted Facilities	SYS3840 Provision of an Array Operations Center	[020.10.05.00.00-0002-PLA-C, Sec 8.6, Para 1-2]
104	STK2005	Inclusion of a Science Operations Center	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.	SYS3800 Outfitted Facilities	SYS3850 Provision of a Science Operations Center	[020.10.05.00.00-0002-PLA-C, Sec 8.7, Para 1-2]
105	STK2006	Inclusion of Remote Support Stations	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.	SYS3800 Outfitted Facilities	SYS3860 Provision of Remote Support Stations	[020.10.05.00.00-0002-PLA-C, Sec 8.8, Para 1-3]
106	STK2007	Location of the Maintenance Operations Center	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.	SYS3800 Outfitted Facilities	SYS3870 Location of the Maintenance Operations Center	[020.10.05.00.00-0002-PLA-C, Sec 8.5]
107	STK2008	Location of the Array Operations Center	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.	SYS3800 Outfitted Facilities	SYS3871 Location of the Array Operations Center	[020.10.05.00.00-0002-PLA-C, Sec 8.6]
108	STK2009	Location of the Science Operations Center	The Science Operations Center shall be located at a site that facilitates personnel recruitment, such as an attractive metropolitan area.	SYS3800 Outfitted Facilities	SYS3872 Location of the Science Operations Center	[020.10.05.00.00-0002-PLA-C, Sec 8.7]
109	STK2010	Location of the Repair Center	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.	SYS3800 Outfitted Facilities	SYS3873 Location of the Repair Center	[020.10.05.00.00-0002-PLA-C, Sec 8.6]
110	STK2011	Location of the Warehouse	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.	SYS3800 Outfitted Facilities	SYS3874 Location of the Warehouse	[020.10.05.00.00-0002-PLA-C, Sec 8.5]
111	STK2012	Inclusion of a Guard Booth	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.	SYS3800 Outfitted Facilities	SYS3880 Provision of a Guard Booth	[020.10.05.00.00-0002-PLA-C, Sec 8.2 Para 1]
112	STK2013	Inclusion of Central Support Buildings	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.		SYS3881 Provision of Support Buildings	[020.10.05.00.00-0002-PLA-C, Sec 8.2, Para 1]
113		Logistics				

114	STK2100	Inventory Tracking System	A system shall be provided to electronically track inventory to determine usage rate and location of spare assemblies, component level spares, and consumables.		SYS3900 Inventory Tracking System	[020.10.05.00.00-0002-PLA-C, Sec 9.2, Para 1]
115	STK2102	Shipping and Receiving Logistics	Each facility shall have central shipping and receiving and be integrated with a shipping system between sites.		SYS3901 Shipping and Receiving Logistics	[020.10.05.00.00-0002-PLA-C, Sec 9.2, Para 2]
116	STK2103	Repair and Tracking of LRUs	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.		SYS3902 Tracking of LRUs	[020.10.05.00.00-0002-PLA-C, Sec 9.3, Para 1]
117	STK2105	Observatory-Controlled Logistics	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).		SYS3903 Observatory-controlled Logistics	[020.10.05.00.00-0002-PLA-C, Sec 9.2, Para 2]
118	STK2106	Packaging Used for Shipping	Shipping cases and packaging shall be provided with ESD protection and mechanical shock absorption.		SYS3904 Packaging Used for Shipping	[020.10.05.00.00-0002-PLA-C, Sec 9.2, Para 2]
119		Array Operations				
120	STK1501	Array Operations: Subarray Use	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.	CSW0003 Concurrent software versions SYS0606 Sub-Array Configuration		[020.10.05.00.00-0002-PLA-C, Sec 6.1, Para 2]
121	STK1502	Operator Interface	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.	SYS2223 Observation Scheduling GUI SYS2224 Observation Interrupt SYS2308 Operator Interface Location SYS2307 Operator Console SYS2306 Calibration Data Display SYS2305 Single Baseline Data Display		[020.10.05.00.00-0002-PLA-C, Sec 6.2, Para1]
122	STK1506	Array Operations: Remote and Automated Functions	Functions leveraging remote operations and automation of antenna functions shall be implemented when supported by lifecycle cost analysis.	CSW0005 Autonomous antennas CSW0040 Autonomous Operations CSW0043 Automatic Re-configuration SYS2303 Calibration Automation SYS2304 Self-Calibrating Antenna SYS3105 Fast		[020.10.05.00.00-0002-PLA-C, Sec 6.2, Para3]

				Read-Out Modes		
123	STK9944	Operator Interface Location	It shall be possible for authorized personnel to access the operator interface software from any approved workstation in the observatory.		SYS2308 Operator Interface Location	[STRR RID #52]
124		Data Archive				
125	STK1100	Data Product Types to Archive	Raw visibilities, calibration tables, and SRDPs shall be stored and made available to PIs and archival researchers through the Data Archive.	SYS0701 Uncalibrated Data SYS0702 Flagged Data Table SYS0732 Archive Products - High-Level SYS0735 Archive Backup SYS0739 Archive Products - Low-Level		[020.10.05.00.00-0002-PLA-C, Sec 5.3, Para 4]
126	STK1101	ngVLA Data Archive Functionality: Image selection and download	The Archive user interface shall allow users to inspect and select image data for download.	SYS0736 Archive User Reprocessing	SYS0737 Archive Image Selection	[020.10.05.00.00-0002-PLA-C, Sec 5.4, Para 1]
127	STK1102	Reprocessing and Automated QA via Archive	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.	SYS0702 Flagged Data Table SYS0731 Archive Period SYS0734 Archive Batch Reprocessing SYS0736 Archive User Reprocessing SYS0762 Data Quality Assurance		[020.10.05.00.00-0002-PLA-C, Sec 5.4, Para 1]
128	STK1103	Proprietary Period for PI Data	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.	SYS0733 Proprietary Data Rights SYS0738 Proprietary Period SYS0743 Proprietary Period Trigger		[020.10.05.00.00-0002-PLA-C, Sec 5.4, Para 2]
129	STK1104	User Produced Data Products	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.	SYS2206 Quality Assurance Tool Extensibility SYS0762 Data Quality Assurance	SYS0740 External Data Products	[020.10.05.00.00-0002-PLA-C, Sec 5.4, Para 3]
130	STK1105	Proprietary Period for Legacy Program Data	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.	SYS0738 Proprietary Period		[020.10.05.00.00-0002-PLA-C, Sec 5.4, Para 4]
131	STK1106	Data Delivery via Observatory Archive	Data products shall be delivered to the Principal Investigators through an Internet-accessible Observatory Science Data Archive.	SYS0731 Archive Period SYS0735 Archive Backup	SYS0730 Data Delivery via Observatory Archive	[020.10.05.00.00-0002-PLA-C, Sec 5, Para 3]
132	STK9950	Data Provenance	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 sub-systems) used to generate the data set.	SYS3402 Monitor Database SYS3403 RFI Database	SYS2209 Data Provenance Tracking	[STRR RID #25]

				SYS3404 Quality Control Database SYS3400 System Calibration Database SYS3401 Astronomical Calibrator Database		
133		Calibration				
134	STK1300	Storage and Retrieval of Calibration Coefficients	The system shall provide for automatic storage and retrieval of system parameters determined by calibration, such as delays or bandpass gains.	CSW0026 Persistent Configuration Data SYS3400 System Calibration Database SYS4330 Storage and Retrieval of Calibration Parameters		[020.10.05.00.00-0002-PLA-C, Sec 5.8, Para1]
135	STK1301	Automated Re-Measurement of Calibration Coefficients	Re-measurement 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.	SYS4331 Automated Re-Measurement of Parameters SYS4320 Standard Calibration Automation	SYS1069 Calibration Automation	[020.10.05.00.00-0002-PLA-C, Sec 5.8, Para1]
136	STK1302	Inclusion of Calibration Pipelines and Supporting Systems	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.	SYS4301 Standard Observing Mode Calibration SYS4320 Standard Calibration Automation		[020.10.05.00.00-0006-PLA-B, Sec 2.4.3, Para1]
137		Quality Assurance and Quality Control				
138	STK1900	Quality Control Database	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.	SYS3404 Quality Control Database SYS3700 Quality Control Data Access Tool SYS3701 Quality Control Data Access Tool Location		[020.10.05.00.00-0002-PLA-C, Sec 9.3, Para 3]
139	STK1902	Quality Control	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.		SYS3702 Quality Control of Deliverables	[020.10.05.00.00-0002-PLA-C, Sec 9.3, Para 3]
140	STK9948	Automated QA of Data Products	The system shall include an automated quality control check of low-level and high-level data products generated using standard operating modes.		SYS2207 Automated QA of Data Products	[STRR RID #53]
141	STK9949	QA tools for Data Products	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.	SYS2205 Manual Data Quality Assurance SYS2208 Quality Assurance Tools for Standard Modes		[STRR RID #53]
142		Support Datastores				

143	STK1150	System Calibration Database	A System Calibration database shall be provided to store antenna-based calibration parameters such as gain curves and polarization D-terms.		SYS3400 System Calibration Database	[020.10.05.00.00-0006-PLA-B, Sec 2.4.3, Para 1]
144	STK9943	Astronomical Calibrator Database	An Astronomical Calibrator database shall be provided to store calibrator flux density histories and image models.		SYS3401 Astronomical Calibrator Database	[020.10.05.00.00-0006-PLA-B, Sec 5.1, List Item 9]
145		Maintenance Operations				
146	STK5001	Provision of Diagnostic Tools	The system shall include interfaces for engineers and technicians to monitor the health of the system and remotely diagnose failures and behavior anomalies.		SYS3220 Provision of Diagnostic Tools	020.10.05.00.00-0002-PLA-C
147	STK5002	Provision of Predictive Tools	The system shall include automated tools to predict the location and nature of failures in support of maintenance scheduling.	SYS3402 Monitor Database	SYS3221 Provision of Predictive Tools	020.10.05.00.00-0002-PLA-C
148	STK5003	Maintenance Scheduling Tools	Tools for the prioritization and scheduling of corrective and preventive maintenance activities shall be provided.	SYS3222 Maintenance Scheduling Tools SYS3202 Optimization for Maintenance		020.10.05.00.00-0002-PLA-C
149	STK5004	Provision of Corrective Maintenance Equipment	The system shall include the equipment and vehicles necessary to execute planned preventive and corrective maintenance operations.	SYS3300 Provision of Vehicles and Equipment SYS3207 Maintenance Personnel Transportation: Array Site SYS3208 Maintenance Personnel Transportation: Maintenance Center		020.10.05.00.00-0002-PLA-C
150	STK5005	Maintenance Concept	The facility shall include all ancillary buildings, tools, equipment, and system features necessary to support the facility Maintenance Concept.	SYS3200 Preventive Maintenance Schedules SYS3201 Maintenance Tiers SYS3202 Optimization for Maintenance SYS3203 Criteria for Scheduling Maintenance SYS3204 Use of Failure Analysis in Spares Planning SYS3205 Reporting of Failures and Anomalies SYS3209 Maintenance Metrics Definition SYS3110 Performance Analysis and Automated Maintenance Scheduling		020.10.05.00.00-0002-PLA-C

SYS3111 Hot Swaps of LRUs

SYS3112 Intelligent LRUs and Subsystems

SYS3113 Operator Interface to System Monitoring Software

SYS3114 Subsystem Automation

L1 System Requirements - RVTM

#	Id	Name	Text	Derived From	Refines	Refined By	Copied From	Verify Method
1		Functional Operating Modes						
2	SYS0001	Functional Modes	The system shall provide a set of defined Operating Modes that produce corresponding data products.	SCI0006 Observing Modes STK0200 Operations Concept				Inspection
3	SYS0002	Interferometric Mode	The system shall provide an Interferometric Operating Mode with concurrent computation of cross-correlations and self-correlations for arbitrary numbers of antennas with tunable spectral and time resolution.	SCI0006 Observing Modes				Demonstration
4	SYS0003	Phased Array Mode	The system shall provide a Phased Sum Operating Mode that coherently sums the voltage streams from an arbitrary number of antennas and provides a time-tagged voltage data stream with an adjustable phase center on sky.	SCI0007 Phased Array Capability SCI0012 Pulsar Timing Capabilities SCI0013 Time Domain Search Capabilities STK2801 DSN Support				Demonstration
5	SYS0004	Pulsar Timing Mode	The system shall provide a Phased Sum Operating Mode where the time-tagged voltage data stream is processed to time a set of dispersed pulse profiles.	SCI0012 Pulsar Timing Capabilities				Demonstration
6	SYS0005	Pulsar and Transient Search Mode	The system shall provide a Phased Sum Operating Mode where the time-tagged voltage data stream is processed to search for dispersed pulse profiles w/o a priori knowledge of their period.	SCI0013 Time Domain Search Capabilities				Demonstration
7	SYS0006	VLBI Mode	The system shall provide a Phased Sum Operating Mode where the time-tagged voltage data stream is recorded in a VLBI-standard recording format for future processing in a VLBI correlator.	SCI0017 VLBI Capabilities				Demonstration
8	SYS0007	Total Power Mode	The system shall provide an Interferometric Operating Mode with computation of self-correlations on-source and off-source to quantify the total power spectral density of a fixed field.	SCI0104 Largest Recoverable Scale				Demonstration
9	SYS0008	On The Fly Mapping Mode	The system shall provide an Interferometric Operating Mode where areas larger than the antenna primary beam are mapped by a continuous scan of the field.	SCI0004 Mosaics and On-the-Fly Mapping				Demonstration
10	SYS0009	Solar Mode	The system shall provide an Interferometric Operating Mode tailored to the observation of sources up to 30dB brighter than the cold sky.	SCI0016 Solar Observation Capabilities				Demonstration
11		Sub-array Functional Requirements						
12	SYS0601	Sub-Array Capabilities	The system shall be divisible into a minimum of 10 sub-arrays for operation, calibration and maintenance purposes.	SCI0009 Sub-Array Capabilities				Demonstration
13	SYS0602	Phase Preservation	It shall be possible to preserve electronic phase when adding and/or subtracting an element from a sub-array.	STK1403 Calibration Efficiency STK0902 Concurrent Maintenance and				Test

				Observation	
14	SYS0603	Sub-Array Composition	It is desirable that the composition of a sub-array be configurable to any arbitrary combination of antennas from a single antenna to the full array.	SCI0009 Sub-Array Capabilities	Demonstration
15	SYS0604	Sub-Array Operating Modes	It is desirable that any Operating Mode be available in any sub-array.	SCI0009 Sub-Array Capabilities SCI0010 Sub-Array Commensality	Inspection
16	SYS0605	Sub-Array Operating Mode Commensality	The system shall support the commensal sub-array combinations described in Table 1. It is a goal to permit full flexibility in commensal sub-array Operating Modes.	SCI0010 Sub-Array Commensality	Analysis
17	SYS0606	Sub-Array Configuration	It is desirable that the configuration of a sub-array be completely independent of all others, permitting different instances and versions of online software between sub-arrays.	STK1501 Array Operations: Subarray Use	Demonstration
18	SYS0607	Sub-Array Modification	The system shall permit an Array Operator to add or remove antennas to a sub-array without interrupting an in-progress observation.	STK0902 Concurrent Maintenance and Observation	Demonstration
19		Interferometric Operating Mode Functional Requirements			
20	SYS0102	Polarization Products	The system shall simultaneously compute both parallel-pol and cross-pol correlations over the full specified bandwidth, and measure all stokes polarization products simultaneously.	SCI0015 Polarization Products	Demonstration
21	SYS0103	Autocorrelation Products	It is desirable to provide autocorrelation products for all antennas within the interferometric array concurrent with the cross-correlations.	SYS3110 Performance Analysis and Automated Maintenance Scheduling SYS3114 Subsystem Automation	Demonstration
22	SYS0105	Visibility Weighting	The weight of individual visibilities recorded by the system shall be adjustable before gridding in support of synthesized beam sculpting to the scientific requirements.	SCI0107 Quality of the Synthesized Beam	Demonstration
23		Phased Array Operating Mode Functional Requirements			
24	SYS0201	Phased Aperture	The system shall provide phased array capabilities over the full extent of the array (1000km aperture).	SCI0007 Phased Array Capability	Test
25	SYS0202	Concurrent Interferometric Visibilities	The Phased Sum Operating Mode shall support the computation of cross-correlations simultaneous with the phased array capabilities to enable atmospheric calibration. This concurrent interferometric capabilities may have restricted processed bandwidth, spectral and time resolution compared to the mode described in SYS0002.	SCI0007 Phased Array Capability	Demonstration
26	SYS0203	Number of Beams	The system shall support a minimum of 10 beams distributed over 1 to 10 sub-arrays. It is desirable to support 50 beams distributed over 1 to 10 sub-arrays at reduced bandwidth per beam.	SCI0008 Beam Forming SCI0009 Sub-Array Capabilities	Demonstration
27		Transient Pulsar Timing Operating			

		Mode Requirements			
28	SYS0301	Timing Capabilities	The system shall include a back-end timing instrument with a minimum of 5 independent de-dispersion and folding threads. Support for up to 50 de-dispersion and folding threads is desirable.	SCI0012 Pulsar Timing Capabilities	Inspection
29	SYS0302	Timing Sys. Bandwidth	The timing system shall process a minimum of 8 GHz of bandwidth. Processing the full instantaneous bandwidth available in all bands is desirable.	SCI0012 Pulsar Timing Capabilities	Demonstration
30	SYS0303	Timing Sys. Frequency Resolution	The timing system shall support channelization for de-dispersion at a frequency resolution of 1 MHz minimum. Frequency resolution of 50 kHz is desired.	SCI0012 Pulsar Timing Capabilities	Demonstration
31	SYS0304	Pulse Profile Bins	The timing system shall support a minimum of 2048 pulse profile bins.	SCI0012 Pulsar Timing Capabilities	Demonstration
32	SYS0305	Polarization	The timing system shall, at a minimum, process the summed output of both polarizations. It is desirable to process both polarizations independently and provide full-stokes parameters	SCI0012 Pulsar Timing Capabilities	Inspection
33	SYS0306	Pulse Period	The timing system shall be capable of de-dispersion and folding for pulse periods spanning from 1msec to 30 sec.	SCI0012 Pulsar Timing Capabilities	Test
34	SYS0307	Dump Rate	The timing system shall record to disk at least every 10 seconds. It is desirable to record to disk every second.	SCI0012 Pulsar Timing Capabilities	Demonstration
35	SYS0308	Pulse Period Resolution	The time period of the average pulse profile peak (post de-dispersion and folding) shall be reported with an accuracy of 1 usec or smaller.	SCI0012 Pulsar Timing Capabilities	Test
36		Transient Pulsar Search Operating Mode Requirements			
37	SYS0401	Search Capabilities	The system shall include a back-end search instrument which can process a minimum of 10 beams. It is desirable to process up to 50 beams.	SCI0013 Time Domain Search Capabilities	Inspection
38	SYS0402	Search Sys. Bandwidth	The search system shall process a minimum of 8 GHz of bandwidth. Processing the full instantaneous bandwidth available in all bands is desirable.	SCI0013 Time Domain Search Capabilities	Demonstration
39	SYS0403	Search Sys. Frequency Resolution	The timing system shall support channelization for de-dispersion at a frequency resolution better than 1 MHz. Frequency resolution of 100 kHz is desired.	SCI0013 Time Domain Search Capabilities	Demonstration
40	SYS0404	Search Sys. Time Resolution	The search system shall have minimum time resolution of 100 µsec. Resolution of 20 µsec is desired.	SCI0013 Time Domain Search Capabilities	Demonstration
41	SYS0405	Polarization	The search system shall, at a minimum, process the summed output of both polarizations. It is desirable to process both polarizations of each beam independently and provide full-stokes parameters	SCI0013 Time Domain Search Capabilities	Demonstration
42		VLBI Operating Mode Functional Requirements			
43	SYS0501	VLBI Recording Capabilities	It shall be possible to record data from a minimum of 3 beams over 1 to 3 sub-arrays in VLBI compliant formats. It is desirable to support this capability for 10 beams distributed over 1 to 10 sub-arrays.	SCI0017 VLBI Capabilities	Demonstration
44	SYS0502	eVLBI Capabilities	It is desirable, but not required, to interface with network-connected VLBI stations as real-time correlated elements of the ngVLA.	STK2501 Facility Integration	Analysis

45		Observing Modes			
46	SYS3001	Standard Observing Modes	Each functional Operating Mode shall have one or more Standard Observing Modes that can generate observing instructions based on PI-defined scientific requirements and produce quality-assured data products.	STK0700 Standard Modes: Time-Phased Availability STK0701 Standard Modes: Generation of Scheduling Blocks	Inspection
47	SYS3002	Number of Standard Observing Modes	Standard Observing Modes shall be developed to execute all planned observations in support of the KSG science use cases, as defined in the Reference Observing Program (AD 08).	STK0700 Standard Modes: Time-Phased Availability STK0701 Standard Modes: Generation of Scheduling Blocks STK1000 Pipeline Use for Standard Observing Modes	Analysis
48	SYS3003	Non-Standard Observing Modes	Interfaces shall be provided for advanced users to access Non-Standard Observing Modes, to directly generate observing instructions for each functional Operating Mode processed by the system, and to record basic data products.	STK0702 Non-Standard Observing Modes	Demonstration
49	SYS3004	Triggered Observations	The system shall include interfaces to receive external (network) triggers to execute previously approved Standard Observing Mode and Non-Standard Observing Mode instructions.	SCI0005 Triggered Observations	Inspection
50	SYS3005	Triggered Observation Response	The system shall process a trigger and begin an observation (be configured and on source) in a period not to exceed 10 minutes, with a goal of 3 minutes or less.	SCI0005 Triggered Observations	Analysis
51	SYS3006	Trigger Override	The trigger response mechanism shall provide a human Array Operator Override. The Override shall time-out and execute the triggered observation if the observation is not canceled within 60 seconds.	SCI0005 Triggered Observations	Demonstration
52		Data Products			
53		Low-Level Interferometric Data Product Requirements			
54	SYS0701	Uncalibrated Data	The uncalibrated visibilities, as provided by the online system after required averaging, shall be recorded to disk in a standard format inclusive of meta data necessary for calibration (spec. TBD).	STK1100 Data Product Types to Archive	Inspection
55	SYS0702	Flagged Data Table	A flagging table shall be provided along with the visibility data to mark data that is suspected to be corrupted. Causes to be flagged include, but are not limited to, antenna off-source, RFI, or other known issues that would affect data integrity.	STK1100 Data Product Types to Archive STK1102 Reprocessing and Automated QA via Archive	Inspection
56		High-Level Interferometric Data Product Requirements			
57	SYS0703	Calibration	For Standard Observing Modes within the Interferometric Operating Mode, there shall be a standard	STK1000 Pipeline	Inspection

		Pipeline	data reduction performed that produces a calibration table to apply direction-independent corrections that were supported by the observation, including: delay/phase, gain/amplitude, polarization, and bandpass corrections.	Use for Standard Observing Modes			
58	SYS0721	Imaging Pipeline	For Standard Observing Modes within the Interferometric Operating Mode, there shall be a standard data reduction performed resulting in a calibrated image cube.	SCI0020 Data Delivery Latency STK0512 Commissioning-Observing Mode SRDP Pipeline			Test
59	SYS0722	Quick Look Image Pipeline	For triggered observations, there shall be a standard data reduction performed resulting in a continuum image, processed in a time duration equal to or less than the observation duration.	SCI0020 Data Delivery Latency			Test
60		Pulsar Timing and Search Data Product Requirements					
61	SYS0741	Pulsar Timing Data Product	For the Standard Observing Modes within the Transient Timing operating mode, dispersion measures, dedispersed pulse profiles and periods shall be generated and recorded in PSRFITS format. (TBC)	SCI0012 Pulsar Timing Capabilities			Inspection
62	SYS0742	Pulsar Search Data Product	For the Standard Observing Modes within the Transient Search operating mode, dispersion measures, dedispersed pulse profiles and periods shall be generated and recorded in PSRFITS format. (TBC)	SCI0013 Time Domain Search Capabilities			Inspection
63		Frequency Range and RF Coverage					
64	SYS0801	System Frequency Range	System frequency range shall cover, at a minimum, the 1.2 to 50 GHz and 70-116 GHz windows.	SCI0001 Frequency Coverage	SYS0803 Freq. Span A: SYS0804 Freq. Span B: SYS0805 Freq. Span C:		Inspection
65	SYS0802	Optimized Frequency Range	Sensitivity shall be maximized above 8 GHz.	SCI0100 Continuum Sensitivity SCI0102 Line Sensitivity STK2801 DSN Support			Inspection
66	SYS0803	Freq. Span A:	1.2-8 GHz.		SYS0801 System Frequency Range		Inspection
67	SYS0804	Freq. Span B:	8-50 GHz		SYS0801 System Frequency Range		Inspection
68	SYS0805	Freq. Span C:	70-116 GHz		SYS0801 System Frequency Range		Inspection
69	SYS0806	Continuity of Frequency Coverage	There shall be no gaps in frequency coverage within frequency spans (A, B, C) listed above. It is a goal that any band edges include at a minimum 1% overlap in bandwidth.	SCI0001 Frequency Coverage SCI0002 Observing Bands SCI0003			Demonstration

				Frequency Selection	
70		System Bandwidth and Frequency Tunability			
71	SYS0901	Front End Bandwidth Ratio	A minimum receiver bandwidth ratio of 1.5:1 is required, with a 3:1 goal over Frequency Span A.	SCI0100 Continuum Sensitivity SCI0102 Line Sensitivity	Inspection
72	SYS0902	Instantaneous Digitized Bandwidth	It is desirable for the system to digitize the full bandwidth of each receiver band.	SCI0003 Frequency Selection SCI0100 Continuum Sensitivity	Inspection
73	SYS0903	Total Instantaneous Processed Bandwidth	The system shall transmit and process a minimum of 14 GHz/pol from each antenna. Transmitting and processing 20 GHz/pol is desired.	SCI0100 Continuum Sensitivity	Test
74	SYS0904	Sub-Bands	If the digitized bandwidth exceeds the instantaneous transmitted and processed bandwidth, the system shall separate the digitized bandwidth into sub-bands for bandwidth selection, transmission and processing.	SCI0003 Frequency Selection	Inspection
75	SYS0905	Frequency Tunability	If the front-end bandwidth exceeds the instantaneous transmitted and processed bandwidth, it shall be possible to select discontinuous sub-bands for transmission and processing. For example, transmitting both the top and bottom of the 70-116 GHz band.	SCI0003 Frequency Selection	Demonstration
76	SYS0906	Fixed Analog Tunings	While supporting the Frequency Tunability requirement (SYS0905), the analog system setup options shall be minimized to facilitate calibration from catalog values.	STK1403 Calibration Efficiency	Inspection
77	SYS0907	Sub-Band Step Size	Sub-band bandwidth selection shall have a granularity of 250 MHz or smaller.	SCI0003 Frequency Selection	Inspection
78	SYS0908	Band Switching Time	Switching between any receiver bands shall be achievable within 20 seconds. Goal of less than 10 seconds.	SCI0018 Multi-Frequency Observations	Test
79	SYS0909	Contiguous Bandwidth	Any bandwidth division for transmission and processing shall not create gaps in frequency coverage.	SCI0003 Frequency Selection	Inspection
80		Sensitivity Requirements			
81	SYS1001	Effective Area / Tsys Ratio	The effective area / Tsys ratio of the system shall meet or exceed the values given in Figure 1 while operating in the precision environmental conditions defined in 020.10.15.10.00-0001-SPE and assuming 1 mm of PWV. This requirement must be met over 80% of the bandwidth of any given receiver (i.e., band edges are exempted).	SCI0100 Continuum Sensitivity SCI0102 Line Sensitivity SCI0106 Survey Speed	Analysis
82		System Field of View			
83	SYS1101	Instantaneous Field of View	The system instantaneous FOV (FWHM), when scaled by center frequency, shall be larger than 2 arcmin at 28 GHz.	SCI0106 Survey Speed SCI0104 Largest Recoverable Scale	Inspection

84	SYS1102	Accessible Field of View	The system shall be capable of observing at elevations of 12° to 89°, relative to the local horizon.	SCI0019 Accessible Sky		Analysis
85	SYS1103	Slew Rates	The system shall be capable of slewing to any position within the accessible field of view in less than 2 minutes of time.	SCI0005 Triggered Observations		Analysis
86	SYS1104	Tracking Rates	The system shall be capable of tracking objects and mapping an area of sky at 10x sidereal speeds when under 70-degrees in elevation.	SCI0004 Mosaics and On-the-Fly Mapping		Analysis
87		Dynamic Range				
88	SYS1201	Input Dynamic Range	The analog dynamic range of the receiving electronics shall have a minimum of 30dB of headroom, defined at the 1dB compression point. Goal to achieve spec at 1% compression point.	SCI0016 Solar Observation Capabilities		Test
89	SYS1202	Gain Calibration System Dynamic Range	Any gain and bandpass calibration strategy shall also accommodate a 30dB change in system temperature, so any gain calibration signal injection requires a variable input power range of at least 30dB.	SCI0016 Solar Observation Capabilities		Inspection
90	SYS1203	Provision of Variable Attenuators	The system shall provide variable attenuators that accommodate the dynamic range specified in SYS1201, while maintaining the minimum number of bits specified in SYS1035.	SCI0016 Solar Observation Capabilities		Inspection
91	SYS1204	Input Protection	The system shall survive exposure to signals at large as 55 dBm EIRP at a distance of 100m through sidelobes (G=1) with no damage to the receiving elements.	STK2601 RFI Survival		Analysis
92	SYS1205	High-Noise Path	It is desirable to provide a high-noise / low-gain path that permits reception of signals outside the dynamic range requirement specified in SYS1201.	SCI0016 Solar Observation Capabilities		Inspection
93		Spatial Resolution and Spatial Frequency Coverage				
94	SYS1301	Longest Baseline	The longest baseline between antennas in the main array shall be greater than 700 km with extended baselines (VLB) out to 8800 km.	SCI0103 Angular Resolution SCI0118 VLB Angular Resolution		Inspection
95	SYS1302	Shortest Baseline	The shortest baselines between antennas shall be 22 m or less, with a goal of 10 m.	SCI0104 Largest Recoverable Scale		Inspection
96	SYS1303	Zero Spacing / Single Dish Total Power	It is a goal that the system measure total power spectral density in the field, with apertures larger than 1.5x the shortest baseline.	SCI0104 Largest Recoverable Scale		Inspection
97	SYS1304	Integration Time Ratios	If achieving SYS1302 requires multiple array/antenna designs, each array shall sample overlapping spatial scales. The ratio of integration time on one array to the other on these overlapping scales shall not exceed a factor of four, with a goal of matched integration times.	STK1403 Calibration Efficiency	SYS0753 Heterogeneous Arrays	Analysis
98	SYS1306	Fraction of Occupied Cells	The system shall fill at least 50% [TBC] of (u,v)-cells before gridding out to 50 km baselines in a snapshot continuum observation traversing the meridian with a 1,000k x 1,000k pixel grid. Goal to approach this fill ratio out to 700 km scales.	SCI0106 Survey Speed SCI0108 Imaging Fidelity SCI0109 Snapshot Image Fidelity SCI0107 Quality of the Synthesized		Analysis

				Beam			
99	SYS1308	Distribution and Weighting of Visibilities	The system shall achieve a Gaussian distribution via weighting, with the geometric mean of the weights greater than 0.5 over the full range of scales that correspond to 100 m to 700 km baselines on an 8 hr observation about the meridian. Geometric mean of weights shall also be better than 0.05 at scales corresponding to 8600 km baselines.	SCI0100 Continuum Sensitivity SCI0102 Line Sensitivity SCI0103 Angular Resolution SCI0108 Imaging Fidelity SCI0118 VLB Angular Resolution STK2800 SSA Support SCI0107 Quality of the Synthesized Beam			Analysis
100	SYS1309	Collecting Area on VLB Baselines	The system shall provide a minimum of 6000 m^2 of collecting area on the VLB-scale baselines.	SCI0117 VLB Continuum Sensitivity STK2800 SSA Support			Inspection
101		Spectral Resolution					
102	SYS1401	Highest Spectral Resolution	The available spectral resolution shall be finer than 1 kHz/channel. Goal of 400 Hz/channel.	SCI0105 Spectral Resolution			Inspection
103	SYS1402	Number of Spectral Channels	A minimum of 240,000 channels shall be supported by the correlator and post processing systems, across all baselines, with four products per baseline (full stokes). Goal of 2,000,000 channels to be supported by the correlator.	SCI0105 Spectral Resolution			Inspection
104	SYS1403	Flexible Spectral Resolution	The spectral resolution shall be tunable to permit variable resolution across the observed band, increasing the instantaneous processed bandwidth while providing high spectral resolution over defined sub-bands.	SCI0105 Spectral Resolution SCI0006 Observing Modes			Inspection
105	SYS1404	Doppler Corrections	The system shall include a method to correct/set Doppler corrections to a common reference frame.	SCI0105 Spectral Resolution			Demonstration
106		Delay and Phase Stability Requirements					
107	SYS1501	Delay/Phase Variations Magnitude	The delay variations caused by the instrument shall be smaller than those caused by the natural environment for at least 90% of the time. These natural limits are those imposed by the residual delay fluctuations of the troposphere after all available corrections (e.g., fast switching, WVR, etc.) have been applied.	STK1402 Observational Efficiency STK1403 Calibration Efficiency SCI0100 Continuum Sensitivity	SYS1504 Phase Drift Residual SYS1505 Absolute Phase Drift		Analysis
108	SYS1502	SNR Loss to Delay/Phase Variations	The instrumental delay/phase noise shall not degrade overall system SNR by more than 1%.	SCI0100 Continuum Sensitivity STK1403 Calibration Efficiency	SYS1503 Phase Noise		Analysis
109	SYS1503	Phase Noise	Total instrumental integrated phase noise shall not exceed 132 fsec rms.		SYS1502 SNR Loss to		Test

					Delay/Phase Variations	
110	SYS1504	Phase Drift Residual	The (relative) system phase drift residual shall not exceed 95 fsec rms per antenna over 300 seconds. Goal to meet this specification over a period of 1000 seconds.	SCI0111 Relative Astrometric Error	SYS1501 Delay/Phase Variations Magnitude	Test
111	SYS1505	Absolute Phase Drift	The absolute phase drift per antenna over 300 seconds shall not exceed 8 psec. Goal to meet this specification over 1000 seconds.	SCI0111 Relative Astrometric Error	SYS1501 Delay/Phase Variations Magnitude	Test
112		Gain & System Temperature Stability Requirements				
113		Total Power Observations				
114	SYS1601	TP Antennas: Gain Stability	TP Antenna dG/G shall not exceed 1E-3 over a 60 sec period. Goal to not exceed 1E-4.	SCI0104 Largest Recoverable Scale		Test
115	SYS1603	TP Antennas: Gain Variations with Antenna Pointing Angle	TP Antenna dG/G shall not exceed 1E-2 at 10 GHz over a 4° change in elevation, scaled by frequency (TBC).	SCI0104 Largest Recoverable Scale SCI0110 Photometric Error		Test
116	SYS1604	TP Antennas: System Temperature Stability over Time	TREC shall vary by no more than 0.1% over 60 sec period in the precision operating conditions defined in 020.10.15.10.00-0001-SPE. (TBC)	SCI0104 Largest Recoverable Scale SCI0110 Photometric Error		Test
117	SYS1605	TP Antennas: System Temperature Variations with Antenna Pointing Angle	TSPILL and TREC shall vary by no more than 0.1% combined over a 4° change in elevation in the precision operating conditions defined in 020.10.15.10.00-0001-SPE. (TBC)	SCI0104 Largest Recoverable Scale SCI0110 Photometric Error		Test
118	SYS1801	TP Antennas: Gain Calibration Reference	The system shall provide a switched flux reference stable to 1E-3 over a 5 minute period. Stability over a 24 hour period shall be better than 1%.	SCI0104 Largest Recoverable Scale SCI0110 Photometric Error		Test
119		Interferometric Observations				
120	SYS4601	Interferometric Antennas: Gain Stability	Antenna dG/G shall not exceed 4E-3 over a 200 sec period at 1 MHz bandwidth resolution. Goal to not exceed 1E-3.	SCI0113 Brightness Dynamic Range SCI0114 Polarization Dynamic Range SCI0119 Spectral Dynamic Range (Absorptive) SCI0115 Spectral Dynamic Range (Emissive)		Test
121	SYS4602	Interferometric Antennas: Relative Gain	Relative dG/G between polarization pairs shall not exceed 4E-3 over a 200 sec period.	SCI0114 Polarization Dynamic		Test

		Stability		Range		
122	SYS4603	Gain Variations with Antenna Pointing Angle	Antenna dG/G shall not exceed 1E-2 at 8 GHz over a 4° change in elevation, scaled by frequency (TBC).	SCI0110 Photometric Error		Test
123	SYS4801	Gain Calibration Reference	The system shall provide a switched flux reference stable to 1E-3 over a 20 minute period.	SCI0110 Photometric Error SCI0113 Brightness Dynamic Range SCI0114 Polarization Dynamic Range		Test
124		Polarization Requirements				
125	SYS1900	Full Stokes	The system shall measure the full set of stokes parameters that describe the polarization state of the received and correlated signals.	SCI0015 Polarization Products		Demonstration
126	SYS1901	Polarization Purity	The system post-calibration on-axis residual linear pol leakage (amplitude) shall be less than 0.03% at 8 GHz, scaled by observing frequency, where leakage is defined as Stokes Q/I, U/I, or V/I.	SCI0114 Polarization Dynamic Range		Test
127		Temporal Requirements				
128	SYS0104	Variable Time Resolution	It is desirable to provide an option to vary the time resolution on a per-baseline basis (i.e., baseline dependent averaging) in order to reduce the total data volumes generated by the correlator.			Demonstration
129	SYS0106	On-The-Fly Mapping – Data & Control Rates	The system shall support on-the-fly (OTF) mapping rates of 2x sidereal at 28 GHz, with data dump rates and delay update rates <400 msec at the full system bandwidth. Goal to support rates <100 msec at reduced bandwidth or spectral resolution (i.e., fixed data output rate).	SCI0004 Mosaics and On-the-Fly Mapping SCI0106 Survey Speed		Demonstration
130	SYS0107	On-The-Fly Mapping – Antenna Tracking Rate	The antenna and any motion control loops shall support on-the-fly tracking rates of 10x sidereal for elevations below 70° (2.5'/sec).	SCI0004 Mosaics and On-the-Fly Mapping SCI0106 Survey Speed		Demonstration
131	SYS2001	Temporal Resolution	Correlator visibility integration time shall be tunable, with a range of 5 sec to 100 msec (possibly at limited bandwidth) or better. Goal to support integration times as short as 1 msec at limited bandwidth.	SCI0004 Mosaics and On-the-Fly Mapping SCI0103 Angular Resolution		Inspection
132	SYS2002	Temporal Accuracy	Data Product timestamps must be referred to an absolute time standard (e.g., GPS or TAI) with an error of less than 10 ns (goal of 1 ns). This correction may be retroactive (i.e., it is not necessary for it to be known in real time.)	SCI0112 Timing Error SCI0012 Pulsar Timing Capabilities		Analysis
133		Spurious Signals				
134	SYS2104	Self-Generated Spurious Signal Power Level	Self-generated signals shall not exceed -43dB relative to the system noise level on cold sky over a 1 MHz bandwidth.	SCI0116 Spurious Spectral Features STK2600 Self-Interference	EMC0310 Spurious Signal Level EMC0320 Drive System Shielding	Test

				E EMC0321 Relay Contact Arcing E EMC0322 Amplifiers & Oscillators E EMC0323 Silicone Controlled Rectifiers E EMC0324 Gaseous Discharge Devices E EMC0325 Static Discharge Mitigation E EMC0326 Display Shielding E EMC0327 Digital Equipment Shielding E EMC0328 EMC Test Frequencies	
135	SYS2105	E LO Frequency and Sampler Clock Offsets	The system shall include the provisions for frequency offsets and sampler clock offsets at the antenna level to provide additional attenuation of spurious signals.	R SCI0115 Spectral Dynamic Range (Emissive) R SCI0113 Brightness Dynamic Range R SCI0108 Imaging Fidelity R SCI0119 Spectral Dynamic Range (Absorptive) E STK2600 Self-Interference	Demonstration
136	SYS2106	E Shielding & Emission Limits	System shielding and emission limits shall comply with 020.10.15.10.00-0002-REQ.	R SCI0116 Spurious Spectral Features E STK2600 Self-Interference	Test
137		Scientific Operations Requirements			
138		Proposal Submission and Evaluation			
139	SYS2211	E Proposal Submission – standard observing modes	The proposal submission interface shall allow the user to specify their scientific requirements for standard observing modes, without specifying the technical implementation to those requirements.	E STK0801 Proposal Submission Tool E STK0800 Proposal Submission Criteria E STK0805 Proposal Submission Concept	Demonstration

140	SYS2212	Proposal Submission – non-standard observing modes.	For non-standard observing modes, it shall be possible for the user to define their technical observation parameters as part of their proposal.	STK0800 Proposal Submission Criteria STK0801 Proposal Submission Tool STK0702 Non-Standard Observing Modes		Demonstration
141	SYS2213	Scientific Proposal Evaluation	A tool shall be available for proposal evaluation and ranking, and shall permit the anonymization of proposals during evaluation.	STK0802 Proposal Assessment STK0803 Mitigating Bias in Proposal Peer Review		Demonstration
142	SYS2214	Technical Proposal Evaluation	The proposal evaluation tool shall include technical simulation tools to verify the observing resources required (sub-arrays, time) to support the science requirements.	STK0802 Proposal Assessment		Demonstration
143	SYS2215	Observing Time Calculator	The system shall provide users with a tool to calculate the required science subarrays and associated observing time based on the proposal scientific and/or technical requirements.	STK0703 Observing Awards: Array Time on Source STK0805 Proposal Submission Concept		Demonstration
144	SYS2216	Proposal Award Model	The proposal evaluation tools shall support an award model of allocated time by subarray to an observation.	STK0703 Observing Awards: Array Time on Source		Inspection
145	SYS2217	Subarray Support	The proposal tools and scheduling system shall support, at a minimum, a set of predefined science subarrays.		STK1401 Subarrays for Scheduling	Inspection
146	SYS2218	Proposal Attributes	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).		STK0804 Proposal Attributes	Inspection
147		Observation Preparation, Execution and Scheduling				
148	SYS2221	Observation Preparation – Standard Observing Modes	For standard observing modes, the system shall determine the technical configuration of the system and a supporting observation plan that meets the science requirements set by the proposer.	STK0805 Proposal Submission Concept STK0701 Standard Modes: Generation of Scheduling Blocks STK0704 Standard Modes: Observing Strategy		Inspection
149	SYS2222	Observation Preparation – Non-Standard Observing modes	The system shall include tools and interfaces to generate observation instructions for non-standard modes without the use of the end-to-end software system.	STK0402 Provision of System Verification Software Tools STK0502 Provision of Commissioning Tools		Inspection

150	SYS2223	Observation Scheduling GUI	The observation scheduling system shall include a GUI to display completed and scheduled projects to the Operator, and to initiate manual overrides and schedule changes.	STK0901 Priority for Triggered Observations STK1502 Operator Interface	Demonstration
151	SYS2224	Observation Interrupt	It shall be possible to interrupt and cancel an in-progress observation through the observation scheduling system GUI in the Operator Console.	STK0901 Priority for Triggered Observations STK1502 Operator Interface	Demonstration
152	SYS2225	Observation Preparation – Standard Observing Mode Flexibility	For standard observing modes, tools shall support returning the proposed observation plan to the user for review, and to collect user proposed modifications as necessary to support their science requirements.	STK0705 Standard Modes: Flexibility	Demonstration
153	SYS2226	Observation Time Model	The observation preparation, execution, and scheduling tools shall support a scientific operations model of allocated time by subarray to an observation.	STK0703 Observing Awards: Array Time on Source	Inspection
154	SYS2227	Observation Scheduling Criteria	The automatic observation scheduling system shall account for the system status, current and expected weather, project priority and percent complete, and expected RFI when automatically scheduling observations.	STK0900 Priority in Scheduling Observations	Inspection
155	SYS2302	Observation Scheduling	System observations shall be automatically scheduled by an observation scheduling system, although manual over-rides to scheduling shall also be possible.	STK0901 Priority for Triggered Observations STK0900 Priority in Scheduling Observations STK0703 Observing Awards: Array Time on Source	Demonstration
156		User Interfaces			
157	SYS3500	Proposal Preparation Tool	A tool shall be provided to enable users to prepare and submit their proposals.	STK1200 Operational User Support STK0801 Proposal Submission Tool	Demonstration
158	SYS3501	Observation Preparation Tool	A tool shall be provided for users to inspect and modify their observation instructions for approved projects.	STK1200 Operational User Support	Demonstration
159	SYS3502	Data Quality Inspection Tool	A tool shall be provided for users to inspect the data quality of a performed observation.	STK1200 Operational User Support	Demonstration
160	SYS3503	Data Processing Inspection Tool	A tool shall be provided for users to review and modify the post-processing and generation of SRDP for observations using standard observing modes.	STK1200 Operational User Support	Demonstration
161	SYS3504	Data Analysis Package	A data analysis tool kit shall be provided for users to analyze the data products generated by the system, applicable to both high and low-level data products generated with either standard or non-standard observing modes.	STK1200 Operational User Support	Demonstration
162	SYS3505	User Support Tool	A tool shall be provided for users to request support related to proposing, observing, data quality, processing or analysis of ngVLA data.	STK1200 Operational User	Demonstration

				Support			
163	SYS3506	Data Processing Package	A data processing tool kit shall be provided for users to generate high-level data products for non-standard modes using user-provided computational resources.	STK1202 Software Packages Available to User Community: Data Processing			Demonstration
164		Post-Observation					
165	SYS2205	Manual Data Quality Assurance	The system shall include tools and interfaces for manual quality assurance inspections of low-level and high-level data products gathered using non-standard operating modes.	STK9949 QA tools for Data Products			Demonstration
166	SYS2206	Quality Assurance Tool Extensibility	The data quality assurance tools shall be extensible to support the inspection of user-generated data products.	STK1004 Support for Legacy Programs STK1104 User Produced Data Products			Inspection
167	SYS2207	Automated QA of Data Products	The system shall include an automated quality control check of low-level and high-level data products generated using standard operating modes.			STK9948 Automated QA of Data Products	Demonstration
168	SYS2208	Quality Assurance Tools for Standard Modes	The system shall include tools for human inspection when the automated QA system identifies faults on data products generated for standard observing modes.	STK9949 QA tools for Data Products			Demonstration
169	SYS2209	Data Provenance Tracking	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.			STK9950 Data Provenance	Inspection
170	SYS2201	Provision of Software Tools	The system shall include tools for the preparation of proposals, preparation of observations, reduction of data products, and analysis of data products.	STK0801 Proposal Submission Tool STK1201 Software Packages Available to User Community: Data Analysis STK1202 Software Packages Available to User Community: Data Processing STK0805 Proposal Submission Concept STK0200 Operations Concept			Inspection
171		Array Operation Requirements					
172	SYS2303	Calibration Automation	The calculation and updating of parametric delay and pointing models shall be automated.	STK1506 Array Operations: Remote and Automated Functions	SYS1061 Calibration Efficiency SYS1062 Calibration Parallelization		Demonstration
173	SYS2304	Self-Calibrating Antenna	It is a goal that the antenna self-configure and self-calibrate (based on catalog values stored in the calibration database) after maintenance or a power interruption, with limited intervention from the operator.	STK1506 Array Operations: Remote and Automated	SYS1061 Calibration Efficiency		Demonstration

				Functions	SYS1062 Calibration Parallelization	
174	SYS2305	Single Baseline Data Display	Graphical interfaces shall be provided to display single baseline fringe amplitude and phases in near real-time.	STK0402 Provision of System Verification Software Tools STK0502 Provision of Commissioning Tools STK1502 Operator Interface		Demonstration
175	SYS2306	Calibration Data Display	Graphical interfaces shall be provided to tabulate and display common antenna calibration coefficients (delays, TSYS, PDIFF, etc.), and flag values that are possible outliers. The threshold for flagging shall be user tunable (e.g., 1-sigma, 3-sigma, etc.)	SYS3110 Performance Analysis and Automated Maintenance Scheduling STK0402 Provision of System Verification Software Tools STK0502 Provision of Commissioning Tools STK1502 Operator Interface		Demonstration
176	SYS2307	Operator Console	An operator console shall be provided that provides visibility and control of scheduled maintenance and observations, as well as displays of the array configuration, weather, and system status alerts.	SYS3113 Operator Interface to System Monitoring Software STK1502 Operator Interface		Demonstration
177	SYS2308	Operator Interface Location	It shall be possible for authorized personnel to access the operator interface software from any approved workstation in the Observatory.	STK1502 Operator Interface	STK9944 Operator Interface Location	Inspection
178		System Monitoring Requirements				
179	SYS3101	LRU Monitoring	Each LRU shall provide on-board monitoring and diagnostics to determine the health and status of the unit.	SYS3203 Criteria for Scheduling Maintenance SYS3112 Intelligent LRUs and Subsystems		Inspection
180	SYS3102	LRU Alerts	When an LRU is out of specification, it shall generate a prioritized alert for processing by the operator and maintenance scheduler.	SYS3203 Criteria for Scheduling Maintenance		Inspection
181	SYS3103	Monitor Archive	Monitor data and alerts shall be archived at their generated rate (SYS2408) the full life of the instrument. (SYS2801)	SYS3110 Performance Analysis and Automated Maintenance Scheduling		Inspection
182	SYS3105	Fast Read-Out Modes	Fast-read out modes shall be available for remote engineering diagnostics of all LRUs (i.e., an on-board oscilloscope function)	SYS3112 Intelligent LRUs and Subsystems STK1506 Array		Demonstration

				Operations: Remote and Automated Functions	
183	SYS3110	Performance Analysis and Automated Maintenance Scheduling	Array software systems shall provide a continual and automated analysis of array status and health, providing the key source of automatically generated maintenance tickets and automated maintenance scheduling.	STK5005 Maintenance Concept	Demonstration
184	SYS3111	Hot Swaps of LRUs	Hardware and software shall be designed to accommodate and recover from hot swaps with minimal interaction required by the maintenance and operations personnel.	STK5005 Maintenance Concept	Inspection
185	SYS3112	Intelligent LRUs and Subsystems	LRUs and other subsystems shall be smart devices with on-board diagnostics that can be accessed remotely for troubleshooting.	STK5005 Maintenance Concept	Inspection
186	SYS3113	Operator Interface to System Monitoring Software	The monitoring system shall provide the operator with status and alert screens to indicate array health and system configuration.	STK5005 Maintenance Concept	Demonstration
187	SYS3114	Subsystem Automation	Individual antennas and subsystems within the array shall perform system configuration and monitoring functions without the need for human intervention. It is a goal that each subsystem be capable of reaching an operationally-ready state after a full power cycle without human intervention.	STK5005 Maintenance Concept	Demonstration
188		Environmental Monitoring Requirements			
189	SYS2501	Weather Monitoring	Parameters that affect system scheduling or are used for calibration (wind speed, temperature, humidity and barometric pressure), shall be measured over the full extent of the array.	STK0900 Priority in Scheduling Observations SCI0111 Relative Astrometric Error	Inspection
190	SYS2502	Safety Weather Monitoring	Parameters that affect the health/safety of the array (wind, temperature) shall have redundant monitoring.	STK0304 Projected Environment	Inspection
191	SYS2503	Weather Archive	Weather data from all weather stations shall be recorded at no less than 1 minute periods and archived for the life of the instrument.	STK1403 Calibration Efficiency	Inspection
192	SYS2504	Atmospheric Phase Monitor	An atmospheric phase monitor (APM) at the Central Cluster shall be available, and shall interface with the scheduling system.	STK1402 Observational Efficiency	Demonstration
193		System Availability			
194	SYS2601	Antenna System Availability	The combined antenna system availability shall be, at a minimum, 90% (goal of 95%) of time available for science operations.	STK1402 Observational Efficiency	Analysis
195	SYS2602	Centralized Systems Availability	For all centralized systems (e.g., LO distribution, correlator) that are required for data collection, system availability shall be no less than 95%.	STK1402 Observational Efficiency	Analysis
196		Safety			
197	SYS2700	Safety Specification	All designs shall comply with the Level-1 System Safety Specification (020.80.00.00.00-0001-REQ)		Inspection

198	SYS2701	Subsystem self-monitoring	All subsystems shall monitor system health and prohibit actions likely to cause damage.	SYS3112 Intelligent LRUs and Subsystems			Analysis
199		System Life Cycle Requirements					
200		Assembly, Integration and Verification Requirements					
201	SYS2811	Test Fixtures	Test fixtures and procedures shall be provided for subsystem level verification.	STK0400 Provision of Assembly Verification Tools			Inspection
202	SYS2813	System Verification Tools	Tools shall be provided to automate test execution and test reporting as part of array element verification. Such tools shall include near real-time data display for interactive diagnosis by engineers.	STK0402 Provision of System Verification Software Tools STK0400 Provision of Assembly Verification Tools			Demonstration
203	SYS2814	Testing of Software and Firmware	All software and firmware developed by the project shall be delivered with automated unit, integration, and regression testing suites.	STK0400 Provision of Assembly Verification Tools	STK0427 Testing-Software and Firmware		Inspection
204	SYS2815	AIV Software Tools	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.	STK0400 Provision of Assembly Verification Tools	STK0431 AIV Software Tools		Demonstration
205	SYS2816	ICD API and software Definition	All Application Program Interfaces (API) or other software interfaces shall be defined in ICDs.	STK0400 Provision of Assembly Verification Tools	STK0432 ICD-API and Software Definition		Inspection
206	SYS2817	ICD Automated Conformance Testing	Automated test results demonstrating conformance to API ICDs shall be delivered with the product.	STK0400 Provision of Assembly Verification Tools	STK0433 ICD-Automated Conformance Testing		Inspection
207	SYS2818	ICD LRUs	ICDs shall be delivered for each Line Replaceable Unit in the system.	STK0400 Provision of Assembly Verification Tools	STK0434 ICD-LRUs		Inspection
208	SYS2819	VLA Interference	It is a goal to minimize interference with VLA operations during the construction/transition phase.		STK2603 VLA Interference		Inspection
209	SYS2820	AIV Concept	The system shall provide any ancillary features necessary to conform with the Observatory-approved and released AIV Concept.	STK0400 Provision of Assembly Verification Tools STK0536 Assembly, Integration and Verification Concept			Inspection
210		Commissioning and Science Validation					

		Requirements				
211	SYS2830	Incremental Delivery to Operations	Operational capabilities and observing modes shall be made available in stages during the transition from construction through to the commencement of full operations.		STK0511 Transition to Ops-Capabilities and Observing Modes	Inspection
212	SYS2831	Delivery with SRDP Pipeline	Delivery of a commissioned standard observing mode shall include an operational SRDP pipeline before it is offered for regular use through PI proposals.		STK0512 Commissioning-Observing Mode SRDP Pipeline	Demonstration
213	SYS2832	Science Operations API	A science-oriented API (scripting interface) for calling high-level array functions, prior to the widespread use of Scheduling Blocks (SBs), shall be delivered.		STK0516 API and Scheduling Blocks	Demonstration
214	SYS2833	Observing Simulator	Simulators to enable the development of observing scripts without the real system shall be delivered.		STK0517 Simulators-Development of Observing Scripts	Demonstration
215	SYS2834	Interactive Shell Access	The system shall provide interactive shell access to the calibration and imaging software, running on an Observatory-supported OS.		STK0518 Interactive Shell Access	Inspection
216	SYS2835	External Calibrator Data Interface	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.		STK0520 Contemporaneous Calibrator Data	Inspection
217	SYS2836	Availability for Early Science	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.		STK0501 Availability for Early Science	Inspection
218	SYS2837	First Look Science Products	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.		STK0500 First Look Science Products	Inspection
219	SYS2838	CSV Concept	The system shall provide any ancillary features necessary to conform to the Observatory-approved and released CSV Concept.	STK0524 Commissioning and Science Validation Concept		Inspection
220	SYS2801	Design Life	The system shall be designed for an expected operational life of no less than 20 years, where the operational life is defined to start at the full operations milestone and close-out of the construction project.	STK0303 Design Life		Analysis
221	SYS2802	Cost Optimization	The system shall be designed to minimize total life-cycle costs over the projected design life, extending through system decommissioning/ disposal.	STK0303 Design Life STK0600 Disposal Costs		Analysis
222	SYS2803	Sustainability	Sustainability and long-term environmental impact shall be considered in any material or design trade-study.	STK0302 Material Selection & Sustainability		Inspection
223	SYS2805	Part Selection for Maintainability	Individual component selection criteria shall include the projected continuity of support for the component or interchangeable equivalents over the system design life.	STK0310 Part Selection and Obsolescence		Inspection
224	SYS2812	Critical Spares	Critical spares shall be identified and provided with sufficient inventory to support the facility for its operational life (SYS2801). Critical spares are defined as parts that are likely to be obsoleted over the operating life, are unlikely to have market substitutes, and cannot be produced/ordered in small volumes.	STK0403 Spare Parts STK0310 Part Selection and Obsolescence		Inspection

225		Facility Requirements			
226	SYS3800	Outfitted Facilities	All facilities shall be outfitted with the furnishings, tools, equipment, computing, and information technology equipment necessary to fulfill the intended function.	STK2001 Inclusion of a Maintenance Operations Center STK2002 Inclusion of a Warehouse STK2003 Inclusion of a Repair Center STK2004 Inclusion of an Array Operations Center STK2005 Inclusion of a Science Operations Center STK2006 Inclusion of Remote Support Stations STK2007 Location of the Maintenance Operations Center STK2008 Location of the Array Operations Center STK2009 Location of the Science Operations Center STK2010 Location of the Repair Center STK2011 Location of the Warehouse STK2012 Inclusion of a Guard Booth	Inspection
227	SYS3801	Facility Sustainability	All new facilities shall be LEED certified, with a goal of achieving Gold-level certification or higher, as applicable to new construction as defined in LEED v4.1 or newer.	STK0302 Material Selection & Sustainability	Inspection
228	SYS3802	Provision of a Visitor Center	An ngVLA Visitor Center shall be provided for public outreach within view of the array, but at a minimum distance of 1 km from the core antennas to mitigate RFI.	STK2000 Inclusion of a Visitor Center	Inspection
229	SYS3803	Controlled Visitor Access	Facilities shall be provided for controlled visitor access between the visitor center and array core or nearby antennas.	STK2000 Inclusion of a Visitor Center	Inspection
230	SYS3810	Provision of a Maintenance Operations Center	A Maintenance Operations Center shall provide office space and common areas for projected safety, security and maintenance personnel.	STK2001 Inclusion of a Maintenance Operations Center	Inspection
231	SYS3811	Maintenance Center - Support Equipment	The Maintenance Center shall include space for the requisite tools and equipment to support expected preventive and corrective maintenance activities.	STK2001 Inclusion of a Maintenance Operations Center	Inspection
232	SYS3812	Maintenance	The Maintenance Center shall include space for the storage and inventory of LRUs.	STK2001	Inspection

		Center - Ready Spares		Inclusion of a Maintenance Operations Center		
233	SYS3820	Provision of a Warehouse	A central warehouse shall be provided and sized for the central storage and distribution of components, consumables, and critical spares.	STK2002 Inclusion of a Warehouse		Inspection
234	SYS3821	Warehouse Inventory System	The central warehouse shall include provisions for the controlled inventory of all housed components, spares, and consumables.	STK2002 Inclusion of a Warehouse		Demonstration
235	SYS3822	Warehouse Space - AIV	The project shall deliver warehouse capabilities needed to store electronics and other assemblies delivered by the IPTs that require safe keeping prior to antenna integration.	STK2002 Inclusion of a Warehouse		Inspection
236	SYS3830	Provision of a Repair Center	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.		STK2003 Inclusion of a Repair Center	Inspection
237	SYS3840	Provision of an Array Operations Center	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.		STK2004 Inclusion of an Array Operations Center	Inspection
238	SYS3850	Provision of a Science Operations Center	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.		STK2005 Inclusion of a Science Operations Center	Inspection
239	SYS3860	Provision of Remote Support Stations	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.		STK2006 Inclusion of Remote Support Stations	Inspection
240	SYS3870	Location of the Maintenance Operations Center	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.		STK2007 Location of the Maintenance Operations Center	Inspection
241	SYS3871	Location of the Array Operations Center	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.		STK2008 Location of the Array Operations Center	Inspection
242	SYS3872	Location of the Science Operations Center	The Science Operations Center shall be located at a site that facilitates personnel recruitment, such as an attractive metropolitan area.		STK2009 Location of the Science Operations Center	Inspection
243	SYS3873	Location of the Repair Center	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.		STK2010 Location of the Repair Center	Inspection
244	SYS3874	Location of the Warehouse	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.		STK2011 Location of the Warehouse	Inspection
245	SYS3880	Provision of a Guard Booth	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.	STK2201 Physical Security Plans	STK2012 Inclusion of a Guard Booth	Inspection
246	SYS3881	Provision of Support Buildings	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.		STK2013 Inclusion of	

					Central Support Buildings	
247	SYS3885	Facility Space - AIV	The project shall provide adequate space needed for pre-deployment activities, equipment maintenance and storage, and AIV staff office space.			Inspection
248	SYS3886	Data and Voice Services - AIV	It is a goal to deliver data and voice service at each antenna site at the start of civil construction.			Inspection
249	SYS3887	Workspace - CSV	Dedicated workspace shall be provided in the local control room at the array site for CSV activities.			Inspection
250	SYS3888	Workspace - CSV-Operators	The remote control room needed for CSV activities shall contain a sufficient number of IT-supported workstations, in addition to the main multi-monitor control console needed by an operator.			Inspection
251		Maintenance Operations Requirements				
252	SYS2402	Array Element MTBF	The antennas, antenna electronics, array infrastructure, and signal processing systems shall be designed with an expected number of failures to be less than four (4) per array element per year.	SYS3202 Optimization for Maintenance		Analysis
253	SYS2403	Modularization	The system shall be modularized into Line Replaceable Units (LRUs) to facilitate site maintenance.	SYS3202 Optimization for Maintenance STK1603 Packaging as LRUs		Inspection
254	SYS2405	Self-Diagnostic Function	The system shall incorporate self-diagnosis functions to identify faults based on recorded monitor data.	SYS3203 Criteria for Scheduling Maintenance SYS3112 Intelligent LRUs and Subsystems		Demonstration
255	SYS2406	Configuration Monitoring	The system shall include monitoring and tracking of the system configuration to the LRU level, including LRUs that are not network-connected for operation (e.g., Refrigerators).	STK1600 Remote Access of System Configuration		Inspection
256	SYS2407	Engineering Console	The system shall include an engineering console for each subsystem and LRU to communicate system status and assist in real-time diagnosis.	SYS3110 Performance Analysis and Automated Maintenance Scheduling SYS3112 Intelligent LRUs and Subsystems STK0402 Provision of System Verification Software Tools STK0502 Provision of Commissioning Tools		Demonstration
257	SYS2408	Monitor Data Stream	The system shall stream monitor data at variable rates (0.1 sec to 10 min) for automated use by predictive maintenance programs and for direct inspection by engineers and technicians.	SYS3110 Performance Analysis and Automated Maintenance Scheduling SYS3112 Intelligent LRUs and		Inspection

				Subsystems STK0402 Provision of System Verification Software Tools STK0502 Provision of Commissioning Tools		
258	SYS3200	Preventive Maintenance Schedules	The system shall be designed with preventive maintenance (PM) interval no shorter than 1 year.	STK5005 Maintenance Concept		Analysis
259	SYS3201	Maintenance Tiers	Maintenance tasks shall be classified in tiers to assign the level of skill or maintenance visit required. It is a goal that site-based maintenance be limited to lower levels, with high-skill work generally performed at the Repair Center by specialized staff and equipment under a higher degree of environmental and process control.	STK5005 Maintenance Concept		Inspection
260	SYS3202	Optimization for Maintenance	Tools shall be provided for the organization of the maintenance and repair teams in order to maximize the efficiency of time spent on antenna visits and repair of equipment.	STK5005 Maintenance Concept STK5003 Maintenance Scheduling Tools		Demonstration
261	SYS3203	Criteria for Scheduling Maintenance	Tools shall be provided for the automation of preventive and corrective maintenance scheduling, based on a combination of the severity of existing issues, required preventive maintenance, and predictions of pending problems.	STK5005 Maintenance Concept		Inspection
262	SYS3204	Use of Failure Analysis in Spares Planning	Failure analysis shall be used in the planning of spares inventory. Factors considered shall include the projected availability for spares, the time required to repair the failure, and viability of critical vendors.	STK5005 Maintenance Concept		Analysis
263	SYS3205	Reporting of Failures and Anomalies	The system shall permit the reporting of failures and anomalies to operators, data analysts, post-processing pipelines, and users. These reports, along with those generated by automated means, shall be tracked in an issue tracking system with a corresponding database.	STK5005 Maintenance Concept		Demonstration
264	SYS3209	Maintenance Metrics Definition	The operations plan shall detail the specific maintenance metrics to be used in the operations phase, such as mean time to repair, resource utilization, and maintenances costs per antenna. A design baseline for each metric shall be provided in the plan.	STK5005 Maintenance Concept		Inspection
265	SYS3211	Operations and Maintenance: Transfer of Deliverables	All procedures, test equipment, and test software shall be delivered to the Operations and Maintenance staff prior to full operations.			Inspection
266	SYS3220	Provision of Diagnostic Tools	The system shall include interfaces for engineers and technicians to monitor the health of the system and remotely diagnose failures and behavior anomalies.		STK5001 Provision of Diagnostic Tools	Demonstration
267	SYS3221	Provision of Predictive Tools	The system shall include automated tools to predict the location and nature of failures in support of maintenance scheduling.		STK5002 Provision of Predictive Tools	Demonstration
268	SYS3222	Maintenance Scheduling Tools	The maintenance scheduling tool shall include an interface for authorized personnel to reprioritize issues, manipulate the schedule, and ascertain the status of scheduled work.	STK5003 Maintenance Scheduling Tools		Demonstration
269		Logistics Support				
270	SYS3900	Inventory Tracking System	A system shall be provided to electronically track inventory to determine usage rate and location of spare assemblies, component level spares, and consumables.		STK2100 Inventory Tracking System	Demonstration
271	SYS3901	Shipping and Receiving	Each facility shall have central shipping and receiving and be integrated with a shipping system between sites.		STK2102 Shipping and	Inspection

		Logistics			Receiving Logistics	
272	SYS3902	Tracking of LRUs	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.		STK2103 Repair and Tracking of LRUs	Demonstration
273	SYS3903	Observatory-controlled Logistics	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).		STK2105 Observatory-Controlled Logistics	Inspection
274	SYS3904	Packaging Used for Shipping	Shipping cases and packaging shall be provided with ESD protection and mechanical shock absorption consistent with the equipment specifications.		STK2106 Packaging Used for Shipping	Inspection
275	SYS3910	Logistics Tools and Resources	Logistics tools and resources (physical and human) shall be in place to support efficient product flow from suppliers to antenna sites prior to the start of AIV activities.			Inspection
276	SYS3911	Issue Tracking-Tool	Prior to the start of system-level AIV and site deployments, the project shall have in place an issue tracking tool that tracks open action items/punch list for site activities.			Demonstration
277	SYS3912	Packaging - AIV	Packaging for delivered hardware shall ensure the safe storage of equipment in nominal warehouse conditions.			Inspection
278		Support Datastores				
279	SYS3400	System Calibration Database	A System Calibration database shall be provided to store antenna-based calibration parameters such as gain curves and polarization D-terms.	STK1300 Storage and Retrieval of Calibration Coefficients STK9950 Data Provenance	STK1150 System Calibration Database	Inspection
280	SYS3401	Astronomical Calibrator Database	An Astronomical Calibrator database shall be provided to store calibrator flux density histories and image models.	STK9950 Data Provenance	STK9943 Astronomical Calibrator Database	Inspection
281	SYS3402	Monitor Database	A monitor database shall be provided to store system status and history for each monitor point in the array.	STK5002 Provision of Predictive Tools STK9950 Data Provenance		Inspection
282	SYS3403	RFI Database	An RFI database shall be provided to store signal parameters for previously identified interference sources.	STK2602 RFI Mitigation STK9950 Data Provenance		Inspection
283	SYS3404	Quality Control Database	A quality control database shall be provided to record repairs, test data, and associated information on each LRU.	STK1900 Quality Control Database STK9950 Data Provenance		Inspection
284		Security				
285	SYS2703	Security Specification	All designs shall comply with the Level-1 System Security Specification (Doc TBD).			Inspection
286	SYS2704	Physical Security	Physical security and monitoring shall be considered in the array design.	STK2201 Physical Security		Inspection

				Plans			
287		Cybersecurity					
288	SYS2702	IT Security	The data processing, networking, and data archive systems shall be engineered and deployed in accordance with current best practices in IT Security, as defined by the NSF-funded Center for Trustworthy Scientific Infrastructure and the AUI Cyber Security Policy.	STK2202 Cybersecurity			Inspection
289		RFI Mitigation					
290	SYS4100	RFI Flagging	The system shall include flagging and excision algorithms to mitigate the impact of ground-based and orbital RFI present over the ngVLA operating frequency range.	SYS4100 RFI Flagging STK2602 RFI Mitigation			Demonstration
291		Quality Assurance and Quality Control					
292	SYS3700	Quality Control Data Access Tool	A quality control data access tool shall provide an interface to the quality control database for authorized personnel to record repairs, test data, and associated information on each LRU.	STK1900 Quality Control Database			Demonstration
293	SYS3701	Quality Control Data Access Tool Location	The quality control data access tool shall enable authorized personnel to access stored information from any ngVLA location, including antenna sites.	STK1900 Quality Control Database			Inspection
294	SYS3702	Quality Control of Deliverables	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.			STK1902 Quality Control	Inspection
295		Interfaces to External Systems					
296	SYS5900	External eVLBI Elements	It is desirable to provide interfaces to connect up to 10 external eVLBI elements to the real-time ngVLA signal processing system.	STK2501 Facility Integration			Inspection
297	SYS5901	Trigger Subscriptions	The system shall support interfaces to the detection streams from flagship facilities (such as LSST and LIGO) that will generate observation triggers.	SCI0005 Triggered Observations			Demonstration
298		Commensal Data Processing Requirements					
299	SYS5600	Commensal Processing	It is desirable to provide a connection for future commensal processing of visibilities (e.g., transient search) at the native temporal resolution of the observation (prior to any time or frequency averaging).	SCI0013 Time Domain Search Capabilities STK2901 Commensal Back-Ends			Inspection
300	SYS5601	Commensal Voltage Streams	It is desirable to provide interfaces to enable commensal processing of the time-voltage stream from each antenna at the granularity of a digitized sub-band or smaller unit of bandwidth.	STK2901 Commensal Back-Ends			Inspection
301	SYS5602	Commensal Low-Frequency System	It is desirable to provide physical interfaces, data transmission and correlator bandwidth for a future commensal low-frequency (<1 GHz) front end.	STK2900 Commensal Front-Ends			Inspection
302		Configuration Management					
303	SYS3600	Identification by	All configuration items (e.g., all LRUs) shall be uniquely identifiable to facilitate status and location			STK1602	Inspection

		Serial Numbers	tracking across the Observatory.		Identification by Serial Numbers	
304	SYS3601	Configuration Management Tools	The project shall provide configuration management tools for tracking the design versions of construction deliverables throughout the system life cycle.	STK1600 Remote Access of System Configuration	STK1604 Configuration Management Tools	Inspection
305	SYS3602	Version Control for Software and Firmware	All custom software and firmware delivered as part of the system shall be version controlled via a configuration management process.	STK1606 Version Control-Software and Firmware STK1600 Remote Access of System Configuration		Inspection
306	SYS3603	Configuration Retrieval	All configurable LRUs shall retrieve their hardware parameter configuration automatically after replacement, and upon a change in the parameter in the System Calibration database.	STK1600 Remote Access of System Configuration	STK9945 Configuration Retrieval	Demonstration
307		Software Development				
308	SYS2401	SRDP Integration	The ngVLA project should extend and reuse the SRDP Observatory-User interfacing architecture for ngVLA.		STK2500 SRDP Integration	Inspection
309	SYS4200	Open Source Software	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.		STK9947 Open Source Software	Inspection
310	SYS4201	DMS Integration	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.		STK2502 DMS Integration	Inspection
311		Equipment and Vehicles				
312	SYS3207	Maintenance Personnel Transportation: Array Site	A fleet of maintenance and service vehicles shall be provided to enable staff to reach areas of the array requiring maintenance.	STK5004 Provision of Corrective Maintenance Equipment		Inspection
313	SYS3208	Maintenance Personnel Transportation: Maintenance Center	Vehicles shall be provided for daily transportation of staff to the Maintenance Center from the Array Operations and Repair Centers.	STK5004 Provision of Corrective Maintenance Equipment		Inspection
314	SYS3300	Provision of Vehicles and Equipment	Site maintenance vehicles and heavy equipment required for routine operations, preventive maintenance, and corrective maintenance, shall be provided.	STK5004 Provision of Corrective Maintenance Equipment		Inspection
315	SYS3301	Equipment Screening for RFI	Site maintenance vehicles and heavy equipment operating on the Plains of San Agustin shall be screened for RFI emissions.	STK2600 Self-Interference		Demonstration
316	SYS3302	Equipment RFI Standard	Vehicles and Equipment shall not include active emitter systems such as Bluetooth radios or radar that operate in the ngVLA observing bands. Incidental emissions (e.g., radiated emission from spark plugs, engine management systems, etc.) are permitted.	STK2600 Self-Interference		Inspection
317		Data Archive Requirements				

318	SYS0730	Data Delivery via Observatory Archive	Data products shall be delivered to the Principal Investigators through an Internet-accessible Observatory Science Data Archive.		STK1106 Data Delivery via Observatory Archive	Inspection
319	SYS0731	Archive Period	All low-level data products shall be archived for the life of the facility (as defined in SYS2801).	STK1106 Data Delivery via Observatory Archive STK1102 Reprocessing and Automated QA via Archive		Analysis
320	SYS0732	Archive Products - High-Level	All high-level data products, such as calibration tables and image cubes, shall be archived for the life of the facility (as defined in SYS2801).	STK1100 Data Product Types to Archive		Inspection
321	SYS0733	Proprietary Data Rights	The archive shall permit the enforcement of a proprietary period for both low-level and high-level data products, permitting public access only after the proprietary period lapses.	STK1103 Proprietary Period for PI Data		Inspection
322	SYS0734	Archive Batch Reprocessing	The archive shall include an interface for batch re-processing of visibilities and to replace existing low-level and high-level data products.	STK1102 Reprocessing and Automated QA via Archive		Inspection
323	SYS0735	Archive Backup	A full backup (two copies total) of all archived data shall be incorporated into the design. The two copies shall not be collocated/co-managed to reduce the risk of simultaneous failures.	STK1100 Data Product Types to Archive STK1106 Data Delivery via Observatory Archive		Analysis
324	SYS0736	Archive User Reprocessing	The system shall include an interface for users to request limited reprocessing of data within supported Standard Observing Modes.	STK1101 ngVLA Data Archive Functionality: Image selection and download STK1102 Reprocessing and Automated QA via Archive		Demonstration
325	SYS0737	Archive Image Selection	The Archive user interface shall allow users to inspect and select image data for download.		STK1101 ngVLA Data Archive Functionality: Image selection and download	Demonstration
326	SYS0738	Proprietary Period	The proprietary period shall be tunable on a per-class, per-project and per-scan basis.	STK1103 Proprietary Period for PI Data STK1105 Proprietary Period for Legacy Program Data		Inspection
327	SYS0739	Archive Products - Low-Level	All low-level data products, such as visibilities and flagging tables, shall be archived for the life of the facility (as defined in SYS2801).	STK1100 Data Product Types to Archive		Inspection
328	SYS0740	External Data Products	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.		STK1104 User Produced Data Products	Demonstration
329	SYS0743	Proprietary	The proprietary period counter shall start once the data products have undergone any automated or	STK1103		Inspection

		Period Trigger	manual quality inspections and are made available to the principal investigator.	Proprietary Period for PI Data	
330		Data Analysis Requirements			
331	SYS0761	Data Analysis Resources	The system shall provide data analysis resources (both software tools and compute capacity) for users to inspect and analyze the high-level data products from Standard Observing Modes.	STK1201 Software Packages Available to User Community: Data Analysis	Demonstration
332	SYS0762	Data Quality Assurance	The system shall include the analysis tools and interfaces to enable Observatory quality assurance inspections of data products prior to delivery to users.	STK1102 Reprocessing and Automated QA via Archive STK1104 User Produced Data Products STK1200 Operational User Support	Inspection
333		Data Processing Requirements			
334	SYS0750	Data Processing for Standard Observing Modes	For Standard Observing Modes, data processing shall be executed via an automated pipeline that generates the high-level data products (SRDP) for the given mode.	STK0512 Commissioning-Observing Mode SRDP Pipeline	Test
335	SYS0751	Data Processing Resources	The system shall provide data processing resources (both software tools and compute capacity) to generate the high-level data products from Standard Observing Modes.	STK1000 Pipeline Use for Standard Observing Modes STK1202 Software Packages Available to User Community: Data Processing SCI0020 Data Delivery Latency STK0512 Commissioning-Observing Mode SRDP Pipeline STK1001 Computing Resources for Standard Modes: Reprocessing STK1002 Computing Resources for Standard Modes	Analysis
336	SYS0752	Throughput & Latency	The data processing capacity for high-level data products shall be designed for 1.2 times the expected average system throughput (defined in the Expected Observing Program), with no additional constraint on latency. The additional 20% is allocated to expected data reprocessing.	STK1001 Computing Resources for Standard Modes: Reprocessing STK1002 Computing Resources for Standard Modes STK1004 Support for Legacy Programs	Analysis

337	SYS0753	Heterogeneous Arrays	The data processing system shall support data reduction from heterogeneous arrays.	STK1002 Computing Resources for Standard Modes	SYS1304 Integration Time Ratios		Demonstration
338	SYS0754	Processing Triggers	The system shall provide a mechanism to trigger the immediate processing of an observation.	SCI0020 Data Delivery Latency			Demonstration
339	SYS0755	Processing Priorities	The system shall provide a mechanism to set differing processing priorities for the SRDPs associated with a project.	SCI0020 Data Delivery Latency			Inspection
340	SYS0756	Processing in Place	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.			STK1005 Data Delivery: Process in Place	Inspection
341	SYS0757	Support for Legacy Programs	The system shall include interfaces to support generating SRDPs 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.			STK1004 Support for Legacy Programs	Inspection
342	SYS0760	Interactive Processing	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.			STK0523 Data Access-Visibility Data	Inspection
343		Documentation Requirements					
344	SYS6001	As-Built Drawings	As-built drawings shall be provided for all custom hardware and facilities delivered as part of the system.	STK0435 Project Documentation			Inspection
345	SYS6002	Operations and Maintenance Manuals	Operations and Maintenance Manuals shall be provided for each LRU in the system.	STK0435 Project Documentation			Inspection
346	SYS6003	Units	Design materials and documentation shall use ISO standards and SI (metric) units. Imperial units may also be shown for clarity.	STK0435 Project Documentation			Inspection
347	SYS6004	Language	The language used for written documentation shall be English.	STK0435 Project Documentation			Inspection
348	SYS6005	Electronic Document Format	Documents and drawings of record shall be delivered in PDF. Native, editable file formats shall also be delivered.	STK0435 Project Documentation			Inspection
349		Array Infrastructure					
350	SYS4000	Grassland Impact	The design and construction of utility corridors and roads shall minimize the impact on grasslands and water within the Plains of San Agustin.	STK2402 Existing Roads STK2400 Grassland & Water			Analysis
351	SYS4001	Sustainable Roads	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.			STK2401 Roads	Inspection
352	SYS4002	Existing Roads	Existing ranch roads shall be assessed for suitability in both construction and operations. It is a goal to reuse existing roads where possible.			STK2402 Existing Roads	Inspection
353	SYS4003	Fences	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.			STK2403 Fences	Inspection
354	SYS4004	Ranching Impact	The project shall aim to reduce the environmental impact to cattle ranching as well as			STK2404	Analysis

			hunting/outfitting, which are both mainstays of local ranches.			Ranching Impact	
355	SYS4500	Array Core Location	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.			STK2405 Core Site	Inspection
356		Calibration Requirements					
357		Calibration Efficiencies					
358	SYS1061	Calibration Efficiency	Overheads for system calibration shall be minimized, with a goal of 90% of time spent on source for Standard Observing Modes.	SCI0100 Continuum Sensitivity SCI0102 Line Sensitivity SCI0106 Survey Speed STK1403 Calibration Efficiency STK0704 Standard Modes: Observing Strategy	SYS2303 Calibration Automation SYS2304 Self-Calibrating Antenna		Analysis
359	SYS1062	Calibration Parallelization	Any real-time calibration pipelines shall permit parallelization at the antenna or baseline level.	STK1403 Calibration Efficiency	SYS2303 Calibration Automation SYS2304 Self-Calibrating Antenna		Inspection
360	SYS1063	Calibration Recall	The system shall remember prior calibration corrections and apply them if their projected accuracy (given time elapsed) still meets the requirements for a given observation; I.e., a scheduling block need not always include its own calibrators.	STK1403 Calibration Efficiency			Inspection
361	SYS1064	Relative Flux Scale Calibration Efficiency	The system shall permit relative flux scale calibration to 5% precision without the need for tipping scans in Standard (Interferometric) Observing Modes.	STK1403 Calibration Efficiency STK0704 Standard Modes: Observing Strategy			Test
362	SYS1065	Polarization Calibration Efficiency	Polarization calibration shall be achievable with a single observation of a compact polarized source of unknown polarization angle for Standard (Interferometric Continuum) Observing Modes.	STK1403 Calibration Efficiency STK0704 Standard Modes: Observing Strategy			Inspection
363	SYS1066	Bandpass Calibration Efficiency	The system gain stability shall permit application of cataloged bandpass solutions for Standard (Interferometric Continuum) Observing Modes.	STK1403 Calibration Efficiency STK0704 Standard Modes: Observing Strategy			Test
364	SYS1067	Gain Calibration Efficiency	System gain calibration shall be achieved with no more than a 2% degradation in system sensitivity as a function of clock time for standard interferometric continuum modes.	STK1403 Calibration Efficiency			Analysis
365	SYS1068	Phase Calibration Efficiency	Phase calibration overheads shall not exceed 100% of on-source time for observations at 116 GHz when operating in the precision operating conditions. It is a goal to reduce tropospheric and electronic phase calibration overheads to less than 10% of on-source time, consistent with SYS1061.	STK1403 Calibration Efficiency			Analysis
366	SYS1069	Calibration Automation	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			STK1301 Automated Re-	Inspection

			Observatory function.		Measurement of Calibration Coefficients	
367	SYS4301	Standard Observing Mode Calibration	A calibration strategy shall be provided for each standard observing mode.	STK1302 Inclusion of Calibration Pipelines and Supporting Systems STK0704 Standard Modes: Observing Strategy		Analysis
368	SYS4302	Calibration of Triggered Observations	The system shall include the capability to perform rapid and automated calibration, based on previously obtained and archived system calibration parameters, to support triggered observations.	SCI0005 Triggered Observations		Analysis
369	SYS4310	Real Time Atmospheric Delay Calibration	The system shall use contemporaneous cross-correlation visibilities to correct for both electronic and tropospheric delay and amplitude errors (i.e., complex gain errors) in phased array or interferometric functional operating modes in near real time.	SCI0007 Phased Array Capability		Test
370	SYS4320	Standard Calibration Automation	Post-processing calibration for standard observing modes shall be automated via a pipeline.	STK1301 Automated Re-Measurement of Calibration Coefficients STK1302 Inclusion of Calibration Pipelines and Supporting Systems		Demonstration
371	SYS4330	Storage and Retrieval of Calibration Parameters	Parameters for standard observing modes determined by calibration (such as bandpasses and delays) shall be stored in a calibration database and automatically retrieved and applied.	STK1300 Storage and Retrieval of Calibration Coefficients		Inspection
372	SYS4331	Automated Re-Measurement of Parameters	It shall be possible to measure system calibration parameters with both automated and operator-triggered tools, using either the full array or a subarray.	SYS4330 Storage and Retrieval of Calibration Parameters STK1301 Automated Re-Measurement of Calibration Coefficients		Inspection
373		Solar Operating Mode Functional Requirements				
374	SYS5800	Direct Solar Observations	The system shall be capable of safely and directly observing the sun at all frequencies, without the risk of equipment damage.	SCI0016 Solar Observation Capabilities		Analysis
375		TP Operating Mode Functional Requirements				
376	SYS4401	Flux Scale	The autocorrelation products provided in the Total Power Operating Mode shall be linked to a system-provided calibrated flux density reference.	SCI0104 Largest Recoverable Scale SCI0110 Photometric Error		Demonstration
377	SYS4402	Autocorrelation Integration Intervals	The system shall have the capability of bracketing and integrating autocorrelation power around a pointing position at flexible time intervals based on on-source status or a trigger signal (such as a noise diode cycle).	SCI0104 Largest Recoverable Scale		Demonstration

378	SYS4403	PSD Differencing	The system shall be capable of automatically differencing the power spectral density of two pointing positions, or system states, to yield a field power spectral density.	SCI0104 Largest Recoverable Scale	Demonstration
379		OTFM Operating Mode Requirements			
380	SYS5700	Variable Slew Rates	The system shall support using the Interferometric Operating Modes at super-sidereal tracking rates.	SCI0004 Mosaics and On-the-Fly Mapping	Analysis
381	SYS5701	Phase Center Update Rates	The system shall permit updating the interferometric phase center at a rate of 10 Hz or faster. Goal of 20 Hz.	SCI0004 Mosaics and On-the-Fly Mapping	Test

L1 EMC/RFI Requirements - RVTM

<table>
<tr><th>#</th><th>Id</th><th>Name</th><th>Text</th><th>Derived From</th><th>Refines</th><th>Verify Method</th></tr>
<tr><td>1</td><td>EMC0310</td><td>Spurious Signal Level</td><td>Not to exceed the equivalent isotropic radiated power limits in Table 1.

<table><tr><th>Freq (GHz)</th><th>1</th><th>2</th><th>4</th><th>6</th><th>8</th><th>10</th><th>20</th><th>30</th></tr><tr><td>F_h (w/m^2)</td><td>1.5E-19</td><td>1.1E-18</td><td>8.9E-18</td><td>2.9E-17</td><td>6.3E-17</td><td>1.2E-16</td><td>1.2E-15</td><td>4.3E-15</td></tr><tr><td>$EIRP_h$ (W)</td><td>1.9E-16</td><td>1.4E-15</td><td>1.1E-14</td><td>3.7E-14</td><td>7.9E-14</td><td>1.5E-13</td><td>1.6E-12</td><td>5.4E-12</td></tr><tr><td>$EIRP_h$ (dBm)</td><td>-127</td><td>-119</td><td>-110</td><td>-104</td><td>-101</td><td>-98</td><td>-88</td><td>-83</td></tr></table></td><td>SCI0116 Spurious Spectral Features
STK2600 Self-Interference</td><td>SYS2104 Self-Generated Spurious Signal Power Level</td><td>Test</td></tr>
<tr><td>2</td><td>EMC0320</td><td>Drive System Shielding</td><td>All motor leads, both power and control, shall be filtered.</td><td>STK2600 Self-Interference</td><td>SYS2104 Self-Generated Spurious Signal Power Level</td><td>Inspection</td></tr>
<tr><td>3</td><td>EMC0321</td><td>Relay Contact Arcing</td><td>All relay contacts and actuators shall be properly bypassed with snubber circuits, shielded, and/or filtered.</td><td>STK2600 Self-Interference</td><td>SYS2104 Self-Generated Spurious Signal Power Level</td><td>Inspection</td></tr>
<tr><td>4</td><td>EMC0322</td><td>Amplifiers & Oscillators</td><td>All amplifiers and oscillators shall be mounted in shielded enclosures that will provide effective shielding of radio frequency energy.</td><td>STK2600 Self-Interference</td><td>SYS2104 Self-Generated Spurious Signal Power Level</td><td>Test</td></tr>
<tr><td>5</td><td>EMC0323</td><td>Silicone Controlled Rectifiers</td><td>Silicon-controlled rectifier switching devices shall not be used unless phase controlled and zero current crossing switching techniques are used.</td><td>STK2600 Self-Interference</td><td>SYS2104 Self-Generated Spurious Signal Power Level</td><td>Inspection</td></tr>
<tr><td>6</td><td>EMC0324</td><td>Gaseous Discharge Devices</td><td>No gaseous discharge devices, except noise sources for test and calibration, shall be employed.</td><td>STK2600 Self-Interference</td><td>SYS2104 Self-Generated Spurious Signal Power Level</td><td>Inspection</td></tr>
<tr><td>7</td><td>EMC0325</td><td>Static Discharge Mitigation</td><td>Means shall be employed to reduce static electricity and the consequent radio frequency noise generated in any rotating machinery.</td><td>STK2600 Self-Interference</td><td>SYS2104 Self-Generated Spurious Signal Power Level</td><td>Inspection</td></tr>
<tr><td>8</td><td>EMC0326</td><td>Display Shielding</td><td>All displays (LCD, plasma, LED, CRT) shall have a RFI shield in front of the display to avoid radiated RFI. This requirement may be waived if the screen is powered off during typical operation and is used for maintenance purposes only. It must be possible to monitor and turn off such emitting devices remotely (via M&C System).</td><td>STK2600 Self-Interference</td><td>SYS2104 Self-Generated Spurious Signal Power Level</td><td>Test</td></tr>
<tr><td>9</td><td>EMC0327</td><td>Digital Equipment Shielding</td><td>All digital equipment, whether a simple logic circuit, embedded CPU, or rack mounted PC shall be shielded and have its AC power line and communication line(s) filtered at the chassis.</td><td>STK2600 Self-Interference</td><td>SYS2104 Self-Generated Spurious Signal Power Level</td><td>Test</td></tr>
<tr><td>10</td><td>EMC0328</td><td>EMC Test Frequencies</td><td>The frequency range to be covered by these design measures for radiated radio-frequency interference (RFI) suppression shall extend from 50 MHz up to 12 GHz. Demonstration of EMC above 12 GHz is not required because mitigation at 12 GHz and below is expected to be adequate at higher frequencies. An exception is made for the fundamental and harmonic frequencies of LO signals, which shall be tested up to 40 GHz.</td><td>STK2600 Self-Interference</td><td>SYS2104 Self-Generated Spurious Signal Power Level</td><td>Inspection</td></tr>
</table>

L1 Environmental Requirements - RVTM

#	Id	Name	Text	Derived From	Verify Method
1		Precision Operating Conditions			
2	ENV0311	Solar Thermal Load	Nighttime only; no solar thermal load within last 2 hours.	STK1402 Observational Efficiency STK1403 Calibration Efficiency	Analysis
3	ENV0312	Wind Speed	0 ≤ W ≤ 5 m/s average over 10 mins. 7 m/s peak gusts.	STK1402 Observational Efficiency STK1403 Calibration Efficiency	Analysis
4	ENV0313	Temperature	−15 C ≤ T ≤ 25 C	STK1402 Observational Efficiency STK1403 Calibration Efficiency	Analysis
5	ENV0314	Temperature Rate of Change	1.8°C/Hr.	STK1402 Observational Efficiency STK1403 Calibration Efficiency	Analysis
6	ENV0315	Precipitation	No precipitation.	STK1402 Observational Efficiency STK1403 Calibration Efficiency	Analysis
7		Normal Operating Conditions			
8	ENV0321	Solar Thermal Load	Exposed to full sun, 1200W/m^2.	STK1402 Observational Efficiency STK1403 Calibration Efficiency	Analysis
9	ENV0322	Wind Speed	W ≤ 7 m/s average over 10 mins. 10 m/s peak gusts.	STK1402 Observational Efficiency STK1403 Calibration Efficiency	Analysis
10	ENV0323	Temperature	−15 C ≤ T ≤ 35 C	STK1402 Observational Efficiency STK1403 Calibration Efficiency	Analysis
11	ENV0324	Temperature Rate of Change	3.6°C/Hr.	STK1402 Observational Efficiency STK1403 Calibration Efficiency	Analysis
12	ENV0325	Precipitation	No precipitation.	STK1402 Observational Efficiency STK1403 Calibration Efficiency	Analysis

13		Limits to Operating Conditions			
14	ENV0330	Solar Thermal Load	Exposed to full sun, 1200W/m^2	STK1402 Observational Efficiency	Analysis
15	ENV0331	Wind	W ≤15 m/s average over 10 mins W ≤20 m/s gust	STK1402 Observational Efficiency	Analysis
16	ENV0332	Temperature	−20 C ≤ T ≤ 45 C	STK1402 Observational Efficiency	Analysis
17	ENV0333	Precipitation	5 cm/hr over 10 mins	STK1402 Observational Efficiency	Analysis
18	ENV0334	Ice	No ice accumulation on structure.	STK1402 Observational Efficiency	Analysis
19		Survival Conditions			
20	ENV0341	Wind	0 m/s ≤ W ≤ 50 m/s average	STK0304 Projected Environment	Analysis
21	ENV0342	Temperature	−30 C ≤ T ≤ 50 C	STK0304 Projected Environment	Analysis
22	ENV0343	Radial Ice	2.5 cm	STK0304 Projected Environment	Analysis
23	ENV0344	Rain Rate	16 cm/hr over 10 mins	STK0304 Projected Environment	Test
24	ENV0345	Snow Load, Antenna	25 cm	STK0304 Projected Environment	Analysis
25	ENV0346	Snow Load, Equipment & Bldgs	100 kg/m^2 on horizontal surfaces	STK0304 Projected Environment	Analysis
26	ENV0347	Hail Stones	2.0 cm	STK0304 Projected Environment	Test
27	ENV0348	Antenna Orientation	Stow-survival, as defined by antenna designer	STK0304 Projected Environment	Inspection
28		Site Elevation			
29	ENV0351	Altitude Range	All system elements shall be designed for operation and survival at altitudes ranging from sea level to 2500m.	STK0304 Projected Environment	Inspection
30		Lightning			
31	ENV0511	Lightning Protection, Structure	The antenna, buildings, and housed equipment shall be protected from both direct and nearby lightning strikes, achieving Protection Level 1 as defined in IEC 62305-1/3.	STK0304 Projected Environment	Inspection
32	ENV0512	Lightning Protection, Electronics Systems	The building and antenna electrical and electronics systems shall be protected against Lightning Electromagnetic Impulse (LEMP) in accordance with IEC 62305-4.	STK0304 Projected Environment	Inspection
33	ENV0513	Lightning Protection, Personnel	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.	SAF0032 Follow mitigation order of precedence	Inspection
34		Seismic			

35	ENV0521	Seismic Protection	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.	STK0304 Projected Environment	Analysis
36		Vibration			
37	ENV0531	Wind Vibration	Exposed equipment, including all equipment within the antenna, shall be designed to withstand persistent wind-induced vibration.	STK0304 Projected Environment	Inspection
38	ENV0532	Transport Vibration	All line-replaceable units shall be designed to withstand transportation vibration.	STK0304 Projected Environment	Inspection
39		Dust			
40	ENV0541	Equipment Protection	Exposed equipment shall be protected against windblown dust, ashes, and grit.	STK0304 Projected Environment	Inspection
41	ENV0542	Building Protection	Building envelopes shall be tight enough to mitigate penetration of dust. All air circulation penetrations shall be filtered.	STK0304 Projected Environment	Inspection
42		Fauna			
43	ENV0551	Rodent Protection	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.	STK0304 Projected Environment	Inspection
44	ENV0552	Large Mammal Protection	Exposed equipment shall be protected against damage by large mammals such as cattle.	STK0304 Projected Environment	Inspection
45		Solar Radiation			
46	ENV0561	Maximum Solar Flux	All equipment exposed to outside environment shall be designed for a maximum diurnal solar flux of 1200 W/m2 from 0.3–60 µm.	STK0304 Projected Environment	Test
47	ENV0562	Maximum UV Radiation	All equipment exposed to outside environment shall be designed for a maximum diurnal UV radiated flux of 100 W/m2 from 280–400 nm.	STK0304 Projected Environment	Test
48		Rain/Water Infiltration			
49	ENV0571	Rain/Water Infiltration	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.	STK0304 Projected Environment	Test
50		Mechanical Shock			
51	ENV0581	Transportation Environment	Equipment shall be designed to withstand typical loads and environments encountered during transportation as part of assembly or maintenance.	STK0304 Projected Environment	Inspection
52	ENV0582	Mechanical	Equipment shall be designed to survive mechanical shock levels from handling as defined in Table 1.	STK0304 Projected Environment	Inspection

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