The Long Wavelength Array System
Technical Requirements

Version: Draft #10

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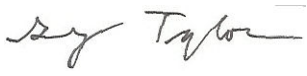
Approval:

G. Taylor, Co-PI: 

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Change Record:

Version	Date	Affected Section(s)	Ref	Remarks
Draft #1	2007-07-25	Original version		
Draft #2	2007-08-21	Re-write		Bring more in line with **[4],** other documents
Draft #3	2007-08-27	All	e-mail 2007-08-23	Incorporate SE's comments
Draft #4	2007-10-10	Table	Sys Arch	Added 2 tunings
Draft #5	2007-10-16	All	e-mail 2007-10-12, Sta Arch V0.6, Sci Reqm Oct 11	Incorporate SE's comments; reference new versions of Sci Reqm, Sta Arch.
Draft #6	2007-11-6	All		Respond to Review comments by Ellingson
Draft #7	2007-11-10	Table 1, 2	SRD V2.1, 8 Nov '07	Requirements modified.
Draft #8	2007-11-14	Table 2	SRD V2.2, 13 Nove '07	No. beams changed
Draft #9	2007-11-19	All	e-mails	Incorporate comments from Ellingson and Taylor
Draft #10	2009-02-24	Table 1 (TR5A, 5B 10B, 11B, 13B, 14D1, 14E, 14F, 14G, 16A, 16B, 18A, 20, 22, 24B, 24C, 25); Table 2 (EN1C, 4A); Table 3 (PA8B); Table 4	Station Architecture; ECN 01, 02, 03, 04; EN004; LWA Memos 121 & 150; LWA Engineering Memo STD0004B	Incorporate post-SRR ECNs and other memos

1. Purpose and Scope

This document lists the technical, environmental, and product assurance requirements necessary for the LWA to perform the required science. The intent is for the system requirements to flow down from the scientific requirements **[1]** where ever possible, so that changes and shortfalls in meeting system requirements can be traced to a specific scientific requirement and the impact on science then assessed. In turn, the system requirements flow down to individual product specifications. The LWA Project is described in the LWA Overview **[2]**, and the Station Architecture document **[3,7].**

Requirements are to be verified using inspection, analysis, test, or simulation during the design phase where possible, and during science commissioning where necessary. Where requirements are not met, Waivers (RFW) may be requested during the design phase and Deviations may be requested (RFD) during the verification and acceptance procedures. Temporary RFWs and RFDs are anticipated during the LWA-1+ pre-production construction phase. Verification of requirements and RFW and RFD procedures are described in the Product Assurance Requirements, Chapter 11 **[4]**.

Acronyms

BW	Bandwidth (frequency)
DR	Dynamic Range
EMC	Electromagnetic Compatibility
FOV	Field of View
G.N.D.	Galactic Noise Dominance
LAS	Largest Angular Scale
LWA	Long Wavelength Array
LWA-N	LWA station; e.g., LWA-1 is Station No. 1
LWA-1+	Initial pre-production construction phase consisting of LWA-1 plus portions of LWA-2 and LWA-3
LWIA-9	Long Wavelength Intermediate Array with 9 antennas (min for calibration)
LWIA-16	Long Wavelength Intermediate Array with 16 antennas (core)
MCS	Monitor and Control System
ns	nanosecond
RFI	Radio Frequency Interference
RFD	Request for Deviation
RWD	Request for Waiver
TBC	To Be Confirmed
TBD	To Be Determined
Z	Zenith angle; i.e., angle measured from zenith

1.2 Definitions

• **Science Requirements**: Physical metrics such as # of beams, bandwidth, time-frequency resolution, etc. that must be achieved to meet science goals
• **Calibration Requirements:** Physical metrics to meet calibration goals.
• **Operations Requirements:** Physical metrics to meet operations goals
• **Technical Requirements**: Architecture- & design-independent engineering metrics such as station dimensions, receiver temperature, dynamic range, etc. that are needed to meet:
  – Science requirements
  – Calibration requirements
  – Operations requirements
  – "Best practice" engineering requirements (e.g., environmentals)
  – Program requirements; e.g., cost, timeframe, other resource constraints
• **Specifications**: Technical requirements further constrained initially by a choice of architecture, and ultimately by performance/cost studies.

1.3 Requirements numbering

Requirements are given an alphanumeric ID to aid tracking to parent and subordinate requirements. The form is XX-N-R where

- XX designates the type of requirement (TR is "technical requirement", PA is "product assurance", and EN is "environmental"),

- N is an alphanumeric identifier consisting of a serial number and, in some cases, a letter where a requirement has multiple parts, and

- R designates revision level. All requirements start at revision level A; revision letters are A understood in this document and not shown.

2. System Technical Requirements (Table 1)

Number	Requirement	Value (for [ν_{min}, ν_{max}] when stated)	Science Requirement [1]	Construction Phase Impacted[1]
TR-1A	Min Frequency Range[2], ν_l	20 MHz Required 3 MHz Desired	**[1]** **[1]**	all
TR-1B	Max Frequency Range[2], ν_u	80 MHz Required 88 MHz Desired	**[1]**	all
TR-2	Instantaneous BW per beam, $\Delta\nu_{max}$	8 MHz Required 50 MHz Desired	**[1]**	I
		50 MHz Required for Solar Beam in core stations	**[1]**	II, III
		8 MHz Required >50 MHz Desired	**[1]**	II, III
TR-3	Minimum channel width, $\Delta\nu_{min}$	$\leq$ 100 Hz Required 10 Hz Desired	**[1]**	all
TR-4	Angular Resolution @ 80 MHz, θ	Not applicable to single station	If outriggers can be used, then $\leq$16" is desired to reduce confusion.	I
		TBC (See Table 4)	**[1]**	II
		$\leq$2" Required $\leq$1" Desired	**[1]**	III
TR-5A	Minimum Temporal Resolution, narrowband, $\Delta\tau_N$[3]	0.1 ms Required < 0.1 ms Desired	**[1]**; driven by pulsar observations	all

[1] Construction phases currently include I: LWA-1+ (LWA-1 plus optional outriggers), II: LWIA-9 and LWIA-16, and III: the full LWA

[2] Domain Requirements **[3]**. These are requirements which say over what domain other requirements must be enforced. For LWA the domains are time, frequency, and space, where space implies pointing direction.

TR-5B	Minimum Temporal Resolution, wideband, $\Delta\tau_W$[4]	13 nsec	**[7]**; Inverse of 78 MHz max BW from TBW	all
TR-6	Primary Beam HPBW, PBW @ 80 MHz	2^o Required $\geq 2^o$ Desired	**[1]**	all
TR-7	Largest Angular Scale, LAS @ 80 MHz	TBC (see Table 4)	**[1]**	II
		1^o Required 2^o Desired	**[1]**	III
TR-8A	Longest Baseline	TBC (see Table 4)	**[1]**	II
		400 km Required 600 km Desired	**[1]**	III
TR-8B	Shortest Baseline	TBC (see Table 4)	**[1]**	II
		200 m Required 100 m Desired	**[1]**	III
TR-9	Sensitivity[4], σ	25 mJy Required	**[1]**	I
		TBC (See Table 4)	**[1]**	II
		1 mJy Required $\leq$1 mJy Desired	**[1]**	III
TR-10A	T_{SYS}	Some degree of galactic noise dominance (GND) required; $\geq$ 6 dB below GND required	**[1], [7], [5]**	I
		$\geq$ 6 dB below GND required $\geq$10 dB below GND desired	**[7]**; 3.2, **[5]**	II, III
TR-10B	Dipole sidelobe performance	Sidelobes < 15 dB	Needed for dynamic range	all
TR-11A	Polarization	Dual circular for each tuning[5]	**[1]**	all
TR-11B	Polarization isolation	$\geq$10 dB Required $\geq$20 dB Desired	**[1]**	all

[3] Wideband and Narrowband are explained in **[7]**, 4.5.1 & 4.5.2, but basically data taking is halted with Wideband while data are readout, while Narrowband runs continuously albeit at less bandwidth.
[4] See Science Requirements for more detail
[5] See TR-13B

TR-11C	Dipoles per stand	Two	Implied by polarization requirement	all
TR-12	Zenith Angle Coverage[6], Z	$\leq 74^o$ required $\leq 80^o$ desired	**[1],** section 4.1.3	all
TR-13A	Simultaneous fully independent spatial and frequency beams	3 Required	**[1]**, **[8]**	I
		4[7] Required $\geq$7 Desired	**[1], [8]**	II&III
TR-13B	Frequency tunings per beam, N_t	2 Required	**[8]**	all
TR-14A	Configuration	2D array	**[1]**	all
TR-14B	Geometry	1 station + 2 partially-populated "outriggers"	**[1]**	I
		9 – 16 stations		II
		53 stations Required >53 stations Desired	**[1]**	III
TR-14D	Number of stands per station, N_a	$\geq$ 256	Calibrate-ability **[3, 6]**, 2.2	all
TR-14D1	Number of stands in LWA-1+ "outriggers"	4 Required 128 Desired	Primarily dependent on budget	I

[6] The goal of this requirement is to be sure that we can do some science at low zenith angles. We realize that there will be reduced sensitivity at such large angles from zenith but that can be compensated for by longer integration times where appropriate.
[7] Fourth beam is wide-bandwidth solar beam; only required in core stations.

TR-14E	Station dimensions	Elliptical, 140 m major axis, 120 m minor axis, so that array is 120 m x 100 m and fence standoff is 10 m. A station footprint of 120m x 120m is accepted for 'current' sites VL, NA, HS, HM, and MA, with a fence standoff distance of 5 m (maximum array size of 110m x 100m)	Constrained by TR-6, **[3]**, 2.2	all
TR-14F	Stand layout	Minimize maximum sidelobe over sky	**[3]**, **[9]**	all
TR-14G	Dipole alignment	Perpendicular within 10^o and one aligned to true north within 10^o	Support polarization requirement and beam pointing; **[10]**	all
TR-15	Lifetime	Maintainability for ≥ 15 years	**[1]**, **[4]**, Chapter 5 & 7	all
TR-16A	Operations	User friendly, open	**[1]**	all
TR-16B	Automatic Recovery	System will recover from power fluctuations without operator intervention		all
TR-17	(Reserved)			
TR-18A	Time base	Accurate to within 50 nsec of UTC	To support Δt and real time sync at station; **[3]**, **[5]**	all
TR-19	Max integration time[2]	8 h	Implied by sensitivity requirement	all
TR-20	Rapid Mode switching	2 sec	$T_{O,setup}$ in **[11]**	all
TR-21	Monitor & Control	Remote operation, diagnosis	**[3]**, 6	all

TR-22	Data Aggregation and Communication	576 Mbps for data, ≥ 48 kbps bidirectional for MCS, all on single fiber.	**[3]**, **[7]**, **[8]**	I
		1.92 Gbps for data, ≥ 48 kbps bidirectional for MCS, all on single fiber.	**[3]**, **[7]**, **[8]**	II, III
TR-23	Calibration, ionosphere	Remove refractive effects of ionosphere for aperture synthesis imaging	**[3]**, 9.1	II, III
TR-24A	RFI mitigation	Ability to observe in presence of RFI	**[3]**, 9.3; **[4]**, Chapter 5.	all
TR-24B	Linearity	IP1dB > -39 dBm IIP3 > -22 dBm	**[12]**	I
		Electronics to be linear in presence of strong RFI		II&III
TR-24C	Electromagnetic Compatibility	RF from LWA electronics or cable system not to interfere with EVLA or cause self-interference	**[4]**	all
TR-25	Observing Modes	Described in **[1]**	**[1]**	all

3. System Environmental Requirements (Table 2).[8]

EN-1A	Outside Temperature	Equipment exposed to weather shall operate normally in temperatures of -20 F to 110 F with daily temperature swings as high as 55 F	**[4]** Chapter 9	all
EN-1B	Temperature survival	Survive temperatures from -50 F to 122 F.	**[4]** Chapter 9	all
EN-1C	Inside Temperature change	Inside temperature shall be maintained at a setpoint +/– 5F	**[4]** Chapter 9	all
EN-1D	Inside Temperature	Set point shall be adjustable from 65 F to 75 F	**[4]** Chapter 9	all
EN-2A	Precipitation	Equipment exposed to the weather shall survive without damage: Rain falling at the rate of up to 6"/hr; A single rainfall of up to 2"; A snowfall of up to 2'; Hail up to 1 cm in diameter; Ice loading of up to 1" followed by a 35 mph wind.	**[4]** Chapter 9	all
EN-2B	Precipitation drainage	Site drainage shall provide for a 2" rain over a 20 minute period	**[4]** Chapter 9	all

[8] From **[4]**, Chapter 9

EN-3A	Relative humidity outside	Equipment exposed to the weather shall operate normally in RH of 10% to 90%	**[4]** Chapter 9	all
EN-3B	Relative humidity survival	Survive RH of 5% to 99%.	**[4]** Chapter 9	all
EN-3C	Relative humidity inside	Not permitted to fall below 20% in shelter	**[4]** Chapter 9	all
EN-4A	Wind	All structures at LWA shall be designed according to the requirements of the publication ASCE 7-05 of the American Society of Civil Engineers, "Minimum Design Loads for Buildings and Other Structures", using 90 MPH nominal design 3-second gust wind speeds at 33 ft above ground Exposure C category.	**[4]** Chapter 9	all
EN-4B	Wind erosion	Structures shall be protected from wind erosion.	**[4]** Chapter 9	all
EN-5	Dust	The shelter shall reduce the particulate count to <200,000 particles per cubic foot of a size 0.5 micron and larger, or 1000 particles per cubic foot of a size 5.0 micron and larger.	**[4]** Chapter 9	all
EN-6	Solar UV	Equipment exposed to solar radiation shall be selected that have a lifetime of 15 years.	**[4]** Chapter 9	all

EN-7A	Fauna	The LWA site shall be protected by a fence selected to defend against cattle and antelope, with at least one 12' metal and hinged gate. Outside cables shall be protected by plastic conduit. Conduit entries shall be sealed. Crawl spaces, crevices, voids shall be avoided. Where unpreventable, ingress shall be blocked by screens or gnaw-resistant materials to keep out insects and bats. There shall be no overhangs on the shelter or other buildings.	**[4]** Chapter 9	all
EN-7B	Fauna	The outside structures shall survive without damage the alighting of a 4 lb bird.	**[4]** Chapter 9	all
EN-8	Flora	Spiny plants that can cause injury shall be cleared from walkways.	**[4]** Chapter 9	all
EN-9	Seismology	LWA equipment shall survive without damage horizontal and vertical accelerations to be expected in a magnitude 3.5 earthquake as rated by USGS.	**[4]** Chapter 9	all
EN-10	Lightning	Equipment shall be protected IAW NFPA 760 or other more stringent standard	**[4]** Chapter 9	all

EN-11	Environment	Select equipment for power efficiency	**[4]** Chapter 9	all

4. System Product Assurance Requirements (Table 3)[9]

PA-1	PA program	The project shall conduct a Product Assurance Program	**[4]** Chapter 1	all
PA-2	Documentation	LWA documentation shall be sufficient to facilitate understanding, procurement, qualification, maintenance (to include repair), operation, revision, and even duplication of the design at a later date, if necessary.	**[4]** Chapter 2	all
PA-3	Configuration Management	LWA products shall be uniquely identified and labeled	**[4]** Chapter 3	all
PA-4	Pre-production reviews	An SSR, PDR, and CDR shall be conducted for each construction phase	**[4]** Chapter 4	all
PA-5	Design practice	Good design and workmanship practice as defined in various industry standards	**[4]** Chapter 5	all
PA-6	Electrostatic Discharge protection	Work places shall establish ESD procedures, as necessary	**[4]** Chapter 5	all
PA-7	Interface Control Documents	ICDs shall define interfaces between products as required by System Engineer	**[4]** Chapter 6	all

[9] Since LWA-1+ is a pre-production construction phase, PA requirements may need to be modified; see Overview section of Product Assurance document **[4].**

PA-8A	Reliability	Maximize reliability through design, workmanship, inspection, calibration, maintainability	**[4]** Chapter 7	all
PA-8B	MTBF	Requirements suggested in **[4]**	[4]	all
PA-9	Manufacturing procedures	Adequate reviews, SoWs, specifications shall be prepared	**[4]** Chapter 10	all
PA-10	Verification and acceptance	All requirements are to be verified. Each unit to be accepted	**[4]** Chapter 11	all
PA-11	Shipping and storage	All equipment to be designed to survive shipping and storage requirements	**[4]** Chapter 12	all
PA-12	Safety	Safety hazards to be minimized and those remaining identified	**[4]** Chapter 13	all
PA-13	Equipment safety	Shelter shall self-protect: Power shall be shut off in the event of fire or HVAC failure independent of computer software, and remote notification provided	**[4]** Chapter 13 and 8	all

5. System Requirements to be Determined or Confirmed (Table 4)[10]

TR-4	Angular Resolution, θ	~5 arcseconds at 80 MHz (TBC)	(Scales) Relates to site acquisition	II
TR-7	Largest Angular Scale, LAS	~5 arcminutes at 80 MHz (TBC)		II
TR-8A	Longest Baseline	180 km (TBC)	Relates to site acquisition	II
TR-8B	Shortest Baseline	1 km (TBC)	Relates to site acquisition	II
TR-9	Sensitivity per beam, σ	~20 mJy/beam (80 MHz, t = 1 minute, BW = 4 MHz) (TBC)	(Scales)	II
TR-14C	uv coverage	"good", details TBD	2D array	II, III
TR-18B	VLBI time base	Upgrade for wavefront sync, TBD	**[3]**, **[5]**	III

[10] Any requirement having a "TBD" or "TBC" has been moved to this table for action. Such requirements are for later phases of construction.

4. Acknowledgements

Where the System Technical Requirements are correct and helpful, the credit goes to Steve Ellingson (VT) who has worked tirelessly to define the requirements, architecture, preliminary design, and costs of the LWA. Steve also commented extensively on the preparation of this document. As well, this document would not have been possible without the diligent efforts of Namir Kassim and Tracy Clarke to identify and document the Science Requirements.

5. Reference Documents

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[6] S. Ellingson, System Parameters Affecting LWA Calibration, LWA Memo 52 Redux, 2008-10-11
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