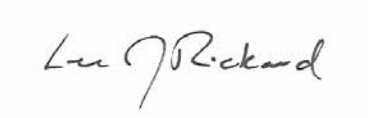
Title	The LWA "Pile of Parts" Cost Model
Original Create Date	August 5, 2006
Latest Revision Date	February 25, 2009
Station Architecture Version	2
Cost Model Version Number	8

Cover Sheet should be signed by:

 Lee J Rickard	Executive Project Director
 Joe Craig	System Engineer

Notes

This spreadsheet contains the cost model for the Long Wavelength Array. The model is derived from the original "A "Pile of Parts" Cost Model for LWA Stations", prepared by Steve Ellingson, and recorded in the LWA Memo Series memo 45 . It contains some of the original information, but has been reformatted to make maintenance easier. Because derived versions of the original cost model contained change information, that information has been captured here for continuity purposes. This model is consistent with the Station Architecture version provided above. As the station architecture changes, the costs should be updated, or the reference should be updated and a note added if no cost changes are anticipated. If additional component architecture documents are added, these should be incorporated and an appropriate version number referenced.

Changes	Called Version	Revision Data	Change	Notes
S. Ellingson		August 5, 2006	Created	
S. Ellingson	1	August 8, 2006	Revised	
S. Ellingson	2	August 11, 2006	Revised	
C. Janes	3	October 10, 2007	Revised	
C. Janes	4	October 18, 2007	Revised	
D. Munton		November 1, 2007	Refactored	No changes to costs, just revised spreadsheet.
D. Munton		November 4, 2007	Revised	Completed changes.
D. Munton		November 4, 2007	Revised	Included new DRX cost breakdown on high side only. Need to include low end estimate. Revised cable costs to remove high end cable costs that now seem unrealistic
C. Janes	5	November 7, 2007	Revised	Revised format for printability; minor corrections
S. Ellingson	6	November 18, 2007	Revised	
J. Craig	7	November 19, 2008	Revised	Changes to FEE
J. Craig	8	February 19, 2009	Revised	Changes accumulating
L. Rickard	8	February 23, 2009	Revised	Corrections to STD, GND, Summary; Addition of spares

Architecture Naming

This sheet contains a list of acronyms used to describe LWA system and subsystem components. Where required, it is consistent with the architecture documents listed on the "Notes and Changes" sheet. Costs associated with items not included in the station architecture are identifed with names provided below.

System	*Subsystem*	*Component*	*Name*
ARR			**Array of antenna stands**
	STD		Single antenna stand
		ANT	Antenna
		FEE	Front end electronics
	RPD		RF & Power Distribution
	GND		Ground Screen
ASP			**Analog Signal Processing**
	ARX		Analog Receiver
	PCD		Power Conditioning and Distribution
	MCS		Monitoring and Control System
	EMD		Electromechanical Design
DP			**Digital Processor**
	DIG		Digitizer
	BFU		Beamforming Unit
	TBW		Transient Buffer - Wideband
	TBN		Transient Buffer - Narrowband
	DRX		Digital Receiver
	PCD		Power Conditioning and Distribution
	MCS		Monitoring and Control System
	EMD		Electromechanical Design
TCD			**Timebase and Clock Distribution**
MCS			**Monitoring and Control System**
DAC			**Data Aggregation and Communications**
SHL			**Shelter**
	SEP		Shelter Entry Panel
	PCD		Power Conditioning and Distribution
	ECS		Environmental Control System
SIT			**Site Preparation**
POW			**Power Supplies**
RAC			**Racks**
LP			**Lightning Protection**
OPS			**Operations**

Cost Summary

This is the spreadsheet summarizing all costs. Except for the number of dipoles, no other numbers should be changed on this sheet. (Note: 3 pages)

Number of Dipoles 512 Total number of dipoles in an LWA station
Number of Stands 256 Total number of stands in an LWA station

Costs for LWAn: These costs incorporate savings for ordering in 'large quantities', i.e., in amounts appropriate for the 16 station LWIA

Details

Summary: LWA-1

Component	Quantity	Unit Cost	Subtotal	% of total	Spares Cost
STD	256	$243	$62,241	9.0%	$7,548
FEE	256	$130	$33,280	4.8%	$6,400
GND	256	$19	$4,849	0.7%	$281
RPD	1	$52,352	$52,352	7.6%	
ARX	512	$141	$72,440	10.5%	$400
DP	512	$487	$249,228	36.0%	
MCS	1	$10,000	$10,000	1.4%	$6,000
MCS-DR	1	$33,500	$33,500	4.8%	
TCD	1	$9,000	$9,000	1.3%	
SHL	1	$85,200	$85,200	12.3%	
PCD	1	$6,800	$6,800	1.0%	
SIT	1	$74,300	$74,300	10.7%	**Total with Spares**
TOTAL			**$693,190**	100.0%	**$20,629** **$713,819**
Cost per stand			$2,708		$2,788

Summary: LWAn, n>3, not applicable to LWA1+

Component	Quantity	Best Guess Unit Cost	Subtotal	% of total
STD	256	$218	$55,841	8.0%
FEE	256	$100	$25,600	3.7%
GND	256	$19	$4,849	0.7%
RPD	1	$52,352	$52,352	7.5%
ARX	512	$141	$72,440	10.4%
DP	512	$487	$249,228	35.7%
DAC	1	$51,775	$51,775	7.4%
TCD	1	$9,000	$9,000	1.3%
MCS	1	$10,000	$10,000	1.4%
PCD	1	$6,800	$6,800	1.0%
SHL	1	$85,200	$85,200	12.2%
SIT	1	$74,300	$74,300	10.7%
TOTAL			**$697,386**	100.0%
Cost per stand			$2,724	

STD

The stand contains two, orthogonal, linearly polarized antenna elements, the mechanical support and the mounting mechanism for the FEE. Current plans call for 256 stands, or 512 dipoles per station.

Cost Summary

LWA1+ Cost/Unit	$243
LWA1+ Cost/Dipole	$122
Large Quantity Cost/Unit	$218
LQ Cost/Dipole	$109

Details

		LWA1				Large Quantities			
Component	***Quantity***	***Unit Cost per Stand***	***Subtotal***	***% of total***	***Spares***	***Unit Cost per Stand***	***Subtotal***	***% of total***	***Justification***
Assembled Antenna Stand	1	$225	$225	92.5	30	$200	$200	91.7	(1), [1]
OzPost	1	$18	$18	7.5	44	$14	$18	8.3	(1), [1]
Total cost			$243		$7,548		$218		

Notes

(1) Assuming Burns Central Mast Tied-Fork approved at PDR

References

[1] Array Subsystem PDR Document

FEE

The FEE is located at the antenna and includes the balun and gain.

Cost Summary

LWA1+ Cost/Unit	$130
LWA1+ Cost/Dipole	$65
Large Quantity Cost/Unit	$100
LQ Cost/Dipole	$50

Details

		Large Quantities				LWA1+			
Component	***Quan.***	***Unit Cost per Stand***	***Subtotal***	***% of total***	***Spares***	***Unit Cost per Stand***	***Subtotal***	***% of total***	***Justification***
Turnkey (Assembly, PCB, Parts), dual-polarization (1)	1	$100	$100	100.0	64	$130	$130	100.0	[1]
Total Cost			**$100**		**$6,400**		**$130**		

Notes

(1) Turnkey (Assembly, PCB, Parts) quoted for station (512) quantity, dual-polarization consists of two assemblies

References

[1] B. Hicks, LWA Engineering Memo FEE0001

RPD									
	The RPD is the subsystem consisting of RF cables from the STD to the SEP. It also includes connectors, conduit if used, and and power distribution cables out to the antennas (if not via the RF cables).								
Cost Summary									
LWA Array Cable Cost	$52,352								
LWA1+ Cost/Dipole	$102.25								
Large Quantity Cost/Unit	N/A								
LQ Cost/Dipole	N/A								
Details									
		Low Cost			**High Cost**				
Component	***Quantity***	***Cost for Unit***	***Subtotal***	***% of total***	***Cost per Unit***	***Subtotal***	***% of total***	***Justification***	
RF Cable	512	47.50	$24,320	46.5	$77.90	$39,885	53.5	(2), [3]	
Connectors (two per cable)	512	4.00	$2,048	3.9	$4.00	$2,048	2.7	[1]	
Conduit and Junctions	512	35.75	$18,304	35.0	35.75	$18,304	24.5	(1), [3], (3)	
Cable Lightning Protection	512	$15	$7,680	14.7	$28	$14,336	19.2	[1], [3]	
Total Cost			**$52,352**			**$74,573**			
Notes									
(1)	Based on UNM Civil Engineering Estimate								
(2)	Assume average length of 95 m per cable run, [1]								
(3)	Cost does not currently reflect cost of assembly, only raw costs of components.								
References									
[1]	Engineering Memo RPD0002								
[2]	Engineering Memo RPD0003								
[3]	RPD PDR Design								

GND

Ground screens for individual stands.

Cost Summary

Cost	$4,849
Cost/Dipole	$9
Cost/Stand	$19

Details

Component	***Quantity***	***Unit Cost***	***Subtotal***	***% of total***	***Spares***	***Justification***
Screen	256	$15	$3,789	78.1%	14	[1]
Splicing sleeves	1536	$0.20	$307	6.3%	164	Assume 6 sleeves per stand
Anchors	2048	$0.37	$753	15.5%	112	Assume 8 anchors per stand
Total			**$4,849**	100.0%	**$281**	

Notes

References

[1] Array PDR doc

ARX

The analog receiver, which begins at end of long cable, ends with digitized bandpass. One required per dipole (2 per stand).

Cost Summary

LWA1+ Cost/Unit	$283
LWA1+ Cost/Dipole	$141
Large Quantities Cost/Unit	$256

Details

		LWA-1				Large Quantities			
		Unit Cost	Sub total	% of total	Spares	Unit Cost	Sub total	% of total	
Components	Quantity								Justification
ARX Turnkey Electronics	512	$50	$25,600	35.3%	8	$40	$20,480	31.3%	(1), [1]
ARX Chassis	4	$1,250	$5,000	6.9%		$800	$3,200	4.9%	[1]
Monitor/Control	1	$1,000	$1,000	1.4%		$1,000	$1,000	1.5%	[1]
ARX to DP cabling & bulkheads	512	$20	$10,240	14.1%		$20	$10,240	15.6%	[1]
SEP to ARX cabling & bulkheads	512	$50	$25,600	35.3%		$50	$25,600	39.1%	[1]
ARX & FEE Power Supplies	2	$2,500	$5,000	6.9%		$2,500	$5,000	7.6%	[1]
TOTAL			**$72,440**	100.0%	**$400**		**$65,520**	100.0%	

Notes

(1) 16 ARX channel PCBs assumed

References

[1] ASP PDR doc

DP								
	Digital Processing							
Cost Summary								
Cost	$249,228							
Cost/Dipole	$487							
Details								
		Component	***Quantity***	***Unit Cost***	***Subtotal***	***% of total***	***Spares***	***Justification***
		DIG	26	$1,800	$46,800	18.8%		(1), [1]
		DP board	28	$6,426	$179,928	72.2%		(2), [1]
		Chassis	2	$7,500	$15,000	6.0%		[1]
		MCS Computer	1	$1,500	$1,500	0.6%		[1]
		Synthesizer	1	$1,500	$1,500	0.6%		[1]
		Network Switch	1	$1,500	$1,500	0.6%		
		Power Supplies	2	$1,500	$3,000	1.2%		
		Total			$249,228			
Notes	(1)	20 ADCs per board						
	(2)	26 DP1 boards & 2 DP2 boards						
References								
	[1]	DP PDR doc						

DAC

Subsystem providing the interface between DP!, DP2, MCS, and the outside world.
Costs here are based on the ETA design for a similar subsystem.

Cost Summary

DAC Total Cost	$51,775
DAC Cost/Dipole	$101

Details

		Actual			
Component	Quantity	Unit Cost	Subtotal	% of total	Justification
EDT boards w/ Cables	5	$1,743	$8,713	16.8	[1], updated pricing information.
Dell SC430 PCs	5	$2,733	$13,663	26.4	Configuration details are important; See [1]
Mark 5 recording unit	1	$25,000	$25,000	48.3	[1]
Disk modules	3	$1,333	$4,000	7.7	[1]; one for the field and one for "home"
Rack for above	1	$400	$400	0.8	Actual cost, from ETA
Total			**$51,775**	100.0	

Notes

(1) See "ARX" worksheet for details

(2) Cost of Aggregator subsumed into Operating Costs at $10k/yr, per e-mail from Greg Taylor (to C. Janes) 2007-10-10

(3) Currently presuming Greg Taylor sneaker-net, i.e., store at site in Mark 5, transport disk physically to central location for processing.

References

[1] Section III.I of S. Ellingson et al., "Annual Progress Report on NSF Award AST-0504677"
http://www.ece.vt.edu/swe/eta/reports/ETA_APR_0604.pdf

TCD					
	Time Base and Clock Distribution				
Cost Summary					
Cost LWA1+	$9,000				
Cost/Dipole	$18				
Details					
		LWA1+			
Component	***Quantity***	***Unit Cost***	***Subtotal***	***% of total***	***Justification***
GPS Receiver	1	$7,500	$7,500	83.3%	(1), [1]
Distribution System	1	$1,500	$1,500	16.7%	(2), [1]
Total			**$9,000**	100.0%	
Notes					
	(1)	GPS Receiver, Antenna, Cabling, & Rb Oscillator			
	(2)	In-House Distribution Design			
References	[1]	TCD PDR doc			

MCS								
	Monitoring and Control							
Cost Summary								
Cost	$10,000							
Cost/Dipole	$20							
Details								
		Component	***Quantity***	***Unit Cost***	***Subtotal***	***% of total***	***Spares***	***Justification***
		Computers	3	$2,000	$6,000	60.0%	4	[1]; spares are PCs a
		Network Switch	2	$1,500	$3,000	30.0%		[1]
		Other	1	$1,000	$1,000	10.0%		(1), [1]
		Total			**$10,000**		**$6,000**	
Notes								
	(1)	cables, cable management, power strips, rack hardware (but not racks), and TCD interface						
References	[1]	MCS PDR doc						

MCS-DR

Data Recorders

Cost Summary

Cost	$33,500
Cost/Dipole	$65

Details

Component	*Quantity*	*Unit Cost*	*Subtotal*	*% of total*	*Justification*
Computers	5	$2,000	$10,000	29.9%	(1), [1]
10GbE NIC	5	$595	$2,975	8.9%	(1), [1]
TB drives	5	$200	$1,000	3.0%	(1), [1]
Other	5	$200	$1,000	3.0%	(1), (2), [1]
CXP4 cables	5	$105	$525	1.6%	
Storage Tapes	100	$30	$3,000	9.0%	
LTO Drives	5	$3,000	$15,000	44.8%	(3), [1]
Total			**$33,500**		

Notes

(1) Data Recorders implemented for LWA-1 only

(2) cables, cable management, power strips, rack hardware (but not racks), and TCD

(3) optional, but recommended

References

[1] MCS PDR doc

SHL

The shelter which contains the LWA electronics. Intended to be purchased as single deliverable.
Includes cost of shielded equipment racks.

Cost Summary

Total cost (low)	$85,200
Total cost/dipole	$166
Total cost (high)	$100,200
Total cost/dipole	$196

Details

		Low Cost			High Cost			
Component	***Quantity***	***Unit Cost***	***Subtotal***	***% of total***	***Unit Cost***	***Subtotal***	***% of total***	***Justification***
Shelter	1	$35,000	$35,000	41.1	$50,000	$50,000	49.9%	(1)
Foundations	4	$250	$1,000	1.2	$250	$1,000	1.0%	(2), [1]
Lightning Protection	1	$4,000	$4,000	4.7	$4,000	$4,000	4.0%	(3)
Racks	8	$5,000	$40,000	46.9	$5,000	$40,000	39.9%	(4)
Patch panel	8	$500	$4,000	4.7	$500	$4,000	4.0%	(5)
Connectors	600	$2	$1,200	1.4	$2	$1,200	1.2%	(6)
			$85,200			**$100,200**	100.0%	

Notes

(1) Munton email dtd. 8/7/06

(2) Initial cost estimate for a piling foundation.

(3) Crude guess at cost of providing ground radials, and lightning protection external to shelter. Does NOT include surge protection on incoming lines.

(4) Cost of LWDA Equipto FCC Compliant rack.

(5) Cost of fabrication of back-of-rack panels.

(6) Cost of bulkhead connectors - just a guess at this point. We need at least connectors for 512 cables from SEP to ARX + additional cables.

References

[1] Copeland, J. "LWA Shelter Design Drawings"

PCD					
	Power supplies need to provide power supplies to the FEE.				
Cost Summary					
Cost	$6,800				
Cost/Dipole	$13				
Details					
Component	***Quantity***	***Unit Cost***	***Subtotal***	***% of total***	***Justification***
Power Distribution	6	$800	$4,800	70.6	(1), [1]
MCS	1	$1,000	$1,000	14.7	(3), [1]
Other	1	$1,000	$1,000	14.7	(2), [1]
Total Cost			**$6,800**		
Notes					
(1)	Remote Power Management Distribution Units				
(2)	Cabling, Connectors, etc				
(3)	PCD/Shelter MCS Computer				
References					
[1]	Systems Engineering				

SIT

Site infrastructure costs are those costs associated with site preparation, and installation. There are two main components: **Fixed** costs per site, and costs which **Scale** as the antenna number. Scaling costs are presented as the cost for a full 256 stands.

Cost Summary	
Fixed Costs	$45,884
Scaling Costs	$28,416
Total Cost	$74,300
Scaling Site Costs/Dipole	$55.50

Details

Justification

Fixed Costs per Site

Component	Quantity	Fixed Costs	% of total
RFI Survey, 2 people, 2 day per diem and mileage	1	$245	0.53%
Biological/archelogical survey, (based on cost of 1 survey)	1	$1,127	2.46%
Leveling, gravel (none planned)	1	$0	0.00%
Fencing (400 m, 6 wire, 2 gates. Ref: Acme installation at LWDA)	1	$7,000	15.26%
NRAO builds road, 960' x 9' @ $1.50 per ft	1	$1,422	3.10%
NRAO installs fiber optic cable, 5280' @ $1.46/ft	1	$7,709	16.80%
NRAO connects fiber.	1	$1,580	3.44%
Power Line installation, 2640' @ $8.43/ft and transformer by SEC	1	$22,255	48.50%
Surveying Site	1	$3,000	6.54%
Miscellaneous travel	1	$1,546	3.37%
Total Fixed Costs		**$45,884**	**100%**

Scaling Costs per Site

Component	Quantity	Fixed Costs	% of total	
Install Antenna foundations (4 people x 8 days + equipment rental)	1	$15,000	52.79%	(1), [1]
Bury conduit for signal cable to 256 stands (cable not incl)	1	$10,000	35.19%	
Electrical infrastructure (lights, lighting panel, concrete pastel	1	$3,416	12.02%	
Total Scaling Costs		**$28,416**	100%	
Total Cost for Full Station		**$74,300**		

Notes

(1) LWA-2 and LWA-3 estimated to be 256/2 = 128 stands as part of LWA-1+ construction phase

References

[1] Walter Gerstle, LWA Memo 48, 2006-08-15

OPS

Operations Costs

Details

Category	LWA-1	LWA-2 (1/2)	LWA-3 (1/2)	Central Office	Total	% of GT
Electrical Power (30 kW/sta @ $0.125/kW-hr)	$32,850	$16,425	$16,425	$0	$65,700	18%
Communications	$0	$10,000	$10,000	$17,000	$37,000	10%
Maintenance	$5,000	$2,500	$2,500	$0	$10,000	3%
Land	$1,000	$1,000	$1,000	$0	$3,000	1%
Archive and Correlator	$0	$0	$0	$10,000	$10,000	3%
Personnel	$0	$0	$0	$240,000	$240,000	66%
Subtotals by Location	$38,850	$29,925	$29,925	$267,000	$365,700	
Annual operating cost (stations only)			**$98,700**			

Notes

[1] Year 1 costs est. $20k for LWDA pwr and commo; Year 2 est $183k; Year 3 full $365,700 for LWA-1+.

[2] Maintenance costs based on 1% failure rate at station; included in personnel costs at Central Office

[3] Land costs assumed based on verbal communication with land owners; central office on NRAO or UNM property so no charge

[4] Correlator costs based on 2 dual processor PCs 1st year plus 2 more PCs each year and 10 TB storage. Location TBD

[5] Station cost of data communications based on est. cost of dark fiber lease; CWDM link permits voice, data, Ethernet, video on one fiber

[6] Current SEC billing for LWDA is $0.125/kW-hr and useage is 1390 kW-hr/mo for 16 antennas.

Reference

[1] Greg Taylor e-mail (to Clint Janes) dated 2007-10-07

[2] Guy Stanzione (NRAO) e-mail (to Clint Janes) dated 2007-10-10 confirms Electrical Power cost of $0.10/kW/hr if central office bundled with NRAO

[3] Central Office cost of $17k for data communications is current cost of link from VLA to Socorro

[4] LWA Memo 69, Power Budget for LWDA