

Millimeter Array Construction 2001

WBS	Name	Scientists Work- Months	Programmers Work-Months	Engineers Work- Months	Technicians Work- Months	Personnel Cost	Materials and Supplies	Transfer to Operations	Adjustment to Scope	Contingency	Sum Cost	Inflated Contingency	Inflated Sum
1	Administration												
1.1	Project Management	72			24	\$ 702				\$ 105	\$ 702	\$ 105	\$ 702
1.1.1	Management, Planning, and Oversight						\$ 500			\$ 75	\$ 500	\$ 75	\$ 500
1.1.2	Business Operations						\$ 40			\$ 6	\$ 40	\$ 6	\$ 40
1.1.3	Chilean Operations						\$ 50			\$ 8	\$ 50	\$ 8	\$ 50
1.1.4	Safety and Health												
1.1.5	Personnel												
1.1.6	Project Science Office												
1.1.7	AUI Management						\$ 350			\$ -	\$ 350	\$ -	\$ 350
1.2	Engineering			24	12	\$ 293	\$ 20			\$ 47	\$ 313	\$ 47	\$ 313
1.2.1	System Engineering--Phase II												
1.2.2	Documentation System												
1.2.3	Production Engineering												
1.3	US Facilities												
1.3.1	CDL Permanent Facilities						\$ 600			\$ -	\$ 600	\$ -	\$ 600
1.3.2	Manufacturing Facilities						\$ 100			\$ 15	\$ 100	\$ 15	\$ 100
1.3.3	Common Infrastructure						\$ 200			\$ 30	\$ 200	\$ 30	\$ 200
2	Site Development			12		\$ 117	\$ 50			\$ 25	\$ 167	\$ 25	\$ 167
2.1	Review Legalities Regarding Array and OSF Sites												
2.2	Maintain Mining claims						\$ 25			\$ -	\$ 25	\$ -	\$ 25
2.3	Contract A&E Studies						\$ 938		\$ 104	\$ 167	\$ 834	\$ 167	\$ 834
2.4	Hire Construction Manager for Chile												
2.5	Array Site												
2.5.1	Prepare Site Development Bid Packages												
2.5.1.1	Prepare Package for Array Site												
2.5.1.2	Review Bid Packages												
2.5.1.3	Bid Civil Works Construction												
2.5.2	Evaluate Array Site Bid Response												
2.5.2.1	Review Bids												
2.5.2.2	Recommend Contractors												
2.5.2.3	Award Array Site Contracts												
2.5.3	Contract Array Site Civil Works												
2.5.3.1	Array Site												
2.5.3.2	Inspect Completed Site Constr												
2.5.3.3	Accept Site Facility												
2.6	Operations Support Facility												
2.6.1	Prepare OSF Bid Packages												
2.6.1.1	Prepare Package for OSF												
2.6.1.2	Review Bid Packages												
2.6.1.3	Bid Civil Works Construction												
2.6.2	Evaluate OSF Bid Response												
2.6.2.1	Review Bids												
2.6.2.2	Recommend Contractors												
2.6.2.3	Award Contracts												

2.6.3	Contract OSF Civil Works												
2.6.3.1	Operations Support Facility												
2.6.3.2	Inspect Completed OSF Constr												
2.6.3.3	Accept OSF Facility												
2.7	OSF/Array Link												
2.7.1	Prepare OSF/Array Link Bid Package												
2.7.1.1	Prepare Package for OSF/Array F/O Link												
2.7.1.2	Review Bid Package												
2.7.1.3	Bid OSF/Array Link Construction												
2.7.2	Evaluate Bid Response												
2.7.2.1	Review Bids												
2.7.2.2	Recommend Contractors												
2.7.2.3	Award Contracts												
2.7.3	Contract Civil Works												
2.7.3.1	OSF/Array Link												
2.7.3.2	Inspect Completed OSF/Array Link Constr												
2.7.3.3	Accept OSF/Array Link												
2.8	Prepare for Instrument Assembly												
2.8.1	Equip Array Site												
2.8.2	Equip Operations Support Facility												
3	Antenna												
3.1	Antenna Engineering Support		48		\$	468				\$	70	\$	468
3.3.40	Acceptance Tests Antenna #1												
3.3.45	Delivery of Antenna #1												
3.8.10	Sign Transporter Contract					\$	600				\$	180	\$
3.8.15	Transporter Acceptance tests												
3.8.20	Deliver/Accept Transporter #1												
3.7	Procurement of Antenna #2												
3.7.1	Antenna #2 Contract Supervision												
3.7.2	Antenna #2 Acceptance tests												
3.8	Negotiate Production Antenna Contract												
3.9	Sign Contract for Production Antennas												
3.10	Antenna Contract Supervision												
3.11	Accept Antenna #3 at OSF												
3.12	Prepare Antenna #3												
3.12.1	Outfit & Verify Ant #3 at OSF												
3.12.2	Move, Install & Verify Ant #3 on Site												
3.13	Accept Antenna #4 at OSF												
3.14	Prepare Antenna #4												
3.14.1	Outfit & Verify Ant #4 at OSF												
3.14.2	Move, Install & Verify Ant #4 on Site												
3.15	Accept Antenna#5 at OSF												
3.16	Prepare Antenna #5												
3.16.1	Outfit & Verify Ant #5 at OSF												
3.16.2	Move, Install & Verify Ant #5 on Site												
3.17	Accept Antenna#6 at OSF												
3.18	Prepare Antenna #6												
3.18.1	Outfit & Verify Ant #6 at OSF												
3.18.2	Move, Install & Verify Ant #6 on Site												
3.19	Accept Antenna #7 at OSF												

3.20	Prepare Antenna #7												
3.20.1	Outfit & Verify Ant #7 at OSF												
3.20.2	Move, Install & Verify Ant #7 on Site												
3.21	Accept Antenna #8 at OSF												
3.22	Prepare Antenna #8												
3.22.1	Outfit & Verify Ant #8 at OSF												
3.22.2	Move, Install & Verify Ant #8 on Site												
3.23	Accept Antenna #9 at OSF												
3.24	Prepare Antenna #9												
3.24.1	Outfit & Verify Ant #9 at OSF												
3.24.2	Move, Install & Verify Ant #9 on Site												
3.25	Accept Antenna #10 at OSF												
3.26	Prepare Antenna #10												
3.26.1	Outfit & Verify Ant #10 at OSF												
3.26.2	Move, Install and Verify Ant #10 on Site												
3.27	Accept Antenna #11 at OSF												
3.28	Prepare Antenna #11												
3.28.1	Outfit & Verify Ant #11 at OSF												
3.28.2	Move, Install & Verify Ant #11 on Site												
3.29	Accept Antenna #12 at OSF												
3.30	Prepare Antenna #12												
3.30.1	Outfit & Verify Ant #12 at OSF												
3.30.2	Move, Install & Verify Ant #12 on Site												
3.31	Accept Antenna #13 at OSF												
3.32	Prepare Antenna #13												
3.32.1	Outfit & Verify Ant #13 at OSF												
3.32.2	Move, Install & Verify Ant #13 on Site												
3.33	Accept Antenna #14 at OSF												
3.34	Prepare Antenna #14												
3.34.1	Outfit & Verify Ant #14 at OSF												
3.34.2	Move, Install & Verify Ant #14 on Site												
3.35	Accept Antenna #15 at OSF												
3.36	Prepare Antenna #15												
3.36.1	Outfit & Verify Ant #15 at OSF												
3.36.2	Move, Install & Verify Ant #15 on Site												
3.37	Accept Antenna #16 at OSF												
3.38	Prepare Antenna #16												
3.38.1	Outfit & Verify Ant #16 at OSF												
3.38.2	Move, Install & Verify Ant #16 on Site												
3.39	Accept Antenna #17 at OSF												
3.40	Prepare Antenna #17												
3.40.1	Outfit & Verify Ant #17 at OSF												
3.40.2	Move, Install & Verify Ant #17 on Site												
3.41	Accept Antenna #18 at OSF												
3.42	Prepare Antenna #18												
3.42.1	Outfit & Verify Ant #18 at OSF												
3.42.2	Move, Install & Verify Ant #18 on Site												
3.43	Accept Antenna #19 at OSF												
3.44	Prepare Antenna #19												
3.44.1	Outfit & Verify Ant #19 at OSF												
3.44.2	Move, Install & Verify Ant #19 on Site												
3.45	Accept Antenna #20 at OSF												
3.46	Prepare Antenna #20												
3.46.1	Outfit & Verify Ant #20 at OSF												

3.46.2	Move, Install & Verify Ant #20 on Site												
3.47	Accept Antenna #21 at OSF												
3.48	Prepare Antenna #21												
3.48.1	Outfit & Verify Ant #21 at OSF												
3.48.2	Move, Install & Verify Ant #21 on Site												
3.49	Accept Antenna #22 at OSF												
3.50	Prepare Antenna #22												
3.50.1	Outfit & Verify Ant #22 at OSF												
3.50.2	Move, Install & Verify Ant #22 on Site												
3.51	Accept Antenna #23 at OSF												
3.52	Prepare Antenna #23												
3.52.1	Outfit & Verify Ant #23 at OSF												
3.52.2	Move, Install & Verify Ant #23 on Site												
3.53	Accept Antenna #24 at OSF												
3.54	Prepare Antenna #24												
3.54.1	Outfit & Verify Ant #24 at OSF												
3.54.2	Move, Install & Verify Ant #24 on Site												
3.55	Accept Antenna #25 at OSF												
3.56	Prepare Antenna #25												
3.56.1	Outfit & Verify Ant #25 at OSF												
3.56.2	Move, Install & Verify Ant #25 on Site												
3.57	Accept Antenna #26 at OSF												
3.58	Prepare Antenna #26												
3.58.1	Outfit & Verify Ant #26 at OSF												
3.58.2	Move, Install & Verify Ant #26 on Site												
3.59	Accept Antenna #27 at OSF												
3.60	Prepare Antenna #27												
3.60.1	Outfit & Verify Ant #27 at OSF												
3.60.2	Move, Install & Verify Ant #27 on Site												
3.61	Accept Antenna #28 at OSF												
3.62	Prepare Antenna #28												
3.62.1	Outfit & Verify Ant #28 at OSF												
3.62.2	Move, Install & Verify Ant #28 on Site												
3.63	Accept Antenna #29 at OSF												
3.64	Prepare Antenna #29												
3.64.1	Outfit & Verify Ant #29 at OSF												
3.64.2	Move, Install & Verify Ant #29 on Site												
3.65	Accept Antenna #30 at OSF												
3.66	Prepare Antenna #30												
3.66.1	Outfit & Verify Ant #30 at OSF												
3.66.2	Move, Install & Verify Ant #30 on Site												
3.67	Accept Antenna #31 at OSF												
3.68	Prepare Antenna #31												
3.68.1	Outfit & Verify Ant #31 at OSF												
3.68.2	Move, Install and Verify Ant #31 on Site												
3.69	Accept Antenna #32 at OSF												
3.70	Prepare Antenna #32												
3.70.1	Outfit & Verify Ant #32 at OSF												
3.70.2	Move, Install & Verify Ant #32 on Site												
3.71	Accept Antenna #33 at OSF												
3.72	Prepare Antenna #33												
3.72.1	Outfit & Verify Ant #33 at OSF												
3.72.2	Move, Install and Verify Ant #33 on Site												
3.73	Accept Antenna #34 at OSF												

3.74	Prepare Antenna #34												
3.74.1	Outfit & Verify Ant #34 at OSF												
3.74.2	Move, Install and Verify Ant #34 on Site												
3.75	Accept Antenna #35 at OSF												
3.76	Prepare Antenna #35												
3.76.1	Outfit & Verify Ant #35 at OSF												
3.76.2	Move, Install & Verify Ant #35 on Site												
3.77	Accept Antenna #36 at OSF												
3.78	Prepare Antenna #36												
3.78.1	Outfit & Verify Ant #36 at OSF												
3.78.2	Move, Install & Verify Ant #36 on Site												
3.79	Prepare Antenna #1												
3.79.1	Antenna #1 Reassembled at OSF												
3.79.2	Outfit & Verify Ant #1 at OSF												
3.79.3	Move, Install & Verify Ant #1 on Site												
3.80	Prepare Antenna #2												
3.80.1	Antenna #2 Reassembled at OSF												
3.80.2	Outfit & Verify Ant #2 at OSF												
3.80.3	Move, Install & Verify Ant #2 on Site												
3.81	Antenna Transporter												
3.81.1	Contract for Transporter #1 move to site												
3.81.2	Contract for Transporters #2, #3												
3.81.3	Accept Transporters #2, #3 at OSF												
4	Receivers												
4.1	Receiver Package												
4.1.1	Prototype Production Receiver Cryogenics			12	12	\$ 176	\$ 100			\$ 41	\$ 276	\$ 41	\$ 276
4.1.1.1	CDR: Cryogenics Development												
4.1.1.2	Construct & test prototype cryogenics												
4.1.1.3	Deliver Prototype Cryogenics Subsystem												
4.1.2	Prototype Production Receiver Package			24	24	\$ 351	\$ 150			\$ 75	\$ 501	\$ 75	\$ 501
4.1.2.1	Prototype Receiver Package Integration												
4.1.2.2	Prot. Rcvr. Pckg Lab Test & Evaluation												
4.1.2.3	Complete Prototype MMA Receiver Package												
4.1.3	MMA Rcvr Pckg Design Refinement												
4.1.4	Documentation												
4.1.5	Release MMA Receiver Pckg for manufacture												
4.1.6	Contract for Receiver Pckg Subassemblies												
4.1.6.1	Machine Dewars												
4.1.6.2	Fabricate Cryogenics subsystems												
4.1.6.3	Fabricate windows, IR filters, etc												
4.1.7	Accept Receiver Pckg Subassemblies												
4.1.7.1	Subassemblies #1-6												
4.1.7.2	Subassemblies #7-16												
4.1.7.3	Subassemblies #17-26												
4.1.7.4	Subassemblies #27-36												
4.1.7.5	Subassemblies #37-40												
4.1.8	Fab Rcvr Pckg Instrumentation & Electronics												
4.1.9	Fabricate Receiver Inserts												
4.1.10	Assemble Receiver Package												
4.1.10.1	Integrate Rcvr Instrumentation & subass'y												

4.1.10.2	Deliver Receiver Package #1-6												
4.1.10.3	Deliver Receiver Package #7-16												
4.1.10.4	Deliver Receiver Package #17-26												
4.1.10.5	Deliver Receiver Package #27-36												
4.1.10.6	Deliver Receiver Package #37-40												
4.2	SIS Receiver Modules												
4.2.1	211-275 GHz Module		24	24	\$ 351	\$ 400		\$ 83	\$ 148	\$ 668	\$ 148	\$ 668	
4.2.1.1	SIS Mixer												
4.2.1.1.1	Design, Fab and Test Mixer Design												
4.2.1.1.2	Deliver Production Design												
4.2.1.1.3	Fabricate Production Mixers												
4.2.1.2	Design & Verify Optics		6		\$ 59	\$ 50		\$ 24	\$ 109	\$ 24	\$ 109		
4.2.1.3	Design Module		6		\$ 59	\$ 50		\$ 24	\$ 109	\$ 24	\$ 109		
4.2.1.4	Contract Fabrication			4	\$ 20	\$ 25		\$ 10	\$ 45	\$ 10	\$ 45		
4.2.1.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.1.4.2	Assemble Modules												
4.2.1.5	Install SIS Mixer & Test Modules												
4.2.1.6	Deliver 211-275 GHz Receiver Modules												
4.2.1.6.1	Deliver Modules #1-7												
4.2.1.6.2	Deliver Modules #8-26												
4.2.1.6.3	Deliver Modules #27-40												
4.2.2	602-720 GHz Module		24	24	\$ 351	\$ 400		\$ 751	\$ -	\$ -	\$ -	\$ -	
4.2.2.1	SIS Mixer												
4.2.2.1.1	Design, Fabricate and Test Mixer Design												
4.2.2.1.2	Deliver Production Design												
4.2.2.1.3	Fabricate Production Mixers												
4.2.2.2	Design & Verify Optics		6		\$ 59	\$ 50		\$ 109	\$ -	\$ -	\$ -	\$ -	
4.2.2.3	Design Module		6		\$ 59	\$ 50		\$ 109	\$ -	\$ -	\$ -	\$ -	
4.2.2.4	Contract Fabrication			4	\$ 20	\$ 25		\$ 45	\$ -	\$ -	\$ -	\$ -	
4.2.2.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.2.4.2	Assemble Modules												
4.2.2.5	Install SIS Mixer and Test Modules												
4.2.2.6	Deliver 602-720 GHz Receiver Modules												
4.2.2.6.1	Deliver Modules #1-7												
4.2.2.6.2	Deliver Modules #8-26												
4.2.2.6.3	Deliver Modules #27-40												
4.2.3	275-370 GHz Receiver Module												
4.2.3.1	SIS Mixer												
4.2.3.1.1	Design, Fabricate and Test Mixer Design												
4.2.3.1.2	Deliver Production Design												
4.2.3.1.3	Fabricate Production Mixers												
4.2.3.2	Design & Verify Optics		4		\$ 39	\$ 50		\$ 21	\$ 89	\$ 21	\$ 89		
4.2.3.3	Design Module												
4.2.3.4	Contract Fabrication												
4.2.3.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.3.4.2	Assemble Modules												
4.2.3.5	Install SIS Mixer and Test Modules												
4.2.3.6	Deliver 275-370 GHz Receiver Module												
4.2.3.6.1	Deliver Modules #1-5												
4.2.3.6.2	Deliver Modules #6-30												
4.2.3.6.3	Deliver Modules #30-40												

4.2.4	91-119 GHz Receiver Module												
4.2.4.1	SIS Mixer												
4.2.4.1.1	Design, Fabricate & Test Mixer Design												
4.2.4.1.2	Deliver Production Design												
4.2.4.1.3	Fabricate Production Mixers												
4.2.4.2	Design & Verify Optics			4		\$ 39	\$ 50			\$ 21	\$ 89	\$ 21	\$ 89
4.2.4.3	Design Module												
4.2.4.4	Contract Fabrication												
4.2.4.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.4.4.2	Assemble Modules												
4.2.4.5	Install SIS Mixer and Test Modules												
4.2.4.6	Deliver 91-119 GHz Receiver Modules												
4.2.4.6.1	Deliver Modules #1-5												
4.2.4.6.2	Deliver Modules #6-30												
4.2.4.6.3	Deliver Modules # 31-40												
4.2.5	163-211 GHz Receiver Module												
4.2.5.1	SIS Mixer												
4.2.5.1.1	Design, Fabricate & Test Mixer Design												
4.2.5.1.2	Deliver Production Design												
4.2.5.1.3	Fabricate Production Mixers												
4.2.5.2	Design & Verify Optics												
4.2.5.3	Design Module												
4.2.5.4	Contract Fabrication												
4.2.5.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.5.4.2	Assemble Modules												
4.2.5.5	Install SIS Mixer and Test												
4.2.5.6	Deliver 163-211 GHz Receiver Modules												
4.2.5.6.1	Deliver Modules #1-5												
4.2.5.6.2	Deliver Modules #6-30												
4.2.5.6.3	Deliver Modules #31-40												
4.2.6	385-500 GHz Receiver Module												
4.2.6.1	SIS Mixer												
4.2.6.1.1	Design, Fabricate & Test Mixer Design												
4.2.6.1.2	Deliver Production Design												
4.2.6.1.3	Fabricate Production Mixers												
4.2.6.2	Design and Verify Optics												
4.2.6.3	Design Module												
4.2.6.4	Contract Fabrication												
4.2.6.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.6.4.2	Assemble Modules												
4.2.6.5	Install SIS Mixer and Test												
4.2.6.6	Deliver 385-500 GHz Receiver Modules												
4.2.6.6.1	Deliver Modules #1-5												
4.2.6.6.2	Deliver Modules #6-30												
4.2.6.6.3	Deliver Modules #31-40												
4.2.7	125-163 GHz Receiver Module												
4.2.7.1	SIS Mixer												
4.2.7.1.1	Design, Fabricate & Test Mixer Design												
4.2.7.1.2	Deliver Production Design												
4.2.7.1.3	Fabricate Production Mixers												

4.2.7.2	Design & Verify Optics												
4.2.7.3	Design Module												
4.2.7.4	Contract Fabrication												
4.2.7.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.7.4.2	Assemble Modules												
4.2.7.5	Install SIS Mixer and Test												
4.2.7.6	Deliver 125-163 GHz Receiver Modules												
4.2.7.6.1	Deliver 125-163 GHz Modules #1-5												
4.2.7.6.2	Deliver 125-163 GHz Modules #6-30												
4.2.7.6.3	Deliver 125-163 GHz Modules #31-40												
4.3	HFET Receiver Modules			10	18	\$ 185	\$ 119		\$ 34	\$ 41	\$ 270	\$ 41	\$ 270
4.3.1	Contract for HFET Wafer												
4.3.2	Receive Diced HFET Wafer												
4.3.3	33-45 GHz Module												
4.3.3.1	Design Module												
4.3.3.2	Design & Verify Optics												
4.3.3.3	Contract Fabrication												
4.3.3.3.1	Machine Blocks, Feed, WG, Lenses												
4.3.3.3.2	Assemble Modules												
4.3.3.3.3	Flip-in Mirror												
4.3.4	Install HFET & Test Modules												
4.3.5	Deliver 33-45 GHz Receiver Modules												
4.3.5.1	Deliver Modules #1-20												
4.3.5.2	Deliver Modules #21-40												
4.3.6	67-95 GHz Module												
4.3.6.1	Design Amplifier												
4.3.6.2	Design Module												
4.3.6.3	Design & Verify Optics												
4.3.6.4	Contract Fabrication												
4.3.6.4.1	Machine Blocks, Feed, WG, Lenses												
4.3.6.4.2	Assemble Modules												
4.3.6.5	Install HFET & Test Modules												
4.3.6.6	Deliver 67-95 GHz Receiver Modules												
4.3.6.6.1	Deliver Modules 67-95GHz #1-20												
4.3.6.6.2	Deliver Modules 67-95GHz #21-40												
5	LO System												
5.1	LO Reference: Prototype Systems			12	12	\$ 176	\$ 200			\$ 56	\$ 376	\$ 56	\$ 376
5.1.1	Deliver: Bench Prototype												
5.1.2	Testing and Design Refinement												
5.1.3	Procure/Fab Field Prototypes												
5.1.4	Deliver: LO Ref Field Prototypes												
5.1.5	Field Prototype testing and Design Refinement												
5.1.6	Preproduction Review												
5.1.7	Final Documentation and Design Modifications												
5.1.8	Release for Manufacture												
5.2	LO Reference: Production System												
5.1.1	Production test and lab equipment												
5.1.2	H-maser Frequency Standard (& Rb)												
5.1.3	8 GHz PL Oscillator & Distributor												
5.1.4	10 GHz PL Oscillator & Distributor												

5.1.5	12 GHz PL Oscillator & Distributor												
5.1.6	14 GHz PL Oscillator & Distributor												
5.1.7	3.2-5.2 GHz Synthesizer												
5.1.8	3.2 -5.2 GHz PLO and Fringe Generator												
5.1.9	Sampler Clock 4 GHz PL Osc & Distributor												
5.1.10	LO Ref Generator												
5.1.11	LO Ref Distributor - Control Bldg												
5.1.12	Microwave Round-trip Phase Measurement												
5.1.13	10-15 GHz Frequency Synthesizer												
5.1.14	First LO Fringe Generator												
5.1.15	16 GHz PL Oscillator												
5.1.16	26 GHz PL Oscillator												
5.1.17	LO Ref Distributor - Antenna												
5.1.18	VXCO Clean-up Loop												
5.1.19	Power supply module												
5.1.20	Bins / Racks (assemble and test)												
5.3	Millimeter LO Drivers												
5.3.1	Design and System Integration		3		\$	29				\$	4	\$	29
5.3.2	72-95 GHz Source		6	8	\$	98	\$	180		\$	31	\$	59
5.3.2.1	Contract Procurement and Fabrication											\$	247
5.3.2.1.1	YIG-tuned Oscillator												
5.3.2.1.2	18.00 - 23.75 GHz 10 db Amplifier												
5.3.2.1.3	18.00 - 23.75 GHz x2 Multiplier												
5.3.2.1.4	36.0 - 47.5 GHz 10 db Amplifier												
5.3.2.1.5	36.0 - 47.5 GHz x2 Multiplier												
5.3.2.1.6	Mount and Tuning circuitry												
5.3.2.2	Assembly and Test												
5.3.2.3	Deliver 72 - 95 GHz LO Sources												
5.3.2.3.1	Deliver Modules #1-6												
5.3.2.3.2	Deliver Modules #7-24												
5.3.2.3.3	Deliver Modules #25-40												
5.3.3	100-120 GHz Source		6	8	\$	98	\$	180		\$	278	\$	-
5.3.3.1	Contract Procurement and Fabrication											\$	-
5.3.3.1.1	YIG-tuned Oscillator												
5.3.3.1.2	25.00 - 30.00 GHz 10 db Amplifier												
5.3.3.1.3	15.00 - 30.00 GHz x2 Multiplier												
5.3.3.1.4	50.0 - 60.0 GHz 10 db Amplifier												
5.3.3.1.5	50-60 GHz x2 Multiplier												
5.3.3.1.6	Mount and Tuning circuitry												
5.3.3.2	Assembly and Test												
5.3.3.3	Deliver 100 - 120 GHz LO Sources												
5.3.3.3.1	Deliver Modules #1-3												
5.3.3.3.2	Deliver Modules #4-21												
5.3.3.3.3	Deliver Modules #22-40												
5.3.4	87 - 108 GHz Source												
5.3.4.1	Contract Procurement and Fabrication												
5.3.4.1.1	YIG-tuned Oscillator												
5.3.4.1.2	21.75-27.00 GHz 10 db Amplifier												
5.3.4.1.3	21.75-27.00 GHz x2 Multiplier												
5.3.4.1.4	43.5-54.0 GHz 10 db Amplifier												
5.3.4.1.5	43.5-54.0 GHz x2 Multiplier												

5.3.4.1.6	Mount and Tuning Circuitry												
5.3.4.2	Assembly and Test												
5.3.4.3	Deliver 87 - 108 GHz LO Sources												
5.3.4.3.1	Deliver Modules #1-6												
5.3.4.3.2	Deliver Modules #7-20												
5.3.4.3.3	Deliver Modules #21-35												
5.3.4.3.4	Deliver Modules #36-40												
5.3.5	65 - 85 GHz Source												
5.3.5.1	Contract Procurement and Fabrication												
5.3.5.1.1	YIG-tuned Oscillator												
5.3.5.1.2	16.25-21.25 GHz 10 db Amplifier												
5.3.5.1.3	16.25-21.25 GHz x2 Multiplier												
5.3.5.1.4	32.5-42.5 GHz 10 db Amplifier												
5.3.5.1.5	32.5-42.5 GHz x2 Multiplier												
5.3.5.1.6	Mount and Tuning Circuitry												
5.3.5.2	Assembly and Test												
5.3.5.3	Deliver 65 - 85 GHz LO Sources												
5.3.5.3.1	Deliver Modules #1-6												
5.3.5.3.2	Deliver Modules #7-20												
5.3.5.3.3	Deliver Modules #21-35												
5.3.5.3.4	Deliver Modules #36-40												
5.4	Millimeter LO Multiplier Chains												
5.4.1	Design and System Integration			24	24	\$ 351	\$ 250			\$ 128	\$ 601	\$ 128	\$ 601
5.4.2	211 - 275 GHz Receiver LO												
5.4.2.1	Contract Fabrication												
5.4.2.1.1	X3 Diode for 72-95 GHz Source												
5.4.2.1.2	Machine Mount												
5.4.2.1.3	Bias and Control circuits												
5.4.2.2	Assemble Multiplier and Test												
5.4.2.3	Integrate Source and Multiplier; test												
5.4.2.4	Deliver 211-275 GHz Rcvr LO Modules												
5.4.2.4.1	Deliver Modules #1-3												
5.4.2.4.2	Deliver Modules #4-21												
5.4.2.4.3	Deliver Modules #22-40												
5.4.3	602 - 720 GHz Receiver LO												
5.4.3.1	Contract Fabrication												
5.4.3.1.1	X2 Diode for 100-120 GHz Source												
5.4.3.1.2	X3 Diode for 200-240 GHz Input												
5.4.3.1.3	Machine Mount												
5.4.3.1.4	Bias and Control circuits												
5.4.3.2	Assemble Multipliers and Test												
5.4.3.3	Integrate Source and Multipliers; test												
5.4.3.4	Deliver 602-720 GHz Rcvr LO Modules												
5.4.3.4.1	Deliver Modules #1-6												
5.4.3.4.2	Deliver Modules #7-18												
5.4.3.4.3	Deliver Modules #19-34												
5.4.3.4.4	Deliver Modules #35-40												
5.4.4	275 - 370 GHz Receiver LO												
5.4.4.1	Contract Fabrication												
5.4.4.1.1	X2 Diode for 72-95 GHz Source												

5.4.4.1.2	X2 Diode for 144-190 GHz Input																				
5.4.4.1.3	Machine Mount																				
5.4.4.1.4	Bias and Control Circuits																				
5.4.4.2	Assemble Multipliers and Test																				
5.4.4.3	Integrate Source and Multipliers; test																				
5.4.4.4	Deliver 275-370 GHz Rcvr LO Modules																				
5.4.4.4.1	Deliver Modules #1-6																				
5.4.4.4.2	Deliver Modules #7-27																				
5.4.4.4.3	Deliver Modules #28-40																				
5.4.5	163 - 211 GHz Receiver LO																				
5.4.5.1	Contract Fabrication																				
5.4.5.1.1	X2 Diode for 87-108 GHz Source																				
5.4.5.1.2	Machine Mount																				
5.4.5.1.3	Bias and Control Circuits																				
5.4.5.2	Assemble Multiplier and Test																				
5.4.5.3	Integrate Source and Multiplier; test																				
5.4.5.4	Deliver 163 - 211 GHz Rcvr LO Modules																				
5.4.5.4.1	Deliver Modules #1-6																				
5.4.5.4.2	Deliver Modules #7-24																				
5.4.5.4.3	Deliver Modules #25-40																				
5.4.6	385 - 500 GHz Receiver LO																				
5.4.6.1	Contract Fabrication																				
5.4.6.1.1	X3 Diode for 65-85 GHz Source																				
5.4.6.1.2	X2 Diode for 130-170 GHz Input																				
5.4.6.1.3	Machine Mount																				
5.4.6.1.4	Bias and Control Circuits																				
5.4.6.2	Assemble Multiplier and test																				
5.4.6.3	Integrate source and Multiplier; test																				
5.4.6.4	Deliver 385-500 GHz Rcvr LO Modules																				
5.4.6.4.1	Deliver Modules #1-6																				
5.4.6.4.2	Deliver Modules #7-24																				
5.4.6.4.3	Deliver Modules #25-40																				
5.4.7	125 - 163 GHz Receiver LO																				
5.4.7.1	Contract Fabrication																				
5.4.7.1.1	X2 Diode for 65 - 85 GHz Source																				
5.4.7.1.2	Machine Mount																				
5.4.7.1.3	Bias and Control Circuits																				
5.4.7.2	Assemble Multiplier and test																				
5.4.7.3	Integrate Source and Multiplier; test																				
5.4.7.4	Deliver 125-163 GHz Rcvr LO Modules																				
5.4.7.4.1	Deliver Modules #1-6																				
5.4.7.4.2	Deliver Modules #7-18																				
5.4.7.4.3	Deliver Modules #19-34																				
5.4.7.4.4	Deliver Modules #35-40																				
5.4.8	33-45 GHz Receiver LO																				
5.4.8.1	Design & Fab Selection & Coupling from Sources				3		6	\$	59	\$	25			\$	13	\$	84	\$	13	\$	84
6	IF System																				
6.1	IF System: Prototype Systems																				

6.1.1	Deliver (Bench) Prototype IF System												
6.1.2	Testing and Design Refinement												
6.1.3	Procure/Fab Field Prototypes												
6.1.4	Deliver IF Field Prototypes to Test Interfeometer												
6.1.5	Field Prototype testing and Design Refinement												
6.1.6	Preproduction Review												
6.1.7	Final Documentation and Design Modifications												
6.1.8	Release for Manufacture												
6.2	Production test and lab equipment		12	12	\$ 176	\$ 200				\$ 56	\$ 376	\$ 56	\$ 376
6.3	IF Multiplexer												
6.4	IF Demultiplexer												
6.5	IF Matrix Switch												
6.6	Baseband Converter												
6.7	Power supply module												
6.8	Bins / Racks (assemble and test)												
7	Optical Fiber System												
7.1	Optical Fiber System: Prototype Systems												
7.1.1	Deliver (Bench) Prototype FO System												
7.1.2	Testing and Design Refinement												
7.1.3	Procure/Fab Field Prototypes												
7.1.4	Deliver FO Field Prototypes to Test Interfeometer												
7.1.5	Field Prototype testing and Design Refinement												
7.1.6	Preproduction Review												
7.1.7	Final Documentation and Design Modifications												
7.1.8	Release for Manufacture												
7.1	Production test and lab equipment		12	12	\$ 176	\$ 200				\$ 56	\$ 376	\$ 56	\$ 376
7.2	IF TX / RX												
7.3	LO Reference TX / RX												
7.4	Microwave Round-trip Phase TX / RX												
7.5	Monitor / Control TX / RX												
7.6	Power supply module												
7.7	Bins / Racks (assemble and test)												
8	Correlator		36	36	\$ 527	\$ 2,000			\$ 281	\$ 337	\$ 2,246	\$ 337	\$ 2,246
8.1	Digital Sampler, 4 GHz		12	12	\$ 176	\$ 428			\$ 67	\$ 80	\$ 536	\$ 80	\$ 536
8.1.1	Refine Design												
8.1.2	Release Digital Sampler for Manufacture												
8.1.3	Contract Materials												
8.1.4	Assembly												
8.1.5	Validation and Delivery												
8.2	Digital FIR Filter		24	24	\$ 351	\$ 533			\$ 67	\$ 123	\$ 817	\$ 123	\$ 817
8.2.1	Prototype testing on Test Interferometer												
8.2.2	Design Refinement												
8.2.3	Release FIR Filter for manufacture												
8.2.4	Chip Fabrication												
8.2.5	Assembly												
8.2.6	Validation and Delivery												
8.3	Custom Boards												
8.3.1	Correlator Board												

8.3.1.1	Prototype assembly												
8.3.1.2	Prototype test												
8.3.1.3	Design modifications												
8.3.1.4	Fab, assemble and test with design mods												
8.4	Correlator Chip												
8.4.1	Prototype chip fabrication												
8.4.2	Prototype chip test												
8.4.3	Design modifications												
8.4.4	Fabricate and test design mods												
8.4.5	Fabricate production run												
8.5	Racks												
8.5.1	Design control wiring												
8.5.2	Design signal wiring												
8.5.3	Order parts												
8.5.4	Assemble prototypes												
8.6	Software												
8.7	Prototype Correlator Production												
8.7.1	Order parts												
8.7.2	Assemble												
8.7.3	Test												
8.7.4	Deliver Prototype Correlator to VLA site												
8.8	Site Correlator Production												
8.8.1	First 1/4 correlator												
8.8.1.1	Determine configuration												
8.8.1.2	Order parts												
8.8.1.3	Assemble												
8.8.1.4	Test												
8.8.1.5	Deliver 1/4 Correlator to MMA site												
8.8.2	Second 1/4 correlator												
8.8.2.1	Order parts												
8.8.2.2	Assemble												
8.8.2.3	Test												
8.8.2.4	Deliver 1/4 Correlator to MMA site												
8.8.3	Third 1/4 correlator												
8.8.3.1	Order parts												
8.8.3.2	Assemble												
8.8.3.3	Test												
8.8.3.4	Deliver 1/4 Correlator to MMA site												
8.8.4	Fourth 1/4 correlator												
8.8.4.1	Order parts												
8.8.4.2	Assemble												
8.8.4.3	Test												
8.8.4.4	Deliver 1/4 Correlator to MMA site												
8.9	Continued Support												
9	Computing						\$ 50			\$ 15	\$ 50	\$ 15	\$ 50
9.1	Control Software												
9.1.1	Test Interferometer Control & Analysis		33			\$ 286				\$ 43	\$ 286	\$ 43	\$ 286
9.1.2	MMA correlator software		52			\$ 451				\$ 68	\$ 451	\$ 68	\$ 451
9.1.3	Multi-antenna & sub-array control												
9.1.4	Operators & Observers interfaces		27			\$ 234				\$ 35	\$ 234	\$ 35	\$ 234
9.1.5	Deliver Control Software												
9.1.6	Maintenance												

9.2	Scheduling												
9.2.1	Static scheduling system		10			\$	87				\$	13	\$ 87
9.2.2	Dynamic scheduling simulations		24			\$	208				\$	31	\$ 208
9.2.3	Dynamic scheduling prototype												
9.2.4	Dynamic scheduling implementation												
9.2.5	Initial Operations with Dynamic Scheduling												
9.3	Proposal Preparation Software												
9.3.1	Prototype		7			\$	61				\$	9	\$ 61
9.3.2	Production version												
9.4	Image Pipeline												
9.4.1	Automated calibration & imaging heuristics		7			\$	61				\$	9	\$ 61
9.4.2	Prototype image pipeline												
9.4.3	Parallelization studies and implementation												
9.4.4	Initial Image Pipeline Operations												
9.4.5	Production image pipeline												
9.5	Archiving												
9.5.1	Prototype distributed archive		10			\$	87				\$	13	\$ 87
9.5.2	Evaluate storage hardware												
9.5.3	Production archive												
9.5.4	Data Archive operational												
9.6	Post-processing												
9.6.1	Define MMA Data formats												
9.6.2	MMA filler & format conversions												
9.6.3	MMA-specific calibrations												
9.6.4	MMA Post-processing begins												
9.6.5	Maintenance		6			\$	52				\$	8	\$ 52
10	System Integration												
10.4	Test Interferometer Site Preparation				4	\$	20	\$ 40			\$	15	\$ 60
10.4.1	Complete Office and Lab Space Preparation												
10.4.2	Cabling												
10.4.3	Test Interferometer Site Complete												
10.10.4	Prototype Antenna Outfitting				18	\$	88	\$ 50			\$	28	\$ 138
10.10.4.1	Cabling												
10.10.4.2	Instrumentation												
10.10.4.3	Eval. Rcvr. #1 / Ant. #1 Integration												
10.10.4.4	Antenna #1 Outfitting Complete												
10.10.5	Integration Holography System/Antenna				2	\$	10				\$	1	\$ 10
10.10.6	Integration Metrology/Antenna				5	\$	24				\$	4	\$ 24
10.10.7	Antenna #1 Integration & Testing				7	\$	34				\$	5	\$ 34
10.10.8	Prot. Rcvr. Test & Evaluation												
10.10.9	Antenna #2 Outfitting				21	\$	102	\$ 50			\$	30	\$ 152
10.10.9.1	Cabling												
10.10.9.2	Instrumentation												
10.10.9.3	Eval. Rcvr. #2 / Ant. #2 Integration												
10.10.9.4	Antenna #2 Outfitting Complete												
10.11	Test Interferometer												
10.11.1	Antenna Evaluation & Characterization												
10.11.1.1	Antenna Verification												
10.11.1.4	Holography												
10.11.1.5	Beam and Sidelobes												
10.11.1.6	Gain vs. Elevation: Spillover Temp												
10.11.1.7	Effect of Sun in & Near the Beam												

10.11.2	Engineering Recommendations re Prod. Ant.												
10.11.3	Revise Interface Specifications												
10.11.5	Operations Personnel Training												
10.11.5.1	Recruit Initial Chile Ops Staff												
10.11.5.2	Array Operations												
10.11.5.3	Engineering Maintenance												
10.11.5.4	Scientific Support & Analysis												
10.12.2	Relocate Ops Staff to Chile												
10.8.4.6	Start On-site Operations												
10.12	Disassemble Test Interferometer												
10.12.1	Prepare & Ship Antenna #1, #2												
10.12.3	Restore Facilities at VLA Site												
10.13	On Site System Integration												
11	Calibration and Imaging												
11.1	Radiometric Phase Design & Prototype			8		\$ 78	\$ 20			\$ 18	\$ 98	\$ 18	\$ 98
11.1.1	Complete 183GHz Phase Mon Prototype												
11.1.2	Demo 183 GHz Phase Monitor Radiometer on-Site												
11.1.3	Design Refinement												
11.1.4	Release Phase Mon Radiometer for manufacture												
11.2	Production Fab of Phase Monitor Radiometer					\$ 170		\$ 19	\$ 45	\$ 151	\$ 45	\$ 151	
11.2.1	Contract Subassembly Fabrication												
11.2.1.1	Radiometer & Local Oscillator												
11.2.1.2	Spectrometer												
11.2.1.3	Feed, Window, lens, instrumentation												
11.2.1.4	M/C Interface												
11.2.2	Assembly & Test												
11.2.3	Deliver Production Radiometers												
11.2.4	Integration in Receiver Package												
11.2.5	Verification on-Site												
11.3	Production Fabrication of Dual-load Amp Cal Sys												
11.3.1	Design Refinement												
11.3.2	Release Phase Mon Radiometer for manufacture												
11.3.3	Contract Subassembly												
11.3.3.1	Machining												
11.3.3.2	Load Fabrication												
11.3.3.3	Motors, Servo												
11.3.3.4	M/C Interface												
11.3.4	Assembly & Test												
11.3.5	Integration on Production Antennas												
11.4	Imaging Studies & Project Support	48				\$ 390			\$ 59	\$ 390	\$ 59	\$ 390	
11.5	Imaging Algorithm Development	8	4			\$ 100			\$ 15	\$ 100	\$ 15	\$ 100	
	TOTALS					\$ 7,928	\$ 9,568	\$ -	\$ 1,976	\$ 2,509	\$ 15,520	\$ 2,509	\$ 15,520

Millimeter Array Construction 2002

WBS	Name	Scientists Work- Months	Programmers Work-Months	Engineers Work- Months	Technicians Work- Months	Personnel Cost	Materials and Supplies	Transfer to Operations	Adjustment to Scope	Contingency	Sum Cost	Inflated Contingency	Inflated Sum
1	Administration												
1.1	Project Management	72			24	\$ 702		\$ 98		\$ 91	\$ 605	\$ 93	\$ 620
1.1.1	Management, Planning, and Oversight						\$ 600			\$ -	\$ 600	\$ -	\$ 615
1.1.2	Business Operations						\$ 50			\$ 8	\$ 50	\$ 8	\$ 51
1.1.3	Chilean Operations						\$ 50			\$ 8	\$ 50	\$ 8	\$ 51
1.1.4	Safety and Health												
1.1.5	Personnel												
1.1.6	Project Science Office												
1.1.7	AUI Management						\$ 350			\$ -	\$ 350	\$ -	\$ 359
1.2	Engineering			24	12	\$ 293	\$ 20			\$ 47	\$ 313	\$ 48	\$ 320
1.2.1	System Engineering--Phase II												
1.2.2	Documentation System												
1.2.3	Production Engineering												
1.3	US Facilities												
1.3.1	CDL Permanent Facilities						\$ 600			\$ -	\$ 600	\$ -	\$ 615
1.3.2	Manufacturing Facilities						\$ 100			\$ 15	\$ 100	\$ 15	\$ 103
1.3.3	Common Infrastructure						\$ 200			\$ 30	\$ 200	\$ 31	\$ 205
2	Site Development			12		\$ 117	\$ 50			\$ 28	\$ 167	\$ 28	\$ 171
2.1	Review Legalities Regarding Array and OSF Sites												
2.2	Maintain Mining claims						\$ 25			\$ -	\$ 25	\$ -	\$ 26
2.3	Contract A&E Studies												
2.4	Hire Construction Manager for Chile												
2.5	Array Site												
2.5.1	Prepare Site Development Bid Packages												
2.5.1.1	Prepare Package for Array Site												
2.5.1.2	Review Bid Packages												
2.5.1.3	Bid Civil Works Construction												
2.5.2	Evaluate Array Site Bid Response												
2.5.2.1	Review Bids												
2.5.2.2	Recommend Contractors												
2.5.2.3	Award Array Site Contracts												
2.5.3	Contract Array Site Civil Works						\$ 17,507		\$ 2,153	\$ 3,071	\$ 15,355	\$ 3,148	\$ 15,738
2.5.3.1	Array Site												
2.5.3.2	Inspect Completed Site Constr												
2.5.3.3	Accept Site Facility												
2.6	Operations Support Facility												
2.6.1	Prepare OSF Bid Packages												
2.6.1.1	Prepare Package for OSF												
2.6.1.2	Review Bid Packages												
2.6.1.3	Bid Civil Works Construction												
2.6.2	Evaluate OSF Bid Response												
2.6.2.1	Review Bids												
2.6.2.2	Recommend Contractors												
2.6.2.3	Award Contracts												

2.6.3	Contract OSF Civil Works						\$ 10,637	\$ 503	\$ 644	\$ 1,923	\$ 9,491	\$ 1,971	\$ 9,728
2.6.3.1	Operations Support Facility												
2.6.3.2	Inspect Completed OSF Constr												
2.6.3.3	Accept OSF Facility												
2.7	OSF/Array Link												
2.7.1	Prepare OSF/Array Link Bid Package												
2.7.1.1	Prepare Package for OSF/Array F/O Link												
2.7.1.2	Review Bid Package												
2.7.1.3	Bid OSF/Array Link Construction												
2.7.2	Evaluate Bid Response												
2.7.2.1	Review Bids												
2.7.2.2	Recommend Contractors												
2.7.2.3	Award Contracts												
2.7.3	Contract Civil Works						\$ 3,890			\$ 778	\$ 3,890	\$ 797	\$ 3,987
2.7.3.1	OSF/Array Link												
2.7.3.2	Inspect Completed OSF/Array Link Constr												
2.7.3.3	Accept OSF/Array Link												
2.8	Prepare for Instrument Assembly												
2.8.1	Equip Array Site						\$ 5,430			\$ 1,086	\$ 5,430	\$ 1,113	\$ 5,566
2.8.2	Equip Operations Support Facility												
3	Antenna												
3.1	Antenna Engineering Support		48				\$ 468			\$ 70	\$ 468	\$ 72	\$ 480
3.3.40	Acceptance Tests Antenna #1												
3.3.45	Delivery of Antenna #1												
3.8.10	Sign Transporter Contract												
3.8.15	Transporter Acceptance tests												
3.8.20	Deliver/Accept Transporter #1												
3.7	Procurement of Antenna #2												
3.7.1	Antenna #2 Contract Supervision												
3.7.2	Antenna #2 Acceptance tests												
3.8	Negotiate Production Antenna Contract												
3.9	Sign Contract for Production Antennas												
3.10	Antenna Contract Supervision												
3.11	Accept Antenna #3 at OSF												
3.12	Prepare Antenna #3												
3.12.1	Outfit & Verify Ant #3 at OSF												
3.12.2	Move, Install & Verify Ant #3 on Site												
3.13	Accept Antenna #4 at OSF												
3.14	Prepare Antenna #4												
3.14.1	Outfit & Verify Ant #4 at OSF												
3.14.2	Move, Install & Verify Ant #4 on Site												
3.15	Accept Antenna#5 at OSF												
3.16	Prepare Antenna #5												
3.16.1	Outfit & Verify Ant #5 at OSF												
3.16.2	Move, Install & Verify Ant #5 on Site												
3.17	Accept Antenna#6 at OSF												
3.18	Prepare Antenna #6												
3.18.1	Outfit & Verify Ant #6 at OSF												
3.18.2	Move, Install & Verify Ant #6 on Site												
3.19	Accept Antenna #7 at OSF												

3.20	Prepare Antenna #7												
3.20.1	Outfit & Verify Ant #7 at OSF												
3.20.2	Move, Install & Verify Ant #7 on Site												
3.21	Accept Antenna #8 at OSF												
3.22	Prepare Antenna #8												
3.22.1	Outfit & Verify Ant #8 at OSF												
3.22.2	Move, Install & Verify Ant #8 on Site												
3.23	Accept Antenna #9 at OSF												
3.24	Prepare Antenna #9												
3.24.1	Outfit & Verify Ant #9 at OSF												
3.24.2	Move, Install & Verify Ant #9 on Site												
3.25	Accept Antenna #10 at OSF												
3.26	Prepare Antenna #10												
3.26.1	Outfit & Verify Ant #10 at OSF												
3.26.2	Move, Install and Verify Ant #10 on Site												
3.27	Accept Antenna #11 at OSF												
3.28	Prepare Antenna #11												
3.28.1	Outfit & Verify Ant #11 at OSF												
3.28.2	Move, Install & Verify Ant #11 on Site												
3.29	Accept Antenna #12 at OSF												
3.30	Prepare Antenna #12												
3.30.1	Outfit & Verify Ant #12 at OSF												
3.30.2	Move, Install & Verify Ant #12 on Site												
3.31	Accept Antenna #13 at OSF												
3.32	Prepare Antenna #13												
3.32.1	Outfit & Verify Ant #13 at OSF												
3.32.2	Move, Install & Verify Ant #13 on Site												
3.33	Accept Antenna #14 at OSF												
3.34	Prepare Antenna #14												
3.34.1	Outfit & Verify Ant #14 at OSF												
3.34.2	Move, Install & Verify Ant #14 on Site												
3.35	Accept Antenna #15 at OSF												
3.36	Prepare Antenna #15												
3.36.1	Outfit & Verify Ant #15 at OSF												
3.36.2	Move, Install & Verify Ant #15 on Site												
3.37	Accept Antenna #16 at OSF												
3.38	Prepare Antenna #16												
3.38.1	Outfit & Verify Ant #16 at OSF												
3.38.2	Move, Install & Verify Ant #16 on Site												
3.39	Accept Antenna #17 at OSF												
3.40	Prepare Antenna #17												
3.40.1	Outfit & Verify Ant #17 at OSF												
3.40.2	Move, Install & Verify Ant #17 on Site												
3.41	Accept Antenna #18 at OSF												
3.42	Prepare Antenna #18												
3.42.1	Outfit & Verify Ant #18 at OSF												
3.42.2	Move, Install & Verify Ant #18 on Site												
3.43	Accept Antenna #19 at OSF												
3.44	Prepare Antenna #19												
3.44.1	Outfit & Verify Ant #19 at OSF												
3.44.2	Move, Install & Verify Ant #19 on Site												
3.45	Accept Antenna #20 at OSF												
3.46	Prepare Antenna #20												
3.46.1	Outfit & Verify Ant #20 at OSF												

3.46.2	Move, Install & Verify Ant #20 on Site												
3.47	Accept Antenna #21 at OSF												
3.48	Prepare Antenna #21												
3.48.1	Outfit & Verify Ant #21 at OSF												
3.48.2	Move, Install & Verify Ant #21 on Site												
3.49	Accept Antenna #22 at OSF												
3.50	Prepare Antenna #22												
3.50.1	Outfit & Verify Ant #22 at OSF												
3.50.2	Move, Install & Verify Ant #22 on Site												
3.51	Accept Antenna #23 at OSF												
3.52	Prepare Antenna #23												
3.52.1	Outfit & Verify Ant #23 at OSF												
3.52.2	Move, Install & Verify Ant #23 on Site												
3.53	Accept Antenna #24 at OSF												
3.54	Prepare Antenna #24												
3.54.1	Outfit & Verify Ant #24 at OSF												
3.54.2	Move, Install & Verify Ant #24 on Site												
3.55	Accept Antenna #25 at OSF												
3.56	Prepare Antenna #25												
3.56.1	Outfit & Verify Ant #25 at OSF												
3.56.2	Move, Install & Verify Ant #25 on Site												
3.57	Accept Antenna #26 at OSF												
3.58	Prepare Antenna #26												
3.58.1	Outfit & Verify Ant #26 at OSF												
3.58.2	Move, Install & Verify Ant #26 on Site												
3.59	Accept Antenna #27 at OSF												
3.60	Prepare Antenna #27												
3.60.1	Outfit & Verify Ant #27 at OSF												
3.60.2	Move, Install & Verify Ant #27 on Site												
3.61	Accept Antenna #28 at OSF												
3.62	Prepare Antenna #28												
3.62.1	Outfit & Verify Ant #28 at OSF												
3.62.2	Move, Install & Verify Ant #28 on Site												
3.63	Accept Antenna #29 at OSF												
3.64	Prepare Antenna #29												
3.64.1	Outfit & Verify Ant #29 at OSF												
3.64.2	Move, Install & Verify Ant #29 on Site												
3.65	Accept Antenna #30 at OSF												
3.66	Prepare Antenna #30												
3.66.1	Outfit & Verify Ant #30 at OSF												
3.66.2	Move, Install & Verify Ant #30 on Site												
3.67	Accept Antenna #31 at OSF												
3.68	Prepare Antenna #31												
3.68.1	Outfit & Verify Ant #31 at OSF												
3.68.2	Move, Install and Verify Ant #31 on Site												
3.69	Accept Antenna #32 at OSF												
3.70	Prepare Antenna #32												
3.70.1	Outfit & Verify Ant #32 at OSF												
3.70.2	Move, Install & Verify Ant #32 on Site												
3.71	Accept Antenna #33 at OSF												
3.72	Prepare Antenna #33												
3.72.1	Outfit & Verify Ant #33 at OSF												
3.72.2	Move, Install and Verify Ant #33 on Site												
3.73	Accept Antenna #34 at OSF												

3.74	Prepare Antenna #34																			
3.74.1	Outfit & Verify Ant #34 at OSF																			
3.74.2	Move, Install and Verify Ant #34 on Site																			
3.75	Accept Antenna #35 at OSF																			
3.76	Prepare Antenna #35																			
3.76.1	Outfit & Verify Ant #35 at OSF																			
3.76.2	Move, Install & Verify Ant #35 on Site																			
3.77	Accept Antenna #36 at OSF																			
3.78	Prepare Antenna #36																			
3.78.1	Outfit & Verify Ant #36 at OSF																			
3.78.2	Move, Install & Verify Ant #36 on Site																			
3.79	Prepare Antenna #1																			
3.79.1	Antenna #1 Reassembled at OSF																			
3.79.2	Outfit & Verify Ant #1 at OSF																			
3.79.3	Move, Install & Verify Ant #1 on Site																			
3.80	Prepare Antenna #2																			
3.80.1	Antenna #2 Reassembled at OSF																			
3.80.2	Outfit & Verify Ant #2 at OSF																			
3.80.3	Move, Install & Verify Ant #2 on Site																			
3.81	Antenna Transporter																			
3.81.1	Contract for Transporter #1, move to Site																			
3.81.2	Contract for Transporters #2, #3																			
3.81.3	Accept Transporters #2, #3 at OSF																			
4	Receivers																			
4.1	Receiver Package																			
4.1.1	Prototype Production Receiver Cryogenics																			
4.1.1.1	CDR: Cryogenics Development																			
4.1.1.2	Construct & test prototype cryogenics																			
4.1.1.3	Deliver Prototype Cryogenics Subsystem																			
4.1.2	Prototype Production Receiver Package	12	12	\$	176	\$	100			\$	56	\$	276	\$	58	\$	282			
4.1.2.1	Prototype Receiver Package Integration																			
4.1.2.2	Prot. Rcvr. Pckg Lab Test & Evaluation																			
4.1.2.3	Complete Prototype MMA Receiver Package																			
4.1.3	MMA Rcvr Pckg Design Refinement																			
4.1.4	Documentation																			
4.1.5	Release MMA Receiver Pckg for manufacture																			
4.1.6	Contract for Receiver Pckg Subassemblies																			
4.1.6.1	Machine Dewars		30	\$	146	\$	50		\$	22	\$	30	\$	174	\$	31	\$	179		
4.1.6.2	Fabricate Cryogenics subsystems	6	24	\$	176	\$	240		\$	46	\$	84	\$	369	\$	87	\$	379		
4.1.6.3	Fabricate windows, IR filters, etc	6	30	\$	205	\$	100		\$	34	\$	51	\$	271	\$	52	\$	278		
4.1.7	Accept Receiver Pckg Subassemblies																			
4.1.7.1	Subassemblies #1-6																			
4.1.7.2	Subassemblies #7-16																			
4.1.7.3	Subassemblies #17-26																			
4.1.7.4	Subassemblies #27-36																			
4.1.7.5	Subassemblies #37-40																			
4.1.8	Fab Rcvr Pckg Instrumentation & Electronics	12	12		12	\$	280	\$	100		\$	42	\$	59	\$	337	\$	61	\$	346
4.1.9	Fabricate Receiver Inserts		24		24	\$	351	\$	100		\$	50	\$	68	\$	401	\$	69	\$	411
4.1.10	Assemble Receiver Package																			
4.1.10.1	Integrate Rcvr Instrumentation & subass'y		24		36	\$	410	\$	80		\$	54	\$	69	\$	435	\$	71	\$	446

4.1.10.2	Deliver Receiver Package #1-6												
4.1.10.3	Deliver Receiver Package #7-16												
4.1.10.4	Deliver Receiver Package #17-26												
4.1.10.5	Deliver Receiver Package #27-36												
4.1.10.6	Deliver Receiver Package #37-40												
4.2	SIS Receiver Modules												
4.2.1	211-275 GHz Module		36	24	\$ 468	\$ 100		\$ 63	\$ 81	\$ 505	\$ 83	\$ 518	
4.2.1.1	SIS Mixer												
4.2.1.1.1	Design, Fab and Test Mixer Design												
4.2.1.1.2	Deliver Production Design												
4.2.1.1.3	Fabricate Production Mixers												
4.2.1.2	Design & Verify Optics												
4.2.1.3	Design Module												
4.2.1.4	Contract Fabrication			4	\$ 20	\$ 100		\$ 13	\$ 29	\$ 106	\$ 30	\$ 109	
4.2.1.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.1.4.2	Assemble Modules												
4.2.1.5	Install SIS Mixer & Test Modules		12	24	\$ 234	\$ 40		\$ 30	\$ 38	\$ 244	\$ 39	\$ 250	
4.2.1.6	Deliver 211-275 GHz Receiver Modules												
4.2.1.6.1	Deliver Modules #1-7												
4.2.1.6.2	Deliver Modules #8-26												
4.2.1.6.3	Deliver Modules #27-40												
4.2.2	602-720 GHz Module												
4.2.2.1	SIS Mixer												
4.2.2.1.1	Design, Fabricate and Test Mixer Design		36	24	\$ 468	\$ 100		\$ 568	\$ -	\$ -	\$ -	\$ -	
4.2.2.1.2	Deliver Production Design												
4.2.2.1.3	Fabricate Production Mixers												
4.2.2.2	Design & Verify Optics												
4.2.2.3	Design Module												
4.2.2.4	Contract Fabrication			4	\$ 20	\$ 100		\$ 120	\$ -	\$ -	\$ -	\$ -	
4.2.2.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.2.4.2	Assemble Modules												
4.2.2.5	Install SIS Mixer and Test Modules		12	24	\$ 234	\$ 40		\$ 274	\$ -	\$ -	\$ -	\$ -	
4.2.2.6	Deliver 602-720 GHz Receiver Modules												
4.2.2.6.1	Deliver Modules #1-7												
4.2.2.6.2	Deliver Modules #8-26												
4.2.2.6.3	Deliver Modules #27-40												
4.2.3	275-370 GHz Receiver Module		24	24	\$ 351	\$ 400		\$ 83	\$ 148	\$ 668	\$ 151	\$ 684	
4.2.3.1	SIS Mixer												
4.2.3.1.1	Design, Fabricate and Test Mixer Design												
4.2.3.1.2	Deliver Production Design												
4.2.3.1.3	Fabricate Production Mixers												
4.2.3.2	Design & Verify Optics		2		\$ 20			\$ 2	\$ 2	\$ 17	\$ 2	\$ 18	
4.2.3.3	Design Module		6		\$ 59	\$ 50		\$ 12	\$ 20	\$ 96	\$ 21	\$ 99	
4.2.3.4	Contract Fabrication			2	\$ 10	\$ 50		\$ 7	\$ 14	\$ 53	\$ 15	\$ 54	
4.2.3.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.3.4.2	Assemble Modules												
4.2.3.5	Install SIS Mixer and Test Modules												
4.2.3.6	Deliver 275-370 GHz Receiver Module												
4.2.3.6.1	Deliver Modules #1-5												
4.2.3.6.2	Deliver Modules #6-30												
4.2.3.6.3	Deliver Modules #30-40												

4.2.4	91-119 GHz Receiver Module												
4.2.4.1	SIS Mixer												
4.2.4.1.1	Design, Fabricate & Test Mixer Design		24	24	\$ 351	\$ 400		\$ 83	\$ 148	\$ 668	\$ 151	\$ 684	
4.2.4.1.2	Deliver Production Design												
4.2.4.1.3	Fabricate Production Mixers												
4.2.4.2	Design & Verify Optics		2		\$ 20			\$ 2	\$ 2	\$ 17	\$ 2	\$ 18	
4.2.4.3	Design Module		6		\$ 59	\$ 50		\$ 12	\$ 20	\$ 96	\$ 21	\$ 99	
4.2.4.4	Contract Fabrication			2	\$ 10	\$ 50		\$ 7	\$ 14	\$ 53	\$ 15	\$ 54	
4.2.4.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.4.4.2	Assemble Modules												
4.2.4.5	Install SIS Mixer and Test Modules												
4.2.4.6	Deliver 91-119 GHz Receiver Modules												
4.2.4.6.1	Deliver Modules #1-5												
4.2.4.6.2	Deliver Modules #6-30												
4.2.4.6.3	Deliver Modules # 31-40												
4.2.5	163-211 GHz Receiver Module												
4.2.5.1	SIS Mixer												
4.2.5.1.1	Design, Fabricate & Test Mixer Design												
4.2.5.1.2	Deliver Production Design												
4.2.5.1.3	Fabricate Production Mixers												
4.2.5.2	Design & Verify Optics		6		\$ 59	\$ 50		\$ 12	\$ 20	\$ 96	\$ 21	\$ 99	
4.2.5.3	Design Module		6		\$ 59	\$ 50		\$ 12	\$ 20	\$ 96	\$ 21	\$ 99	
4.2.5.4	Contract Fabrication												
4.2.5.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.5.4.2	Assemble Modules												
4.2.5.5	Install SIS Mixer and Test												
4.2.5.6	Deliver 163-211 GHz Receiver Modules												
4.2.5.6.1	Deliver Modules #1-5												
4.2.5.6.2	Deliver Modules #6-30												
4.2.5.6.3	Deliver Modules #31-40												
4.2.6	385-500 GHz Receiver Module												
4.2.6.1	SIS Mixer												
4.2.6.1.1	Design, Fabricate & Test Mixer Design												
4.2.6.1.2	Deliver Production Design												
4.2.6.1.3	Fabricate Production Mixers												
4.2.6.2	Design and Verify Optics		6		\$ 59	\$ 50		\$ 109	\$ -	\$ -	\$ -	\$ -	
4.2.6.3	Design Module		6		\$ 59	\$ 50		\$ 109	\$ -	\$ -	\$ -	\$ -	
4.2.6.4	Contract Fabrication												
4.2.6.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.6.4.2	Assemble Modules												
4.2.6.5	Install SIS Mixer and Test												
4.2.6.6	Deliver 385-500 GHz Receiver Modules												
4.2.6.6.1	Deliver Modules #1-5												
4.2.6.6.2	Deliver Modules #6-30												
4.2.6.6.3	Deliver Modules #31-40												
4.2.7	125-163 GHz Receiver Module												
4.2.7.1	SIS Mixer												
4.2.7.1.1	Design, Fabricate & Test Mixer Design												
4.2.7.1.2	Deliver Production Design												
4.2.7.1.3	Fabricate Production Mixers												

4.2.7.2	Design & Verify Optics												
4.2.7.3	Design Module												
4.2.7.4	Contract Fabrication												
4.2.7.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.7.4.2	Assemble Modules												
4.2.7.5	Install SIS Mixer and Test												
4.2.7.6	Deliver 125-163 GHz Receiver Modules												
4.2.7.6.1	Deliver 125-163 GHz Modules #1-5												
4.2.7.6.2	Deliver 125-163 GHz Modules #6-30												
4.2.7.6.3	Deliver 125-163 GHz Modules #31-40												
4.3	HFET Receiver Modules		7	15	\$ 141	\$ 70		\$ 23	\$ 28	\$ 188	\$ 29	\$ 193	
4.3.1	Contract for HFET Wafer												
4.3.2	Receive Diced HFET Wafer												
4.3.3	33-45 GHz Module												
4.3.3.1	Design Module												
4.3.3.2	Design & Verify Optics												
4.3.3.3	Contract Fabrication												
4.3.3.3.1	Machine Blocks, Feed, WG, Lenses												
4.3.3.3.2	Assemble Modules												
4.3.3.3.3	Flip-in Mirror												
4.3.4	Install HFET & Test Modules												
4.3.5	Deliver 33-45 GHz Receiver Modules												
4.3.5.1	Deliver Modules #1-20												
4.3.5.2	Deliver Modules #21-40												
4.3.6	67-95 GHz Module												
4.3.6.1	Design Amplifier												
4.3.6.2	Design Module												
4.3.6.3	Design & Verify Optics												
4.3.6.4	Contract Fabrication												
4.3.6.4.1	Machine Blocks, Feed, WG, Lenses												
4.3.6.4.2	Assemble Modules												
4.3.6.5	Install HFET & Test Modules												
4.3.6.6	Deliver 67-95 GHz Receiver Modules												
4.3.6.6.1	Deliver Modules 67-95GHz #1-20												
4.3.6.6.2	Deliver Modules 67-95GHz #21-40												
5	LO System												
5.1	LO Reference: Prototype Systems												
5.1.1	Deliver: Bench Prototype												
5.1.2	Testing and Design Refinement												
5.1.3	Procure/Fab Field Prototypes												
5.1.4	Deliver: LO Ref Field Prototypes												
5.1.5	Field Prototype testing and Design Refinement												
5.1.6	Preproduction Review												
5.1.7	Final Documentation and Design Modifications												
5.1.8	Release for Manufacture												
5.2	LO Reference: Production System		12	12	\$ 176			\$ 26	\$ 176	\$ 27	\$ 180		
5.1.1	Production test and lab equipment												
5.1.2	H-maser Frequency Standard (& Rb)												
5.1.3	8 GHz PL Oscillator & Distributor				\$ 3		\$ 0	\$ 1	\$ 3	\$ 1	\$ 3		
5.1.4	10 GHz PL Oscillator & Distributor				\$ 5		\$ 1	\$ 1	\$ 4	\$ 1	\$ 5		

5.1.5	12 GHz PL Oscillator & Distributor						\$ 5		\$ 1	\$ 1	\$ 4	\$ 1	\$ 5
5.1.6	14 GHz PL Oscillator & Distributor						\$ 5		\$ 1	\$ 1	\$ 4	\$ 1	\$ 5
5.1.7	3.2-5.2 GHz Synthesizer						\$ 40		\$ 4	\$ 11	\$ 36	\$ 11	\$ 36
5.1.8	3.2 -5.2 GHz PLO and Fringe Generator						\$ 800		\$ 89	\$ 213	\$ 711	\$ 219	\$ 729
5.1.9	Sampler Clock 4 GHz PL Osc & Distributor						\$ 3		\$ 0	\$ 1	\$ 3	\$ 1	\$ 3
5.1.10	LO Ref Generator						\$ 8		\$ 1	\$ 2	\$ 7	\$ 2	\$ 7
5.1.11	LO Ref Distributor - Control Bldg						\$ 3		\$ 0	\$ 1	\$ 3	\$ 1	\$ 3
5.1.12	Microwave Round-trip Phase Measurement						\$ 300		\$ 33	\$ 80	\$ 267	\$ 82	\$ 273
5.1.13	10-15 GHz Frequency Synthesizer						\$ 500		\$ 56	\$ 133	\$ 444	\$ 137	\$ 456
5.1.14	First LO Fringe Generator						\$ 100		\$ 11	\$ 27	\$ 89	\$ 27	\$ 91
5.1.15	16 GHz PL Oscillator						\$ 200		\$ 22	\$ 53	\$ 178	\$ 55	\$ 182
5.1.16	26 GHz PL Oscillator						\$ 200		\$ 22	\$ 53	\$ 178	\$ 55	\$ 182
5.1.17	LO Ref Distributor - Antenna						\$ 100		\$ 11	\$ 27	\$ 89	\$ 27	\$ 91
5.1.18	VXCO Clean-up Loop						\$ 100		\$ 11	\$ 27	\$ 89	\$ 27	\$ 91
5.1.19	Power supply module						\$ 300		\$ 33	\$ 80	\$ 267	\$ 82	\$ 273
5.1.20	Bins / Racks (assemble and test)						\$ 80		\$ 9	\$ 21	\$ 71	\$ 22	\$ 73
5.3	Millimeter LO Drivers												
5.3.1	Design and System Integration		3			\$ 29				\$ 4	\$ 29	\$ 4	\$ 30
5.3.2	72-95 GHz Source		6	8	\$ 98	\$ 240			\$ 38	\$ 75	\$ 300	\$ 77	\$ 308
5.3.2.1	Contract Procurement and Fabrication												
5.3.2.1.1	YIG-tuned Oscillator												
5.3.2.1.2	18.00 - 23.75 GHz 10 db Amplifier												
5.3.2.1.3	18.00 - 23.75 GHz x2 Multiplier												
5.3.2.1.4	36.0 - 47.5 GHz 10 db Amplifier												
5.3.2.1.5	36.0 - 47.5 GHz x2 Multiplier												
5.3.2.1.6	Mount and Tuning circuitry												
5.3.2.2	Assembly and Test												
5.3.2.3	Deliver 72 - 95 GHz LO Sources												
5.3.2.3.1	Deliver Modules #1-6												
5.3.2.3.2	Deliver Modules #7-24												
5.3.2.3.3	Deliver Modules #25-40												
5.3.3	100-120 GHz Source		6	8	\$ 98	\$ 240			\$ 338	\$ -	\$ -	\$ -	\$ -
5.3.3.1	Contract Procurement and Fabrication												
5.3.3.1.1	YIG-tuned Oscillator												
5.3.3.1.2	25.00 - 30.00 GHz 10 db Amplifier												
5.3.3.1.3	15.00 - 30.00 GHz x2 Multiplier												
5.3.3.1.4	50.0 - 60.0 GHz 10 db Amplifier												
5.3.3.1.5	50-60 GHz x2 Multiplier												
5.3.3.1.6	Mount and Tuning circuitry												
5.3.3.2	Assembly and Test												
5.3.3.3	Deliver 100 - 120 GHz LO Sources												
5.3.3.3.1	Deliver Modules #1-3												
5.3.3.3.2	Deliver Modules #4-21												
5.3.3.3.3	Deliver Modules #22-40												
5.3.4	87 - 108 GHz Source												
5.3.4.1	Contract Procurement and Fabrication												
5.3.4.1.1	YIG-tuned Oscillator												
5.3.4.1.2	21.75-27.00 GHz 10 db Amplifier												
5.3.4.1.3	21.75-27.00 GHz x2 Multiplier												
5.3.4.1.4	43.5-54.0 GHz 10 db Amplifier												
5.3.4.1.5	43.5-54.0 GHz x2 Multiplier												

5.3.4.1.6	Mount and Tuning Circuitry																	
5.3.4.2	Assembly and Test																	
5.3.4.3	Deliver 87 - 108 GHz LO Sources																	
5.3.4.3.1	Deliver Modules #1-6																	
5.3.4.3.2	Deliver Modules #7-20																	
5.3.4.3.3	Deliver Modules #21-35																	
5.3.4.3.4	Deliver Modules #36-40																	
5.3.5	65 - 85 GHz Source																	
5.3.5.1	Contract Procurement and Fabrication																	
5.3.5.1.1	YIG-tuned Oscillator																	
5.3.5.1.2	16.25-21.25 GHz 10 db Amplifier																	
5.3.5.1.3	16.25-21.25 GHz x2 Multiplier																	
5.3.5.1.4	32.5-42.5 GHz 10 db Amplifier																	
5.3.5.1.5	32.5-42.5 GHz x2 Multiplier																	
5.3.5.1.6	Mount and Tuning Circuitry																	
5.3.5.2	Assembly and Test																	
5.3.5.3	Deliver 65 - 85 GHz LO Sources																	
5.3.5.3.1	Deliver Modules #1-6																	
5.3.5.3.2	Deliver Modules #7-20																	
5.3.5.3.3	Deliver Modules #21-35																	
5.3.5.3.4	Deliver Modules #36-40																	
5.4	Millimeter LO Multiplier Chains																	
5.4.1	Design and System Integration	2		\$	20				\$	3	\$	20	\$	3	\$	20		
5.4.2	211 - 275 GHz Receiver LO	6	24	\$	176	\$	75		\$	28	\$	40	\$	223	\$	41	\$	228
5.4.2.1	Contract Fabrication																	
5.4.2.1.1	X3 Diode for 72-95 GHz Source																	
5.4.2.1.2	Machine Mount																	
5.4.2.1.3	Bias and Control circuits																	
5.4.2.2	Assemble Multiplier and Test																	
5.4.2.3	Integrate Source and Multiplier; test																	
5.4.2.4	Deliver 211-275 GHz Rcvr LO Modules																	
5.4.2.4.1	Deliver Modules #1-3																	
5.4.2.4.2	Deliver Modules #4-21																	
5.4.2.4.3	Deliver Modules #22-40																	
5.4.3	602 - 720 GHz Receiver LO	6	24	\$	176	\$	75		\$	251	\$	-	\$	-	\$	-	\$	-
5.4.3.1	Contract Fabrication																	
5.4.3.1.1	X2 Diode for 100-120 GHz Source																	
5.4.3.1.2	X3 Diode for 200-240 GHz Input																	
5.4.3.1.3	Machine Mount																	
5.4.3.1.4	Bias and Control circuits																	
5.4.3.2	Assemble Multipliers and Test																	
5.4.3.3	Integrate Source and Multipliers; test																	
5.4.3.4	Deliver 602-720 GHz Rcvr LO Modules																	
5.4.3.4.1	Deliver Modules #1-6																	
5.4.3.4.2	Deliver Modules #7-18																	
5.4.3.4.3	Deliver Modules #19-34																	
5.4.3.4.4	Deliver Modules #35-40																	
5.4.4	275 - 370 GHz Receiver LO	3	9	\$	73	\$	20		\$	10	\$	14	\$	83	\$	14	\$	85
5.4.4.1	Contract Fabrication																	
5.4.4.1.1	X2 Diode for 72-95 GHz Source																	

5.4.4.1.2	X2 Diode for 144-190 GHz Input												
5.4.4.1.3	Machine Mount												
5.4.4.1.4	Bias and Control Circuits												
5.4.4.2	Assemble Multipliers and Test												
5.4.4.3	Integrate Source and Multipliers; test												
5.4.4.4	Deliver 275-370 GHz Rcvr LO Modules												
5.4.4.4.1	Deliver Modules #1-6												
5.4.4.4.2	Deliver Modules #7-27												
5.4.4.4.3	Deliver Modules #28-40												
5.4.5	163 - 211 GHz Receiver LO		3	9	\$ 73	\$ 20		\$ 10	\$ 14	\$ 83	\$ 14	\$ 85	
5.4.5.1	Contract Fabrication												
5.4.5.1.1	X2 Diode for 87-108 GHz Source												
5.4.5.1.2	Machine Mount												
5.4.5.1.3	Bias and Control Circuits												
5.4.5.2	Assemble Multiplier and Test												
5.4.5.3	Integrate Source and Multiplier; test												
5.4.5.4	Deliver 163 - 211 GHz Rcvr LO Modules												
5.4.5.4.1	Deliver Modules #1-6												
5.4.5.4.2	Deliver Modules #7-24												
5.4.5.4.3	Deliver Modules #25-40												
5.4.6	385 - 500 GHz Receiver LO												
5.4.6.1	Contract Fabrication												
5.4.6.1.1	X3 Diode for 65-85 GHz Source												
5.4.6.1.2	X2 Diode for 130-170 GHz Input												
5.4.6.1.3	Machine Mount												
5.4.6.1.4	Bias and Control Circuits												
5.4.6.2	Assemble Multiplier and test												
5.4.6.3	Integrate source and Multiplier; test												
5.4.6.4	Deliver 385-500 GHz Rcvr LO Modules												
5.4.6.4.1	Deliver Modules #1-6												
5.4.6.4.2	Deliver Modules #7-24												
5.4.6.4.3	Deliver Modules #25-40												
5.4.7	125 - 163 GHz Receiver LO												
5.4.7.1	Contract Fabrication												
5.4.7.1.1	X2 Diode for 65 - 85 GHz Source												
5.4.7.1.2	Machine Mount												
5.4.7.1.3	Bias and Control Circuits												
5.4.7.2	Assemble Multiplier and test												
5.4.7.3	Integrate Source and Multiplier; test												
5.4.7.4	Deliver 125-163 GHz Rcvr LO Modules												
5.4.7.4.1	Deliver Modules #1-6												
5.4.7.4.2	Deliver Modules #7-18												
5.4.7.4.3	Deliver Modules #19-34												
5.4.7.4.4	Deliver Modules #35-40												
5.4.8	33-45 GHz Receiver LO		3	6	\$ 59	\$ 25		\$ 9	\$ 13	\$ 74	\$ 14	\$ 76	
5.4.8.1	Design & Fab Selection & Coupling from Sources												
6	IF System		12	12	\$ 176			\$ 26	\$ 176	\$ 27	\$ 180		
6.1	IF System: Prototype Systems												

6.1.1	Deliver (Bench) Prototype IF System												
6.1.2	Testing and Design Refinement												
6.1.3	Procure/Fab Field Prototypes												
6.1.4	Deliver IF Field Prototypes to Test Interfeometer												
6.1.5	Field Prototype testing and Design Refinement												
6.1.6	Preproduction Review												
6.1.7	Final Documentation and Design Modifications												
6.1.8	Release for Manufacture												
6.2	Production test and lab equipment												
6.3	IF Multiplexer					\$ 800		\$ 89	\$ 107	\$ 711	\$ 109	\$ 729	
6.4	IF Demultiplexer					\$ 400		\$ 44	\$ 53	\$ 356	\$ 55	\$ 364	
6.5	IF Matrix Switch					\$ 320		\$ 36	\$ 43	\$ 284	\$ 44	\$ 292	
6.6	Baseband Converter					\$ 800		\$ 89	\$ 107	\$ 711	\$ 109	\$ 729	
6.7	Power supply module					\$ 200		\$ 22	\$ 27	\$ 178	\$ 27	\$ 182	
6.8	Bins / Racks (assemble and test)					\$ 80		\$ 9	\$ 11	\$ 71	\$ 11	\$ 73	
7	Optical Fiber System		12	12	\$ 176				\$ 26	\$ 176	\$ 27	\$ 180	
7.1	Optical Fiber System: Prototype Systems												
7.1.1	Deliver (Bench) Prototype FO System												
7.1.2	Testing and Design Refinement												
7.1.3	Procure/Fab Field Prototypes												
7.1.4	Deliver FO Field Prototypes to Test Interfeometer												
7.1.5	Field Prototype testing and Design Refinement												
7.1.6	Preproduction Review												
7.1.7	Final Documentation and Design Modifications												
7.1.8	Release for Manufacture												
7.1	Production test and lab equipment												
7.2	IF TX / RX					\$ 1,200		\$ 133	\$ 160	\$ 1,067	\$ 164	\$ 1,093	
7.3	LO Reference TX / RX					\$ 200		\$ 22	\$ 27	\$ 178	\$ 27	\$ 182	
7.4	Microwave Round-trip Phase TX / RX					\$ 200		\$ 22	\$ 27	\$ 178	\$ 27	\$ 182	
7.5	Monitor / Control TX / RX					\$ 100		\$ 11	\$ 13	\$ 89	\$ 14	\$ 91	
7.6	Power supply module					\$ 200		\$ 22	\$ 27	\$ 178	\$ 27	\$ 182	
7.7	Bins / Racks (assemble and test)					\$ 80		\$ 9	\$ 11	\$ 71	\$ 11	\$ 73	
											\$ -		
8	Correlator		36	36	\$ 527	\$ 2,000		\$ 281	\$ 595	\$ 2,246	\$ 610	\$ 2,302	
8.1	Digital Sampler, 4 GHz		6	12	\$ 117	\$ 428		\$ 61	\$ 128	\$ 484	\$ 131	\$ 497	
8.1.1	Refine Design												
8.1.2	Release Digital Sampler for Manufacture												
8.1.3	Contract Materials												
8.1.4	Assembly												
8.1.5	Validation and Delivery												
8.2	Digital FIR Filter		2	2	\$ 29	\$ 533		\$ 62	\$ 146	\$ 500	\$ 149	\$ 512	
8.2.1	Prototype testing on Test Interferometer												
8.2.2	Design Refinement												
8.2.3	Release FIR Filter for manufacture												
8.2.4	Chip Fabrication												
8.2.5	Assembly												
8.2.6	Validation and Delivery												
8.3	Custom Boards												
8.3.1	Correlator Board												

8.3.1.1	Prototype assembly												
8.3.1.2	Prototype test												
8.3.1.3	Design modifications												
8.3.1.4	Fab, assemble and test with design mods												
8.4	Correlator Chip												
8.4.1	Prototype chip fabrication												
8.4.2	Prototype chip test												
8.4.3	Design modifications												
8.4.4	Fabricate and test design mods												
8.4.5	Fabricate production run												
8.5	Racks												
8.5.1	Design control wiring												
8.5.2	Design signal wiring												
8.5.3	Order parts												
8.5.4	Assemble prototypes												
8.6	Software												
8.7	Prototype Correlator Production												
8.7.1	Order parts												
8.7.2	Assemble												
8.7.3	Test												
8.7.4	Deliver Prototype Correlator to VLA site												
8.8	Site Correlator Production												
8.8.1	First 1/4 correlator												
8.8.1.1	Determine configuration												
8.8.1.2	Order parts												
8.8.1.3	Assemble												
8.8.1.4	Test												
8.8.1.5	Deliver 1/4 Correlator to MMA site												
8.8.2	Second 1/4 correlator												
8.8.2.1	Order parts												
8.8.2.2	Assemble												
8.8.2.3	Test												
8.8.2.4	Deliver 1/4 Correlator to MMA site												
8.8.3	Third 1/4 correlator												
8.8.3.1	Order parts												
8.8.3.2	Assemble												
8.8.3.3	Test												
8.8.3.4	Deliver 1/4 Correlator to MMA site												
8.8.4	Fourth 1/4 correlator												
8.8.4.1	Order parts												
8.8.4.2	Assemble												
8.8.4.3	Test												
8.8.4.4	Deliver 1/4 Correlator to MMA site												
8.9	Continued Support												
9	Computing						\$ 50			\$ 15	\$ 50	\$ 15	\$ 51
9.1	Control Software												
9.1.1	Test Interferometer Control & Analysis												
9.1.2	MMA correlator software		52			\$ 451			\$ 68	\$ 451	\$ 69	\$ 462	
9.1.3	Multi-antenna & sub-array control												
9.1.4	Operators & Observers interfaces		26			\$ 225			\$ 34	\$ 225	\$ 35	\$ 231	
9.1.5	Deliver Control Software												
9.1.6	Maintenance												

9.2	Scheduling												
9.2.1	Static scheduling system	10				\$ 87				\$ 13	\$ 87	\$ 13	\$ 89
9.2.2	Dynamic scheduling simulations	12				\$ 104				\$ 16	\$ 104	\$ 16	\$ 107
9.2.3	Dynamic scheduling prototype												
9.2.4	Dynamic scheduling implementation												
9.2.5	Initial Operations with Dynamic Scheduling												
9.3	Proposal Preparation Software												
9.3.1	Prototype	6				\$ 52				\$ 8	\$ 52	\$ 8	\$ 53
9.3.2	Production version												
9.4	Image Pipeline												
9.4.1	Automated calibration & imaging heuristics	6				\$ 52				\$ 8	\$ 52	\$ 8	\$ 53
9.4.2	Prototype image pipeline												
9.4.3	Parallelization studies and implementation												
9.4.4	Initial Image Pipeline Operations												
9.4.5	Production image pipeline												
9.5	Archiving												
9.5.1	Prototype distributed archive	10				\$ 87				\$ 13	\$ 87	\$ 13	\$ 89
9.5.2	Evaluate storage hardware												
9.5.3	Production archive												
9.5.4	Data Archive operational												
9.6	Post-processing												
9.6.1	Define MMA Data formats	6				\$ 52				\$ 8	\$ 52	\$ 8	\$ 53
9.6.2	MMA filler & format conversions												
9.6.3	MMA-specific calibrations	6				\$ 52				\$ 8	\$ 52	\$ 8	\$ 53
9.6.4	MMA Post-processing begins												
9.6.5	Maintenance												
10	System Integration					\$ 50				\$ 15	\$ 50	\$ 15	\$ 51
10.4	Test Interferometer Site Preparation												
10.4.1	Complete Office and Lab Space Preparation												
10.4.2	Cabling												
10.4.3	Test Interferometer Site Complete												
10.10.4	Prototype Antenna Outfitting												
10.10.4.1	Cabling												
10.10.4.2	Instrumentation												
10.10.4.3	Eval. Rcvr. #1 / Ant. #1 Integration		24	12	\$ 293					\$ 44	\$ 293	\$ 45	\$ 300
10.10.4.4	Antenna #1 Outfitting Complete												
10.10.5	Integration Holography System/Antenna												
10.10.6	Integration Metrology/Antenna												
10.10.7	Antenna #1 Integration & Testing												
10.10.8	Prot. Rcvr. Test & Evaluation												
10.10.9	Antenna #2 Outfitting												
10.10.9.1	Cabling												
10.10.9.2	Instrumentation												
10.10.9.3	Eval. Rcvr. #2 / Ant. #2 Integration												
10.10.9.4	Antenna #2 Outfitting Complete												
10.11	Test Interferometer	6	24	12	\$ 345					\$ 52	\$ 345	\$ 53	\$ 353
10.11.1	Antenna Evaluation & Characterization												
10.11.1.1	Antenna Verification												
10.11.1.4	Holography												
10.11.1.5	Beam and Sidelobes												
10.11.1.6	Gain vs. Elevation: Spillover Temp												
10.11.1.7	Effect of Sun in & Near the Beam												

10.11.2	Engineering Recommendations re Prod. Ant.												
10.11.3	Revise Interface Specifications												
10.11.5	Operations Personnel Training	5				\$ 41		\$ 41		\$ -	\$ -	\$ -	\$ -
10.11.5.1	Recruit Initial Chile Ops Staff												
10.11.5.2	Array Operations												
10.11.5.3	Engineering Maintenance												
10.11.5.4	Scientific Support & Analysis												
10.12.2	Relocate Ops Staff to Chile												
10.8.4.6	Start On-site Operations												
10.12	Disassemble Test Interferometer												
10.12.1	Prepare & Ship Antenna #1, #2												
10.12.3	Restore Facilities at VLA Site												
10.13	On Site System Integration												
11	Calibration and Imaging	1				\$ 8				\$ 1	\$ 8	\$ 1	\$ 8
11.1	Radiometric Phase Design & Prototype												
11.1.1	Complete 183GHz Phase Mon Prototype												
11.1.2	Demo 183 GHz Phase Monitor Radiometer on-Site												
11.1.3	Design Refinement												
11.1.4	Release Phase Mon Radiometer for manufacture												
11.2	Production Fab of Phase Monitor Radiometer					\$ 681		\$ 76	\$ 182	\$ 605	\$ 186	\$ 620	
11.2.1	Contract Subassembly Fabrication												
11.2.1.1	Radiometer & Local Oscillator												
11.2.1.2	Spectrometer												
11.2.1.3	Feed, Window, lens, instrumentation												
11.2.1.4	M/C Interface												
11.2.2	Assembly & Test												
11.2.3	Deliver Production Radiometers												
11.2.4	Integration in Receiver Package												
11.2.5	Verification on-Site												
11.3	Production Fabrication of Dual-load Amp Cal Sys					\$ 291		\$ 32	\$ 78	\$ 259	\$ 80	\$ 265	
11.3.1	Design Refinement												
11.3.2	Release Phase Mon Radiometer for manufacture												
11.3.3	Contract Subassembly												
11.3.3.1	Machining												
11.3.3.2	Load Fabrication												
11.3.3.3	Motors, Servo												
11.3.3.4	M/C Interface												
11.3.4	Assembly & Test												
11.3.5	Integration on Production Antennas												
11.4	Imaging Studies & Project Support	48				\$ 390		\$ 195	\$ 29	\$ 195	\$ 30	\$ 200	
11.5	Imaging Algorithm Development	8	4			\$ 100			\$ 15	\$ 100	\$ 15	\$ 102	
	TOTALS					\$ 10,353	\$ 54,089	\$ 836	\$ 6,596	\$ 10,353	\$ 57,011	\$ 11,498	\$ 58,436

Millimeter Array Construction 2003

WBS	Name	Scientists Work- Months	Programmers Work Months	Engineers Work- Months	Technicians Work- Months	Personnel Cost	Materials and Supplies	Transfer to Operations	Adjustment to Scope	Contingency	Sum Cost	Inflated Contingency	Inflated Sum
1	Administration												
1.1	Project Management	72			48	\$ 819		\$ 215		\$ 91	\$ 605	\$ 95	\$ 635
1.1.1	Management, Planning, and Oversight						\$ 600			\$ -	\$ 600	\$ -	\$ 630
1.1.2	Business Operations						\$ 90			\$ 14	\$ 90	\$ 14	\$ 95
1.1.3	Chilean Operations						\$ 50			\$ 8	\$ 50	\$ 8	\$ 53
1.1.4	Safety and Health												
1.1.5	Personnel												
1.1.6	Project Science Office												
1.1.7	AUI Management						\$ 350			\$ -	\$ 350	\$ -	\$ 368
1.2	Engineering			24	12	\$ 293	\$ 20			\$ 47	\$ 313	\$ 49	\$ 328
1.2.1	System Engineering--Phase II												
1.2.2	Documentation System												
1.2.3	Production Engineering												
1.3	US Facilities												
1.3.1	CDL Permanent Facilities						\$ 600			\$ -	\$ 600	\$ -	\$ 630
1.3.2	Manufacturing Facilities						\$ 100			\$ 15	\$ 100	\$ 16	\$ 105
1.3.3	Common Infrastructure						\$ 200			\$ 30	\$ 200	\$ 32	\$ 210
2	Site Development			12		\$ 117	\$ 50			\$ 28	\$ 167	\$ 29	\$ 175
2.1	Review Legalities Regarding Array and OSF Sites												
2.2	Maintain Mining claims						\$ 25			\$ -	\$ 25	\$ -	\$ 26
2.3	Contract A&E Studies												
2.4	Hire Construction Manager for Chile												
2.5	Array Site												
2.5.1	Prepare Site Development Bid Packages												
2.5.1.1	Prepare Package for Array Site												
2.5.1.2	Review Bid Packages												
2.5.1.3	Bid Civil Works Construction												
2.5.2	Evaluate Array Site Bid Response												
2.5.2.1	Review Bids												
2.5.2.2	Recommend Contractors												
2.5.2.3	Award Array Site Contracts												
2.5.3	Contract Array Site Civil Works						\$ 5,836		\$ 718	\$ 1,024	\$ 5,119	\$ 1,076	\$ 5,378
2.5.3.1	Array Site												
2.5.3.2	Inspect Completed Site Constr												
2.5.3.3	Accept Site Facility												
2.6	Operations Support Facility												
2.6.1	Prepare OSF Bid Packages												
2.6.1.1	Prepare Package for OSF												
2.6.1.2	Review Bid Packages												
2.6.1.3	Bid Civil Works Construction												
2.6.2	Evaluate OSF Bid Response												
2.6.2.1	Review Bids												
2.6.2.2	Recommend Contractors												
2.6.2.3	Award Contracts												

2.6.3	Contract OSF Civil Works						\$ 3,546	\$ 215	\$ 168	\$ 644	\$ 3,164	\$ 676	\$ 3,324
2.6.3.1	Operations Support Facility												
2.6.3.2	Inspect Completed OSF Constr												
2.6.3.3	Accept OSF Facility												
2.7	OSF/Array Link												
2.7.1	Prepare OSF/Array Link Bid Package												
2.7.1.1	Prepare Package for OSF/Array F/O Link												
2.7.1.2	Review Bid Package												
2.7.1.3	Bid OSF/Array Link Construction												
2.7.2	Evaluate Bid Response												
2.7.2.1	Review Bids												
2.7.2.2	Recommend Contractors												
2.7.2.3	Award Contracts												
2.7.3	Contract Civil Works												
2.7.3.1	OSF/Array Link												
2.7.3.2	Inspect Completed OSF/Array Link Constr												
2.7.3.3	Accept OSF/Array Link												
2.8	Prepare for Instrument Assembly												
2.8.1	Equip Array Site												
2.8.2	Equip Operations Support Facility												
3	Antenna												
3.1	Antenna Engineering Support												
3.3.40	Acceptance Tests Antenna #1												
3.3.45	Delivery of Antenna #1												
3.8.10	Sign Transporter Contract												
3.8.15	Transporter Acceptance tests												
3.8.20	Deliver/Accept Transporter #1												
3.7	Procurement of Antenna #2												
3.7.1	Antenna #2 Contract Supervision												
3.7.2	Antenna #2 Acceptance tests												
3.8	Negotiate Production Antenna Contract												
3.9	Sign Contract for Production Antennas						\$ 1,000			\$ 200	\$ 1,000	\$ 210	\$ 1,051
3.10	Antenna Contract Supervision												
3.11	Accept Antenna #3 at OSF			3		\$ 29	\$ 2,832			\$ 571	\$ 2,861	\$ 600	\$ 3,006
3.12	Prepare Antenna #3												
3.12.1	Outfit & Verify Ant #3 at OSF												
3.12.2	Move, Install & Verify Ant #3 on Site												
3.13	Accept Antenna #4 at OSF			3		\$ 29	\$ 2,832			\$ 571	\$ 2,861	\$ 600	\$ 3,006
3.14	Prepare Antenna #4												
3.14.1	Outfit & Verify Ant #4 at OSF												
3.14.2	Move, Install & Verify Ant #4 on Site												
3.15	Accept Antenna#5 at OSF			3		\$ 29	\$ 2,832			\$ 571	\$ 2,861	\$ 600	\$ 3,006
3.16	Prepare Antenna #5												
3.16.1	Outfit & Verify Ant #5 at OSF												
3.16.2	Move, Install & Verify Ant #5 on Site												
3.17	Accept Antenna#6 at OSF			3		\$ 29	\$ 2,832			\$ 571	\$ 2,861	\$ 600	\$ 3,006
3.18	Prepare Antenna #6												
3.18.1	Outfit & Verify Ant #6 at OSF												
3.18.2	Move, Install & Verify Ant #6 on Site												
3.19	Accept Antenna #7 at OSF												

3.20	Prepare Antenna #7												
3.20.1	Outfit & Verify Ant #7 at OSF												
3.20.2	Move, Install & Verify Ant #7 on Site												
3.21	Accept Antenna #8 at OSF												
3.22	Prepare Antenna #8												
3.22.1	Outfit & Verify Ant #8 at OSF												
3.22.2	Move, Install & Verify Ant #8 on Site												
3.23	Accept Antenna #9 at OSF												
3.24	Prepare Antenna #9												
3.24.1	Outfit & Verify Ant #9 at OSF												
3.24.2	Move, Install & Verify Ant #9 on Site												
3.25	Accept Antenna #10 at OSF												
3.26	Prepare Antenna #10												
3.26.1	Outfit & Verify Ant #10 at OSF												
3.26.2	Move, Install and Verify Ant #10 on Site												
3.27	Accept Antenna #11 at OSF												
3.28	Prepare Antenna #11												
3.28.1	Outfit & Verify Ant #11 at OSF												
3.28.2	Move, Install & Verify Ant #11 on Site												
3.29	Accept Antenna #12 at OSF												
3.30	Prepare Antenna #12												
3.30.1	Outfit & Verify Ant #12 at OSF												
3.30.2	Move, Install & Verify Ant #12 on Site												
3.31	Accept Antenna #13 at OSF												
3.32	Prepare Antenna #13												
3.32.1	Outfit & Verify Ant #13 at OSF												
3.32.2	Move, Install & Verify Ant #13 on Site												
3.33	Accept Antenna #14 at OSF												
3.34	Prepare Antenna #14												
3.34.1	Outfit & Verify Ant #14 at OSF												
3.34.2	Move, Install & Verify Ant #14 on Site												
3.35	Accept Antenna #15 at OSF												
3.36	Prepare Antenna #15												
3.36.1	Outfit & Verify Ant #15 at OSF												
3.36.2	Move, Install & Verify Ant #15 on Site												
3.37	Accept Antenna #16 at OSF												
3.38	Prepare Antenna #16												
3.38.1	Outfit & Verify Ant #16 at OSF												
3.38.2	Move, Install & Verify Ant #16 on Site												
3.39	Accept Antenna #17 at OSF												
3.40	Prepare Antenna #17												
3.40.1	Outfit & Verify Ant #17 at OSF												
3.40.2	Move, Install & Verify Ant #17 on Site												
3.41	Accept Antenna #18 at OSF												
3.42	Prepare Antenna #18												
3.42.1	Outfit & Verify Ant #18 at OSF												
3.42.2	Move, Install & Verify Ant #18 on Site												
3.43	Accept Antenna #19 at OSF												
3.44	Prepare Antenna #19												
3.44.1	Outfit & Verify Ant #19 at OSF												
3.44.2	Move, Install & Verify Ant #19 on Site												
3.45	Accept Antenna #20 at OSF												
3.46	Prepare Antenna #20												
3.46.1	Outfit & Verify Ant #20 at OSF												

3.46.2	Move, Install & Verify Ant #20 on Site												
3.47	Accept Antenna #21 at OSF												
3.48	Prepare Antenna #21												
3.48.1	Outfit & Verify Ant #21 at OSF												
3.48.2	Move, Install & Verify Ant #21 on Site												
3.49	Accept Antenna #22 at OSF												
3.50	Prepare Antenna #22												
3.50.1	Outfit & Verify Ant #22 at OSF												
3.50.2	Move, Install & Verify Ant #22 on Site												
3.51	Accept Antenna #23 at OSF												
3.52	Prepare Antenna #23												
3.52.1	Outfit & Verify Ant #23 at OSF												
3.52.2	Move, Install & Verify Ant #23 on Site												
3.53	Accept Antenna #24 at OSF												
3.54	Prepare Antenna #24												
3.54.1	Outfit & Verify Ant #24 at OSF												
3.54.2	Move, Install & Verify Ant #24 on Site												
3.55	Accept Antenna #25 at OSF												
3.56	Prepare Antenna #25												
3.56.1	Outfit & Verify Ant #25 at OSF												
3.56.2	Move, Install & Verify Ant #25 on Site												
3.57	Accept Antenna #26 at OSF												
3.58	Prepare Antenna #26												
3.58.1	Outfit & Verify Ant #26 at OSF												
3.58.2	Move, Install & Verify Ant #26 on Site												
3.59	Accept Antenna #27 at OSF												
3.60	Prepare Antenna #27												
3.60.1	Outfit & Verify Ant #27 at OSF												
3.60.2	Move, Install & Verify Ant #27 on Site												
3.61	Accept Antenna #28 at OSF												
3.62	Prepare Antenna #28												
3.62.1	Outfit & Verify Ant #28 at OSF												
3.62.2	Move, Install & Verify Ant #28 on Site												
3.63	Accept Antenna #29 at OSF												
3.64	Prepare Antenna #29												
3.64.1	Outfit & Verify Ant #29 at OSF												
3.64.2	Move, Install & Verify Ant #29 on Site												
3.65	Accept Antenna #30 at OSF												
3.66	Prepare Antenna #30												
3.66.1	Outfit & Verify Ant #30 at OSF												
3.66.2	Move, Install & Verify Ant #30 on Site												
3.67	Accept Antenna #31 at OSF												
3.68	Prepare Antenna #31												
3.68.1	Outfit & Verify Ant #31 at OSF												
3.68.2	Move, Install and Verify Ant #31 on Site												
3.69	Accept Antenna #32 at OSF												
3.70	Prepare Antenna #32												
3.70.1	Outfit & Verify Ant #32 at OSF												
3.70.2	Move, Install & Verify Ant #32 on Site												
3.71	Accept Antenna #33 at OSF												
3.72	Prepare Antenna #33												
3.72.1	Outfit & Verify Ant #33 at OSF												
3.72.2	Move, Install and Verify Ant #33 on Site												
3.73	Accept Antenna #34 at OSF												

3.74	Prepare Antenna #34																		
3.74.1	Outfit & Verify Ant #34 at OSF																		
3.74.2	Move, Install and Verify Ant #34 on Site																		
3.75	Accept Antenna #35 at OSF																		
3.76	Prepare Antenna #35																		
3.76.1	Outfit & Verify Ant #35 at OSF																		
3.76.2	Move, Install & Verify Ant #35 on Site																		
3.77	Accept Antenna #36 at OSF																		
3.78	Prepare Antenna #36																		
3.78.1	Outfit & Verify Ant #36 at OSF																		
3.78.2	Move, Install & Verify Ant #36 on Site																		
3.79	Prepare Antenna #1																		
3.79.1	Antenna #1 Reassembled at OSF																		
3.79.2	Outfit & Verify Ant #1 at OSF																		
3.79.3	Move, Install & Verify Ant #1 on Site																		
3.80	Prepare Antenna #2																		
3.80.1	Antenna #2 Reassembled at OSF																		
3.80.2	Outfit & Verify Ant #2 at OSF																		
3.80.3	Move, Install & Verify Ant #2 on Site																		
3.81	Antenna Transporter																		
3.81.1	Contract for Transporter #1, move to Site																		
3.81.2	Contract for Transporters #2, #3								\$ 1,508		\$ 754	\$ 151	\$ 754	\$ 158	\$ 792				
3.81.3	Accept Transporters #2, #3 at OSF																		
4	Receivers																		
4.1	Receiver Package																		
4.1.1	Prototype Production Receiver Cryogenics																		
4.1.1.1	CDR: Cryogenics Development																		
4.1.1.2	Construct & test prototype cryogenics																		
4.1.1.3	Deliver Prototype Cryogenics Subsystem																		
4.1.2	Prototype Production Receiver Package																		
4.1.2.1	Prototype Receiver Package Integration																		
4.1.2.2	Prot. Rcvr. Pckg Lab Test & Evaluation																		
4.1.2.3	Complete Prototype MMA Receiver Package																		
4.1.3	MMA Rcvr Pckg Design Refinement																		
4.1.4	Documentation																		
4.1.5	Release MMA Receiver Pckg for manufacture																		
4.1.6	Contract for Receiver Pckg Subassemblies																		
4.1.6.1	Machine Dewars					30	\$ 146	\$ 50		\$ 22	\$ 28	\$ 174	\$ 29	\$ 183					
4.1.6.2	Fabricate Cryogenics subsystems	6			24	\$ 176	\$ 240		\$ 46	\$ 65	\$ 369	\$ 68	\$ 388						
4.1.6.3	Fabricate windows, IR filters, etc	6			30	\$ 205	\$ 100		\$ 34	\$ 44	\$ 271	\$ 46	\$ 285						
4.1.7	Accept Receiver Pckg Subassemblies																		
4.1.7.1	Subassemblies #1-6																		
4.1.7.2	Subassemblies #7-16																		
4.1.7.3	Subassemblies #17-26																		
4.1.7.4	Subassemblies #27-36																		
4.1.7.5	Subassemblies #37-40																		
4.1.8	Fab Rcvr Pckg Instrumentation & Electronics	12	6	12	\$ 221	\$ 100		\$ 36	\$ 46	\$ 285	\$ 48	\$ 300							
4.1.9	Fabricate Receiver Inserts		24	24	\$ 351	\$ 100		\$ 50	\$ 63	\$ 401	\$ 66	\$ 421							
4.1.10	Assemble Receiver Package		24	36	\$ 410	\$ 80		\$ 54	\$ 67	\$ 435	\$ 70	\$ 457							
4.1.10.1	Integrate Rcvr Instrumentation & subass'y																		

4.1.10.2	Deliver Receiver Package #1-6																				
4.1.10.3	Deliver Receiver Package #7-16																				
4.1.10.4	Deliver Receiver Package #17-26																				
4.1.10.5	Deliver Receiver Package #27-36																				
4.1.10.6	Deliver Receiver Package #37-40																				
4.2	SIS Receiver Modules																				
4.2.1	211-275 GHz Module																				
4.2.1.1	SIS Mixer																				
4.2.1.1.1	Design, Fab and Test Mixer Design																				
4.2.1.1.2	Deliver Production Design																				
4.2.1.1.3	Fabricate Production Mixers																				
4.2.1.2	Design & Verify Optics																				
4.2.1.3	Design Module																				
4.2.1.4	Contract Fabrication				4	\$	20	\$	100			\$	13	\$	20	\$	106	\$	21	\$	112
4.2.1.4.1	Machine Mixer Blocks, Feed, WG, Lenses																				
4.2.1.4.2	Assemble Modules																				
4.2.1.5	Install SIS Mixer & Test Modules			18	36	\$	351	\$	30			\$	42	\$	50	\$	339	\$	53	\$	356
4.2.1.6	Deliver 211-275 GHz Receiver Modules																				
4.2.1.6.1	Deliver Modules #1-7																				
4.2.1.6.2	Deliver Modules #8-26																				
4.2.1.6.3	Deliver Modules #27-40																				
4.2.2	602-720 GHz Module																				
4.2.2.1	SIS Mixer																				
4.2.2.1.1	Design, Fabricate and Test Mixer Design																				
4.2.2.1.2	Deliver Production Design																				
4.2.2.1.3	Fabricate Production Mixers																				
4.2.2.2	Design & Verify Optics																				
4.2.2.3	Design Module																				
4.2.2.4	Contract Fabrication				4	\$	20	\$	100			\$	120	\$	-	\$	-	\$	-	\$	-
4.2.2.4.1	Machine Mixer Blocks, Feed, WG, Lenses																				
4.2.2.4.2	Assemble Modules																				
4.2.2.5	Install SIS Mixer and Test Modules			18	36	\$	351	\$	30			\$	381	\$	-	\$	-	\$	-	\$	-
4.2.2.6	Deliver 602-720 GHz Receiver Modules																				
4.2.2.6.1	Deliver Modules #1-7																				
4.2.2.6.2	Deliver Modules #8-26																				
4.2.2.6.3	Deliver Modules #27-40																				
4.2.3	275-370 GHz Receiver Module																				
4.2.3.1	SIS Mixer			36	24	\$	468	\$	100			\$	63	\$	78	\$	505	\$	82	\$	530
4.2.3.1.1	Design, Fabricate and Test Mixer Design																				
4.2.3.1.2	Deliver Production Design																				
4.2.3.1.3	Fabricate Production Mixers																				
4.2.3.2	Design & Verify Optics																				
4.2.3.3	Design Module																				
4.2.3.4	Contract Fabrication				4	\$	20	\$	100			\$	13	\$	20	\$	106	\$	21	\$	112
4.2.3.4.1	Machine Mixer Blocks, Feed, WG, Lenses																				
4.2.3.4.2	Assemble Modules																				
4.2.3.5	Install SIS Mixer and Test Modules			12	24	\$	234	\$	40			\$	30	\$	37	\$	244	\$	39	\$	256
4.2.3.6	Deliver 275-370 GHz Receiver Module																				
4.2.3.6.1	Deliver Modules #1-5																				
4.2.3.6.2	Deliver Modules #6-30																				
4.2.3.6.3	Deliver Modules #30-40																				

4.2.4	91-119 GHz Receiver Module												
4.2.4.1	SIS Mixer		36	24	\$ 468	\$ 100		\$ 63	\$ 78	\$ 505	\$ 82	\$ 530	
4.2.4.1.1	Design, Fabricate & Test Mixer Design												
4.2.4.1.2	Deliver Production Design												
4.2.4.1.3	Fabricate Production Mixers												
4.2.4.2	Design & Verify Optics												
4.2.4.3	Design Module												
4.2.4.4	Contract Fabrication			4	\$ 20	\$ 100		\$ 13	\$ 20	\$ 106	\$ 21	\$ 112	
4.2.4.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.4.4.2	Assemble Modules												
4.2.4.5	Install SIS Mixer and Test Modules		12	24	\$ 234	\$ 40		\$ 30	\$ 37	\$ 244	\$ 39	\$ 256	
4.2.4.6	Deliver 91-119 GHz Receiver Modules												
4.2.4.6.1	Deliver Modules #1-5												
4.2.4.6.2	Deliver Modules #6-30												
4.2.4.6.3	Deliver Modules # 31-40												
4.2.5	163-211 GHz Receiver Module												
4.2.5.1	SIS Mixer		24	24	\$ 351	\$ 400		\$ 83	\$ 116	\$ 668	\$ 122	\$ 701	
4.2.5.1.1	Design, Fabricate & Test Mixer Design												
4.2.5.1.2	Deliver Production Design												
4.2.5.1.3	Fabricate Production Mixers												
4.2.5.2	Design & Verify Optics												
4.2.5.3	Design Module												
4.2.5.4	Contract Fabrication			2	\$ 10	\$ 100		\$ 12	\$ 19	\$ 98	\$ 20	\$ 102	
4.2.5.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.5.4.2	Assemble Modules												
4.2.5.5	Install SIS Mixer and Test												
4.2.5.6	Deliver 163-211 GHz Receiver Modules												
4.2.5.6.1	Deliver Modules #1-5												
4.2.5.6.2	Deliver Modules #6-30												
4.2.5.6.3	Deliver Modules #31-40												
4.2.6	385-500 GHz Receiver Module												
4.2.6.1	SIS Mixer		24	24	\$ 351	\$ 400		\$ 751	\$ -	\$ -	\$ -	\$ -	
4.2.6.1.1	Design, Fabricate & Test Mixer Design												
4.2.6.1.2	Deliver Production Design												
4.2.6.1.3	Fabricate Production Mixers												
4.2.6.2	Design and Verify Optics												
4.2.6.3	Design Module												
4.2.6.4	Contract Fabrication			2	\$ 10	\$ 100		\$ 110	\$ -	\$ -	\$ -	\$ -	
4.2.6.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.6.4.2	Assemble Modules												
4.2.6.5	Install SIS Mixer and Test												
4.2.6.6	Deliver 385-500 GHz Receiver Modules												
4.2.6.6.1	Deliver Modules #1-5												
4.2.6.6.2	Deliver Modules #6-30												
4.2.6.6.3	Deliver Modules #31-40												
4.2.7	125-163 GHz Receiver Module												
4.2.7.1	SIS Mixer												
4.2.7.1.1	Design, Fabricate & Test Mixer Design												
4.2.7.1.2	Deliver Production Design												
4.2.7.1.3	Fabricate Production Mixers												

4.2.7.2	Design & Verify Optics			6		\$ 59	\$ 50		\$ 12	\$ 16	\$ 96	\$ 17	\$ 101
4.2.7.3	Design Module			6		\$ 59	\$ 50		\$ 12	\$ 16	\$ 96	\$ 17	\$ 101
4.2.7.4	Contract Fabrication												
4.2.7.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.7.4.2	Assemble Modules												
4.2.7.5	Install SIS Mixer and Test												
4.2.7.6	Deliver 125-163 GHz Receiver Modules												
4.2.7.6.1	Deliver 125-163 GHz Modules #1-5												
4.2.7.6.2	Deliver 125-163 GHz Modules #6-30												
4.2.7.6.3	Deliver 125-163 GHz Modules #31-40												
4.3	HFET Receiver Modules			6	12	\$ 117	\$ 50		\$ 19	\$ 22	\$ 148	\$ 23	\$ 156
4.3.1	Contract for HFET Wafer												
4.3.2	Receive Diced HFET Wafer												
4.3.3	33-45 GHz Module												
4.3.3.1	Design Module												
4.3.3.2	Design & Verify Optics												
4.3.3.3	Contract Fabrication												
4.3.3.3.1	Machine Blocks, Feed, WG, Lenses												
4.3.3.3.2	Assemble Modules												
4.3.3.3.3	Flip-in Mirror												
4.3.4	Install HFET & Test Modules												
4.3.5	Deliver 33-45 GHz Receiver Modules												
4.3.5.1	Deliver Modules #1-20												
4.3.5.2	Deliver Modules #21-40												
4.3.6	67-95 GHz Module												
4.3.6.1	Design Amplifier												
4.3.6.2	Design Module												
4.3.6.3	Design & Verify Optics												
4.3.6.4	Contract Fabrication												
4.3.6.4.1	Machine Blocks, Feed, WG, Lenses												
4.3.6.4.2	Assemble Modules												
4.3.6.5	Install HFET & Test Modules												
4.3.6.6	Deliver 67-95 GHz Receiver Modules												
4.3.6.6.1	Deliver Modules 67-95GHz #1-20												
4.3.6.6.2	Deliver Modules 67-95GHz #21-40												
5	LO System												
5.1	LO Reference: Prototype Systems												
5.1.1	Deliver: Bench Prototype												
5.1.2	Testing and Design Refinement												
5.1.3	Procure/Fab Field Prototypes												
5.1.4	Deliver: LO Ref Field Prototypes												
5.1.5	Field Prototype testing and Design Refinement												
5.1.6	Preproduction Review												
5.1.7	Final Documentation and Design Modifications												
5.1.8	Release for Manufacture												
5.2	LO Reference: Production System			12	48	\$ 351			\$ 53	\$ 351	\$ 55	\$ 369	
5.1.1	Production test and lab equipment									\$ -			
5.1.2	H-maser Frequency Standard (& Rb)					\$ 300		\$ 33	\$ 40	\$ 267	\$ 42	\$ 280	
5.1.3	8 GHz PL Oscillator & Distributor					\$ 1		\$ 0	\$ 0	\$ 1	\$ 0	\$ 1	
5.1.4	10 GHz PL Oscillator & Distributor					\$ 1		\$ 0	\$ 0	\$ 1	\$ 0	\$ 1	

5.1.5	12 GHz PL Oscillator & Distributor						\$ 1		\$ 0	\$ 0	\$ 1	\$ 0	\$ 1
5.1.6	14 GHz PL Oscillator & Distributor						\$ 1		\$ 0	\$ 0	\$ 1	\$ 0	\$ 1
5.1.7	3.2-5.2 GHz Synthesizer						\$ 8		\$ 1	\$ 1	\$ 7	\$ 1	\$ 7
5.1.8	3.2 -5.2 GHz PLO and Fringe Generator						\$ 160		\$ 18	\$ 21	\$ 142	\$ 22	\$ 149
5.1.9	Sampler Clock 4 GHz PL Osc & Distributor						\$ 1		\$ 0	\$ 0	\$ 1	\$ 0	\$ 1
5.1.10	LO Ref Generator						\$ 2		\$ 0	\$ 0	\$ 2	\$ 0	\$ 2
5.1.11	LO Ref Distributor - Control Bldg						\$ 1		\$ 0	\$ 0	\$ 1	\$ 0	\$ 1
5.1.12	Microwave Round-trip Phase Measurement						\$ 60		\$ 7	\$ 8	\$ 53	\$ 8	\$ 56
5.1.13	10-15 GHz Frequency Synthesizer						\$ 100		\$ 11	\$ 13	\$ 89	\$ 14	\$ 93
5.1.14	First LO Fringe Generator						\$ 20		\$ 2	\$ 3	\$ 18	\$ 3	\$ 19
5.1.15	16 GHz PL Oscillator						\$ 40		\$ 4	\$ 5	\$ 36	\$ 6	\$ 37
5.1.16	26 GHz PL Oscillator						\$ 40		\$ 4	\$ 5	\$ 36	\$ 6	\$ 37
5.1.17	LO Ref Distributor - Antenna						\$ 20		\$ 2	\$ 3	\$ 18	\$ 3	\$ 19
5.1.18	VXCO Clean-up Loop						\$ 20		\$ 2	\$ 3	\$ 18	\$ 3	\$ 19
5.1.19	Power supply module						\$ 60		\$ 7	\$ 8	\$ 53	\$ 8	\$ 56
5.1.20	Bins / Racks (assemble and test)						\$ 16		\$ 2	\$ 2	\$ 14	\$ 2	\$ 15
5.3	Millimeter LO Drivers												
5.3.1	Design and System Integration			3		\$ 29				\$ 4	\$ 29	\$ 5	\$ 31
5.3.2	72-95 GHz Source				3	\$ 15			\$ 2	\$ 2	\$ 13	\$ 2	\$ 14
5.3.2.1	Contract Procurement and Fabrication												
5.3.2.1.1	YIG-tuned Oscillator												
5.3.2.1.2	18.00 - 23.75 GHz 10 db Amplifier												
5.3.2.1.3	18.00 - 23.75 GHz x2 Multiplier												
5.3.2.1.4	36.0 - 47.5 GHz 10 db Amplifier												
5.3.2.1.5	36.0 - 47.5 GHz x2 Multiplier												
5.3.2.1.6	Mount and Tuning circuitry												
5.3.2.2	Assembly and Test												
5.3.2.3	Deliver 72 - 95 GHz LO Sources												
5.3.2.3.1	Deliver Modules #1-6												
5.3.2.3.2	Deliver Modules #7-24												
5.3.2.3.3	Deliver Modules #25-40												
5.3.3	100-120 GHz Source				3	\$ 15			\$ 15	\$ -	\$ -	\$ -	\$ -
5.3.3.1	Contract Procurement and Fabrication												
5.3.3.1.1	YIG-tuned Oscillator												
5.3.3.1.2	25.00 - 30.00 GHz 10 db Amplifier												
5.3.3.1.3	15.00 - 30.00 GHz x2 Multiplier												
5.3.3.1.4	50.0 - 60.0 GHz 10 db Amplifier												
5.3.3.1.5	50-60 GHz x2 Multiplier												
5.3.3.1.6	Mount and Tuning circuitry												
5.3.3.2	Assembly and Test												
5.3.3.3	Deliver 100 - 120 GHz LO Sources												
5.3.3.3.1	Deliver Modules #1-3												
5.3.3.3.2	Deliver Modules #4-21												
5.3.3.3.3	Deliver Modules #22-40												
5.3.4	87 - 108 GHz Source			6	8	\$ 98	\$ 240		\$ 38	\$ 75	\$ 300	\$ 79	\$ 315
5.3.4.1	Contract Procurement and Fabrication												
5.3.4.1.1	YIG-tuned Oscillator												
5.3.4.1.2	21.75-27.00 GHz 10 db Amplifier												
5.3.4.1.3	21.75-27.00 GHz x2 Multiplier												
5.3.4.1.4	43.5-54.0 GHz 10 db Amplifier												
5.3.4.1.5	43.5-54.0 GHz x2 Multiplier												

5.3.4.1.6	Mount and Tuning Circuitry													
5.3.4.2	Assembly and Test													
5.3.4.3	Deliver 87 - 108 GHz LO Sources													
5.3.4.3.1	Deliver Modules #1-6													
5.3.4.3.2	Deliver Modules #7-20													
5.3.4.3.3	Deliver Modules #21-35													
5.3.4.3.4	Deliver Modules #36-40													
5.3.5	65 - 85 GHz Source		6	8	\$ 98	\$ 240		\$ 38	\$ 75	\$ 300	\$ 79	\$ 315		
5.3.5.1	Contract Procurement and Fabrication													
5.3.5.1.1	YIG-tuned Oscillator													
5.3.5.1.2	16.25-21.25 GHz 10 db Amplifier													
5.3.5.1.3	16.25-21.25 GHz x2 Multiplier													
5.3.5.1.4	32.5-42.5 GHz 10 db Amplifier													
5.3.5.1.5	32.5-42.5 GHz x2 Multiplier													
5.3.5.1.6	Mount and Tuning Circuitry													
5.3.5.2	Assembly and Test													
5.3.5.3	Deliver 65 - 85 GHz LO Sources													
5.3.5.3.1	Deliver Modules #1-6													
5.3.5.3.2	Deliver Modules #7-20													
5.3.5.3.3	Deliver Modules #21-35													
5.3.5.3.4	Deliver Modules #36-40													
5.4	Millimeter LO Multiplier Chains													
5.4.1	Design and System Integration		2		\$ 20				\$ 3	\$ 20	\$ 3	\$ 20		
5.4.2	211 - 275 GHz Receiver LO		3	18	\$ 117	\$ 50		\$ 19	\$ 27	\$ 148	\$ 28	\$ 156		
5.4.2.1	Contract Fabrication													
5.4.2.1.1	X3 Diode for 72-95 GHz Source													
5.4.2.1.2	Machine Mount													
5.4.2.1.3	Bias and Control circuits													
5.4.2.2	Assemble Multiplier and Test													
5.4.2.3	Integrate Source and Multiplier; test													
5.4.2.4	Deliver 211-275 GHz Rcvr LO Modules													
5.4.2.4.1	Deliver Modules #1-3													
5.4.2.4.2	Deliver Modules #4-21													
5.4.2.4.3	Deliver Modules #22-40													
5.4.3	602 - 720 GHz Receiver LO		3	18	\$ 117	\$ 50		\$ 167	\$ -	\$ -	\$ -	\$ -		
5.4.3.1	Contract Fabrication													
5.4.3.1.1	X2 Diode for 100-120 GHz Source													
5.4.3.1.2	X3 Diode for 200-240 GHz Input													
5.4.3.1.3	Machine Mount													
5.4.3.1.4	Bias and Control circuits													
5.4.3.2	Assemble Multipliers and Test													
5.4.3.3	Integrate Source and Multipliers; test													
5.4.3.4	Deliver 602-720 GHz Rcvr LO Modules													
5.4.3.4.1	Deliver Modules #1-6													
5.4.3.4.2	Deliver Modules #7-18													
5.4.3.4.3	Deliver Modules #19-34													
5.4.3.4.4	Deliver Modules #35-40													
5.4.4	275 - 370 GHz Receiver LO		6	24	\$ 176	\$ 75		\$ 28	\$ 40	\$ 223	\$ 43	\$ 234		
5.4.4.1	Contract Fabrication													
5.4.4.1.1	X2 Diode for 72-95 GHz Source													

5.4.4.1.2	X2 Diode for 144-190 GHz Input																		
5.4.4.1.3	Machine Mount																		
5.4.4.1.4	Bias and Control Circuits																		
5.4.4.2	Assemble Multipliers and Test																		
5.4.4.3	Integrate Source and Multipliers; test																		
5.4.4.4	Deliver 275-370 GHz Rcvr LO Modules																		
5.4.4.4.1	Deliver Modules #1-6																		
5.4.4.4.2	Deliver Modules #7-27																		
5.4.4.4.3	Deliver Modules #28-40																		
5.4.5	163 - 211 GHz Receiver LO		6	24	\$	176	\$	75		\$	28	\$	40	\$	223	\$	43	\$	234
5.4.5.1	Contract Fabrication																		
5.4.5.1.1	X2 Diode for 87-108 GHz Source																		
5.4.5.1.2	Machine Mount																		
5.4.5.1.3	Bias and Control Circuits																		
5.4.5.2	Assemble Multiplier and Test																		
5.4.5.3	Integrate Source and Multiplier; test																		
5.4.5.4	Deliver 163 - 211 GHz Rcvr LO Modules																		
5.4.5.4.1	Deliver Modules #1-6																		
5.4.5.4.2	Deliver Modules #7-24																		
5.4.5.4.3	Deliver Modules #25-40																		
5.4.6	385 - 500 GHz Receiver LO		6	24	\$	176	\$	75		\$	251	\$	-	\$	-	\$	-	\$	-
5.4.6.1	Contract Fabrication																		
5.4.6.1.1	X3 Diode for 65-85 GHz Source																		
5.4.6.1.2	X2 Diode for 130-170 GHz Input																		
5.4.6.1.3	Machine Mount																		
5.4.6.1.4	Bias and Control Circuits																		
5.4.6.2	Assemble Multiplier and test																		
5.4.6.3	Integrate source and Multiplier; test																		
5.4.6.4	Deliver 385-500 GHz Rcvr LO Modules																		
5.4.6.4.1	Deliver Modules #1-6																		
5.4.6.4.2	Deliver Modules #7-24																		
5.4.6.4.3	Deliver Modules #25-40																		
5.4.7	125 - 163 GHz Receiver LO																		
5.4.7.1	Contract Fabrication																		
5.4.7.1.1	X2 Diode for 65 - 85 GHz Source																		
5.4.7.1.2	Machine Mount																		
5.4.7.1.3	Bias and Control Circuits																		
5.4.7.2	Assemble Multiplier and test																		
5.4.7.3	Integrate Source and Multiplier; test																		
5.4.7.4	Deliver 125-163 GHz Rcvr LO Modules																		
5.4.7.4.1	Deliver Modules #1-6																		
5.4.7.4.2	Deliver Modules #7-18																		
5.4.7.4.3	Deliver Modules #19-34																		
5.4.7.4.4	Deliver Modules #35-40																		
5.4.8	33-45 GHz Receiver LO																		
5.4.8.1	Design & Fab Selection & Coupling from Sources																		
6	IF System		12	36	\$	293						\$	44	\$	293	\$	46	\$	307
6.1	IF System: Prototype Systems																		

6.1.1	Deliver (Bench) Prototype IF System												
6.1.2	Testing and Design Refinement												
6.1.3	Procure/Fab Field Prototypes												
6.1.4	Deliver IF Field Prototypes to Test Interfeometer												
6.1.5	Field Prototype testing and Design Refinement												
6.1.6	Preproduction Review												
6.1.7	Final Documentation and Design Modifications												
6.1.8	Release for Manufacture												
6.2	Production test and lab equipment												
6.3	IF Multiplexer					\$ 160		\$ 18	\$ 21	\$ 142	\$ 22	\$ 149	
6.4	IF Demultiplexer					\$ 80		\$ 9	\$ 11	\$ 71	\$ 11	\$ 75	
6.5	IF Matrix Switch					\$ 64		\$ 7	\$ 9	\$ 57	\$ 9	\$ 60	
6.6	Baseband Converter					\$ 160		\$ 18	\$ 21	\$ 142	\$ 22	\$ 149	
6.7	Power supply module					\$ 40		\$ 4	\$ 5	\$ 36	\$ 6	\$ 37	
6.8	Bins / Racks (assemble and test)					\$ 16		\$ 2	\$ 2	\$ 14	\$ 2	\$ 15	
7	Optical Fiber System		12	36	\$ 293				\$ 44	\$ 293	\$ 46	\$ 307	
7.1	Optical Fiber System: Prototype Systems												
7.1.1	Deliver (Bench) Prototype FO System												
7.1.2	Testing and Design Refinement												
7.1.3	Procure/Fab Field Prototypes												
7.1.4	Deliver FO Field Prototypes to Test Interfeometer												
7.1.5	Field Prototype testing and Design Refinement												
7.1.6	Preproduction Review												
7.1.7	Final Documentation and Design Modifications												
7.1.8	Release for Manufacture												
7.1	Production test and lab equipment												
7.2	IF TX / RX					\$ 240		\$ 27	\$ 32	\$ 213	\$ 34	\$ 224	
7.3	LO Reference TX / RX					\$ 40		\$ 4	\$ 5	\$ 36	\$ 6	\$ 37	
7.4	Microwave Round-trip Phase TX / RX					\$ 40		\$ 4	\$ 5	\$ 36	\$ 6	\$ 37	
7.5	Monitor / Control TX / RX					\$ 20		\$ 2	\$ 3	\$ 18	\$ 3	\$ 19	
7.6	Power supply module					\$ 40		\$ 4	\$ 5	\$ 36	\$ 6	\$ 37	
7.7	Bins / Racks (assemble and test)					\$ 16		\$ 2	\$ 2	\$ 14	\$ 2	\$ 15	
8	Correlator		36	36	\$ 527	\$ 1,000		\$ 170	\$ 328	\$ 1,357	\$ 345	\$ 1,426	
8.1	Digital Sampler, 4 GHz		6	12	\$ 117	\$ 428		\$ 61	\$ 128	\$ 484	\$ 134	\$ 509	
8.1.1	Refine Design												
8.1.2	Release Digital Sampler for Manufacture												
8.1.3	Contract Materials												
8.1.4	Assembly												
8.1.5	Validation and Delivery												
8.2	Digital FIR Filter		2	2	\$ 29	\$ 533		\$ 62	\$ 146	\$ 500	\$ 153	\$ 525	
8.2.1	Prototype testing on Test Interferometer												
8.2.2	Design Refinement												
8.2.3	Release FIR Filter for manufacture												
8.2.4	Chip Fabrication												
8.2.5	Assembly												
8.2.6	Validation and Delivery												
8.3	Custom Boards												
8.3.1	Correlator Board												

8.3.1.1	Prototype assembly												
8.3.1.2	Prototype test												
8.3.1.3	Design modifications												
8.3.1.4	Fab, assemble and test with design mods												
8.4	Correlator Chip												
8.4.1	Prototype chip fabrication												
8.4.2	Prototype chip test												
8.4.3	Design modifications												
8.4.4	Fabricate and test design mods												
8.4.5	Fabricate production run												
8.5	Racks												
8.5.1	Design control wiring												
8.5.2	Design signal wiring												
8.5.3	Order parts												
8.5.4	Assemble prototypes												
8.6	Software												
8.7	Prototype Correlator Production												
8.7.1	Order parts												
8.7.2	Assemble												
8.7.3	Test												
8.7.4	Deliver Prototype Correlator to VLA site												
8.8	Site Correlator Production												
8.8.1	First 1/4 correlator												
8.8.1.1	Determine configuration												
8.8.1.2	Order parts												
8.8.1.3	Assemble												
8.8.1.4	Test												
8.8.1.5	Deliver 1/4 Correlator to MMA site												
8.8.2	Second 1/4 correlator												
8.8.2.1	Order parts												
8.8.2.2	Assemble												
8.8.2.3	Test												
8.8.2.4	Deliver 1/4 Correlator to MMA site												
8.8.3	Third 1/4 correlator												
8.8.3.1	Order parts												
8.8.3.2	Assemble												
8.8.3.3	Test												
8.8.3.4	Deliver 1/4 Correlator to MMA site												
8.8.4	Fourth 1/4 correlator												
8.8.4.1	Order parts												
8.8.4.2	Assemble												
8.8.4.3	Test												
8.8.4.4	Deliver 1/4 Correlator to MMA site												
8.9	Continued Support												
9	Computing						\$ 50			\$ 15	\$ 50	\$ 16	\$ 53
9.1	Control Software												
9.1.1	Test Interferometer Control & Analysis												
9.1.2	MMA correlator software												
9.1.3	Multi-antenna & sub-array control	44				\$ 381			\$ 57	\$ 381	\$ 60	\$ 401	
9.1.4	Operators & Observers interfaces	26				\$ 225			\$ 34	\$ 225	\$ 36	\$ 237	
9.1.5	Deliver Control Software	10				\$ 87			\$ 13	\$ 87	\$ 14	\$ 91	
9.1.6	Maintenance												

9.2	Scheduling												
9.2.1	Static scheduling system		10			\$	87				\$	13	\$ 87 \$ 14 \$ 91
9.2.2	Dynamic scheduling simulations												
9.2.3	Dynamic scheduling prototype		10			\$	87				\$	13	\$ 87 \$ 14 \$ 91
9.2.4	Dynamic scheduling implementation												
9.2.5	Initial Operations with Dynamic Scheduling												
9.3	Proposal Preparation Software												
9.3.1	Prototype		6			\$	52				\$	8	\$ 52 \$ 8 \$ 55
9.3.2	Production version		3			\$	26				\$	4	\$ 26 \$ 4 \$ 27
9.4	Image Pipeline												
9.4.1	Automated calibration & imaging heuristics												
9.4.2	Prototype image pipeline		20			\$	173				\$	26	\$ 173 \$ 27 \$ 182
9.4.3	Parallelization studies and implementation												
9.4.4	Initial Image Pipeline Operations												
9.4.5	Production image pipeline												
9.5	Archiving												
9.5.1	Prototype distributed archive		10			\$	87				\$	13	\$ 87 \$ 14 \$ 91
9.5.2	Evaluate storage hardware												
9.5.3	Production archive		20			\$	173				\$	26	\$ 173 \$ 27 \$ 182
9.5.4	Data Archive operational												
9.6	Post-processing												
9.6.1	Define MMA Data formats		6			\$	52				\$	8	\$ 52 \$ 8 \$ 55
9.6.2	MMA filler & format conversions		6			\$	52				\$	8	\$ 52 \$ 8 \$ 55
9.6.3	MMA-specific calibrations		2			\$	17				\$	3	\$ 17 \$ 3 \$ 18
9.6.4	MMA Post-processing begins												
9.6.5	Maintenance												
10	System Integration						\$ 75				\$ 23	\$ 75	\$ 24 \$ 79
10.4	Test Interferometer Site Preparation												
10.4.1	Complete Office and Lab Space Preparation												
10.4.2	Cabling												
10.4.3	Test Interferometer Site Complete												
10.10.4	Prototype Antenna Outfitting												
10.10.4.1	Cabling												
10.10.4.2	Instrumentation												
10.10.4.3	Eval. Rcvr. #1 / Ant. #1 Integration												
10.10.4.4	Antenna #1 Outfitting Complete												
10.10.5	Integration Holography System/Antenna												
10.10.6	Integration Metrology/Antenna												
10.10.7	Antenna #1 Integration & Testing												
10.10.8	Prot. Rcvr. Test & Evaluation												
10.10.9	Antenna #2 Outfitting												
10.10.9.1	Cabling												
10.10.9.2	Instrumentation												
10.10.9.3	Eval. Rcvr. #2 / Ant. #2 Integration												
10.10.9.4	Antenna #2 Outfitting Complete												
10.11	Test Interferometer												
10.11.1	Antenna Evaluation & Characterization			6		\$	59				\$	9	\$ 59 \$ 9 \$ 61
10.11.1.1	Antenna Verification												
10.11.1.4	Holography												
10.11.1.5	Beam and Sidelobes												
10.11.1.6	Gain vs. Elevation: Spillover Temp												
10.11.1.7	Effect of Sun in & Near the Beam												

10.11.2	Engineering Recommendations re Prod. Ant.												
10.11.3	Revise Interface Specifications			3		\$ 29				\$ 4	\$ 29	\$ 5	\$ 31
10.11.5	Operations Personnel Training												
10.11.5.1	Recruit Initial Chile Ops Staff	6			48	\$ 283		\$ 283		\$ -	\$ -	\$ -	\$ -
10.11.5.2	Array Operations												
10.11.5.3	Engineering Maintenance												
10.11.5.4	Scientific Support & Analysis												
10.12.2	Relocate Ops Staff to Chile												
10.8.4.6	Start On-site Operations												
10.12	Disassemble Test Interferometer												
10.12.1	Prepare & Ship Antenna #1, #2												
10.12.3	Restore Facilities at VLA Site												
10.13	On Site System Integration				36	\$ 176		\$ 176		\$ -	\$ -	\$ -	\$ -
11	Calibration and Imaging												
11.1	Radiometric Phase Design & Prototype												
11.1.1	Complete 183GHz Phase Mon Prototype												
11.1.2	Demo 183 GHz Phase Monitor Radiometer on-Site												
11.1.3	Design Refinement												
11.1.4	Release Phase Mon Radiometer for manufacture												
11.2	Production Fab of Phase Monitor Radiometer			10	12	\$ 156	\$ 684		\$ 93	\$ 201	\$ 747	\$ 211	\$ 784
11.2.1	Contract Subassembly Fabrication												
11.2.1.1	Radiometer & Local Oscillator												
11.2.1.2	Spectrometer												
11.2.1.3	Feed, Window, lens, instrumentation												
11.2.1.4	M/C Interface												
11.2.2	Assembly & Test												
11.2.3	Deliver Production Radiometers												
11.2.4	Integration in Receiver Package												
11.2.5	Verification on-Site												
11.3	Production Fabrication of Dual-load Amp Cal Sys				12	\$ 59	\$ 163		\$ 25	\$ 50	\$ 197	\$ 53	\$ 207
11.3.1	Design Refinement												
11.3.2	Release Phase Mon Radiometer for manufacture												
11.3.3	Contract Subassembly												
11.3.3.1	Machining												
11.3.3.2	Load Fabrication												
11.3.3.3	Motors, Servo												
11.3.3.4	M/C Interface												
11.3.4	Assembly & Test												
11.3.5	Integration on Production Antennas												
11.4	Imaging Studies & Project Support	72				\$ 585		\$ 585		\$ -	\$ -	\$ -	\$ -
11.5	Imaging Algorithm Development	8	4			\$ 100				\$ 15	\$ 100	\$ 16	\$ 105
	TOTALS					\$ 11,580	\$ 33,369	\$ 1,472	\$ 4,840	\$ 7,161	\$ 38,637	\$ 7,523	\$ 40,593

Millimeter Array Construction 2004

WBS	Name	Scientists Work- Months	Programmers Work-Months	Engineers Work- Months	Technicians Work- Months	Personnel Cost	Materials and Supplies	Transfer to Operations	Adjustment to Scope	Contingency	Sum Cost	Inflated Contingency	Inflated Sum
1	Administration												
1.1	Project Management	72			48	\$ 819		\$ 215		\$ 91	\$ 605	\$ 98	\$ 651
1.1.1	Management, Planning, and Oversight						\$ 700			\$ 105	\$ 700	\$ 113	\$ 754
1.1.2	Business Operations						\$ 100			\$ 15	\$ 100	\$ 16	\$ 108
1.1.3	Chilean Operations						\$ 50			\$ 8	\$ 50	\$ 8	\$ 54
1.1.4	Safety and Health												
1.1.5	Personnel												
1.1.6	Project Science Office												
1.1.7	AUI Management						\$ 350			\$ -	\$ 350	\$ -	\$ 377
1.2	Engineering			24	12	\$ 293	\$ 20			\$ 47	\$ 313	\$ 50	\$ 337
1.2.1	System Engineering--Phase II												
1.2.2	Documentation System												
1.2.3	Production Engineering												
1.3	US Facilities												
1.3.1	CDL Permanent Facilities						\$ 600			\$ -	\$ 600	\$ -	\$ 646
1.3.2	Manufacturing Facilities						\$ 100			\$ 15	\$ 100	\$ 16	\$ 108
1.3.3	Common Infrastructure						\$ 200			\$ 30	\$ 200	\$ 32	\$ 215
2	Site Development			12		\$ 117	\$ 50			\$ 28	\$ 167	\$ 30	\$ 180
2.1	Review Legalities Regarding Array and OSF Sites												
2.2	Maintain Mining claims						\$ 25			\$ -	\$ 25	\$ -	\$ 27
2.3	Contract A&E Studies												
2.4	Hire Construction Manager for Chile												
2.5	Array Site												
2.5.1	Prepare Site Development Bid Packages												
2.5.1.1	Prepare Package for Array Site												
2.5.1.2	Review Bid Packages												
2.5.1.3	Bid Civil Works Construction												
2.5.2	Evaluate Array Site Bid Response												
2.5.2.1	Review Bids												
2.5.2.2	Recommend Contractors												
2.5.2.3	Award Array Site Contracts												
2.5.3	Contract Array Site Civil Works												
2.5.3.1	Array Site												
2.5.3.2	Inspect Completed Site Constr												
2.5.3.3	Accept Site Facility												
2.6	Operations Support Facility												
2.6.1	Prepare OSF Bid Packages												
2.6.1.1	Prepare Package for OSF												
2.6.1.2	Review Bid Packages												
2.6.1.3	Bid Civil Works Construction												
2.6.2	Evaluate OSF Bid Response												
2.6.2.1	Review Bids												
2.6.2.2	Recommend Contractors												
2.6.2.3	Award Contracts												

2.6.3	Contract OSF Civil Works												
2.6.3.1	Operations Support Facility												
2.6.3.2	Inspect Completed OSF Constr												
2.6.3.3	Accept OSF Facility												
2.7	OSF/Array Link												
2.7.1	Prepare OSF/Array Link Bid Package												
2.7.1.1	Prepare Package for OSF/Array F/O Link												
2.7.1.2	Review Bid Package												
2.7.1.3	Bid OSF/Array Link Construction												
2.7.2	Evaluate Bid Response												
2.7.2.1	Review Bids												
2.7.2.2	Recommend Contractors												
2.7.2.3	Award Contracts												
2.7.3	Contract Civil Works												
2.7.3.1	OSF/Array Link												
2.7.3.2	Inspect Completed OSF/Array Link Constr												
2.7.3.3	Accept OSF/Array Link												
2.8	Prepare for Instrument Assembly												
2.8.1	Equip Array Site						\$ 2,600	\$ 2,200		\$ 190	\$ 400	\$ 205	\$ 431
2.8.2	Equip Operations Support Facility						\$ 3,450	\$ 1,250		\$ 503	\$ 2,200	\$ 541	\$ 2,369
3	Antenna												
3.1	Antenna Engineering Support												
3.3.40	Acceptance Tests Antenna #1												
3.3.45	Delivery of Antenna #1												
3.8.10	Sign Transporter Contract												
3.8.15	Transporter Acceptance tests												
3.8.20	Deliver/Accept Transporter #1												
3.7	Procurement of Antenna #2						\$ 2,050			\$ 615	\$ 2,050	\$ 662	\$ 2,208
3.7.1	Antenna #2 Contract Supervision												
3.7.2	Antenna #2 Acceptance tests												
3.8	Negotiate Production Antenna Contract												
3.9	Sign Contract for Production Antennas												
3.10	Antenna Contract Supervision												
3.11	Accept Antenna #3 at OSF			1.5		\$ 15				\$ 2	\$ 15	\$ 2	\$ 16
3.12	Prepare Antenna #3												
3.12.1	Outfit & Verify Ant #3 at OSF			2	4	\$ 39				\$ 6	\$ 39	\$ 6	\$ 42
3.12.2	Move, Install & Verify Ant #3 on Site			1	1	\$ 15				\$ 2	\$ 15	\$ 2	\$ 16
3.13	Accept Antenna #4 at OSF			1.5		\$ 15				\$ 2	\$ 15	\$ 2	\$ 16
3.14	Prepare Antenna #4												
3.14.1	Outfit & Verify Ant #4 at OSF			2	4	\$ 39				\$ 6	\$ 39	\$ 6	\$ 42
3.14.2	Move, Install & Verify Ant #4 on Site			1	1	\$ 15				\$ 2	\$ 15	\$ 2	\$ 16
3.15	Accept Antenna#5 at OSF			1.5		\$ 15				\$ 2	\$ 15	\$ 2	\$ 16
3.16	Prepare Antenna #5												
3.16.1	Outfit & Verify Ant #5 at OSF			2	4	\$ 39				\$ 6	\$ 39	\$ 6	\$ 42
3.16.2	Move, Install & Verify Ant #5 on Site			1	1	\$ 15				\$ 2	\$ 15	\$ 2	\$ 16
3.17	Accept Antenna#6 at OSF			1.5		\$ 15				\$ 2	\$ 15	\$ 2	\$ 16
3.18	Prepare Antenna #6												
3.18.1	Outfit & Verify Ant #6 at OSF			2	4	\$ 39				\$ 6	\$ 39	\$ 6	\$ 42
3.18.2	Move, Install & Verify Ant #6 on Site			1	1	\$ 15				\$ 2	\$ 15	\$ 2	\$ 16
3.19	Accept Antenna #7 at OSF			3		\$ 29	\$ 2,832			\$ 854	\$ 2,861	\$ 920	\$ 3,081

3.20	Prepare Antenna #7												
3.20.1	Outfit & Verify Ant #7 at OSF												
3.20.2	Move, Install & Verify Ant #7 on Site												
3.21	Accept Antenna #8 at OSF			3		\$ 29	\$ 2,832			\$ 854	\$ 2,861	\$ 920	\$ 3,081
3.22	Prepare Antenna #8												
3.22.1	Outfit & Verify Ant #8 at OSF												
3.22.2	Move, Install & Verify Ant #8 on Site												
3.23	Accept Antenna #9 at OSF			3		\$ 29	\$ 2,832			\$ 854	\$ 2,861	\$ 920	\$ 3,081
3.24	Prepare Antenna #9												
3.24.1	Outfit & Verify Ant #9 at OSF												
3.24.2	Move, Install & Verify Ant #9 on Site												
3.25	Accept Antenna #10 at OSF			3		\$ 29	\$ 2,832			\$ 854	\$ 2,861	\$ 920	\$ 3,081
3.26	Prepare Antenna #10												
3.26.1	Outfit & Verify Ant #10 at OSF												
3.26.2	Move, Install and Verify Ant #10 on Site												
3.27	Accept Antenna #11 at OSF			3		\$ 29	\$ 2,832			\$ 854	\$ 2,861	\$ 920	\$ 3,081
3.28	Prepare Antenna #11												
3.28.1	Outfit & Verify Ant #11 at OSF												
3.28.2	Move, Install & Verify Ant #11 on Site												
3.29	Accept Antenna #12 at OSF			3		\$ 29	\$ 2,832			\$ 854	\$ 2,861	\$ 920	\$ 3,081
3.30	Prepare Antenna #12												
3.30.1	Outfit & Verify Ant #12 at OSF												
3.30.2	Move, Install & Verify Ant #12 on Site												
3.31	Accept Antenna #13 at OSF			3		\$ 29	\$ 2,832			\$ 854	\$ 2,861	\$ 920	\$ 3,081
3.32	Prepare Antenna #13												
3.32.1	Outfit & Verify Ant #13 at OSF												
3.32.2	Move, Install & Verify Ant #13 on Site												
3.33	Accept Antenna #14 at OSF			3		\$ 29	\$ 2,832			\$ 854	\$ 2,861	\$ 920	\$ 3,081
3.34	Prepare Antenna #14												
3.34.1	Outfit & Verify Ant #14 at OSF												
3.34.2	Move, Install & Verify Ant #14 on Site												
3.35	Accept Antenna #15 at OSF			3		\$ 29	\$ 2,832			\$ 854	\$ 2,861	\$ 920	\$ 3,081
3.36	Prepare Antenna #15												
3.36.1	Outfit & Verify Ant #15 at OSF												
3.36.2	Move, Install & Verify Ant #15 on Site												
3.37	Accept Antenna #16 at OSF												
3.38	Prepare Antenna #16												
3.38.1	Outfit & Verify Ant #16 at OSF												
3.38.2	Move, Install & Verify Ant #16 on Site												
3.39	Accept Antenna #17 at OSF												
3.40	Prepare Antenna #17												
3.40.1	Outfit & Verify Ant #17 at OSF												
3.40.2	Move, Install & Verify Ant #17 on Site												
3.41	Accept Antenna #18 at OSF												
3.42	Prepare Antenna #18												
3.42.1	Outfit & Verify Ant #18 at OSF												
3.42.2	Move, Install & Verify Ant #18 on Site												
3.43	Accept Antenna #19 at OSF												
3.44	Prepare Antenna #19												
3.44.1	Outfit & Verify Ant #19 at OSF												
3.44.2	Move, Install & Verify Ant #19 on Site												
3.45	Accept Antenna #20 at OSF												
3.46	Prepare Antenna #20												
3.46.1	Outfit & Verify Ant #20 at OSF												

3.46.2	Move, Install & Verify Ant #20 on Site												
3.47	Accept Antenna #21 at OSF												
3.48	Prepare Antenna #21												
3.48.1	Outfit & Verify Ant #21 at OSF												
3.48.2	Move, Install & Verify Ant #21 on Site												
3.49	Accept Antenna #22 at OSF												
3.50	Prepare Antenna #22												
3.50.1	Outfit & Verify Ant #22 at OSF												
3.50.2	Move, Install & Verify Ant #22 on Site												
3.51	Accept Antenna #23 at OSF												
3.52	Prepare Antenna #23												
3.52.1	Outfit & Verify Ant #23 at OSF												
3.52.2	Move, Install & Verify Ant #23 on Site												
3.53	Accept Antenna #24 at OSF												
3.54	Prepare Antenna #24												
3.54.1	Outfit & Verify Ant #24 at OSF												
3.54.2	Move, Install & Verify Ant #24 on Site												
3.55	Accept Antenna #25 at OSF												
3.56	Prepare Antenna #25												
3.56.1	Outfit & Verify Ant #25 at OSF												
3.56.2	Move, Install & Verify Ant #25 on Site												
3.57	Accept Antenna #26 at OSF												
3.58	Prepare Antenna #26												
3.58.1	Outfit & Verify Ant #26 at OSF												
3.58.2	Move, Install & Verify Ant #26 on Site												
3.59	Accept Antenna #27 at OSF												
3.60	Prepare Antenna #27												
3.60.1	Outfit & Verify Ant #27 at OSF												
3.60.2	Move, Install & Verify Ant #27 on Site												
3.61	Accept Antenna #28 at OSF												
3.62	Prepare Antenna #28												
3.62.1	Outfit & Verify Ant #28 at OSF												
3.62.2	Move, Install & Verify Ant #28 on Site												
3.63	Accept Antenna #29 at OSF												
3.64	Prepare Antenna #29												
3.64.1	Outfit & Verify Ant #29 at OSF												
3.64.2	Move, Install & Verify Ant #29 on Site												
3.65	Accept Antenna #30 at OSF												
3.66	Prepare Antenna #30												
3.66.1	Outfit & Verify Ant #30 at OSF												
3.66.2	Move, Install & Verify Ant #30 on Site												
3.67	Accept Antenna #31 at OSF												
3.68	Prepare Antenna #31												
3.68.1	Outfit & Verify Ant #31 at OSF												
3.68.2	Move, Install and Verify Ant #31 on Site												
3.69	Accept Antenna #32 at OSF												
3.70	Prepare Antenna #32												
3.70.1	Outfit & Verify Ant #32 at OSF												
3.70.2	Move, Install & Verify Ant #32 on Site												
3.71	Accept Antenna #33 at OSF												
3.72	Prepare Antenna #33												
3.72.1	Outfit & Verify Ant #33 at OSF												
3.72.2	Move, Install and Verify Ant #33 on Site												
3.73	Accept Antenna #34 at OSF												

3.74	Prepare Antenna #34																		
3.74.1	Outfit & Verify Ant #34 at OSF																		
3.74.2	Move, Install and Verify Ant #34 on Site																		
3.75	Accept Antenna #35 at OSF																		
3.76	Prepare Antenna #35																		
3.76.1	Outfit & Verify Ant #35 at OSF																		
3.76.2	Move, Install & Verify Ant #35 on Site																		
3.77	Accept Antenna #36 at OSF																		
3.78	Prepare Antenna #36																		
3.78.1	Outfit & Verify Ant #36 at OSF																		
3.78.2	Move, Install & Verify Ant #36 on Site																		
3.79	Prepare Antenna #1																		
3.79.1	Antenna #1 Reassembled at OSF																		
3.79.2	Outfit & Verify Ant #1 at OSF																		
3.79.3	Move, Install & Verify Ant #1 on Site																		
3.80	Prepare Antenna #2																		
3.80.1	Antenna #2 Reassembled at OSF																		
3.80.2	Outfit & Verify Ant #2 at OSF																		
3.80.3	Move, Install & Verify Ant #2 on Site																		
3.81	Antenna Transporter																		
3.81.1	Contract for Transporter #1 move to site									\$ 60				\$ 18	\$ 60	\$ 19	\$ 65		
3.81.2	Contract for Transporters #2, #3																		
3.81.3	Accept Transporters #2, #3 at OSF																		
4	Receivers																		
4.1	Receiver Package																		
4.1.1	Prototype Production Receiver Cryogenics																		
4.1.1.1	CDR: Cryogenics Development																		
4.1.1.2	Construct & test prototype cryogenics																		
4.1.1.3	Deliver Prototype Cryogenics Subsystem																		
4.1.2	Prototype Production Receiver Package																		
4.1.2.1	Prototype Receiver Package Integration																		
4.1.2.2	Prot. Rcvr. Pckg Lab Test & Evaluation																		
4.1.2.3	Complete Prototype MMA Receiver Package																		
4.1.3	MMA Rcvr Pckg Design Refinement																		
4.1.4	Documentation																		
4.1.5	Release MMA Receiver Pckg for manufacture																		
4.1.6	Contract for Receiver Pckg Subassemblies																		
4.1.6.1	Machine Dewars					30	\$ 146	\$ 50		\$ 22	\$ 30	\$ 174	\$ 33	\$ 188					
4.1.6.2	Fabricate Cryogenics subsystems	6			24	\$ 176	\$ 240		\$ 46	\$ 84	\$ 369	\$ 91	\$ 398						
4.1.6.3	Fabricate windows, IR filters, etc	6			30	\$ 205	\$ 100		\$ 34	\$ 51	\$ 271	\$ 54	\$ 292						
4.1.7	Accept Receiver Pckg Subassemblies																		
4.1.7.1	Subassemblies #1-6																		
4.1.7.2	Subassemblies #7-16																		
4.1.7.3	Subassemblies #17-26																		
4.1.7.4	Subassemblies #27-36																		
4.1.7.5	Subassemblies #37-40																		
4.1.8	Fab Rcvr Pckg Instrumentation & Electronics	6	6		12	\$ 169	\$ 100		\$ 30	\$ 46	\$ 239	\$ 50	\$ 257						
4.1.9	Fabricate Receiver Inserts		18		30	\$ 322	\$ 100		\$ 47	\$ 64	\$ 375	\$ 69	\$ 404						
4.1.10	Assemble Receiver Package																		
4.1.10.1	Integrate Rcvr Instrumentation & subass'y		12		48	\$ 351	\$ 80		\$ 48	\$ 62	\$ 383	\$ 67	\$ 413						

4.1.10.2	Deliver Receiver Package #1-6																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
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4.2.4	91-119 GHz Receiver Module																					
4.2.4.1	SIS Mixer																					
4.2.4.1.1	Design, Fabricate & Test Mixer Design																					
4.2.4.1.2	Deliver Production Design																					
4.2.4.1.3	Fabricate Production Mixers																					
4.2.4.2	Design & Verify Optics																					
4.2.4.3	Design Module																					
4.2.4.4	Contract Fabrication					4	\$	20	\$	100			\$	11	\$	30	\$	108	\$	32	\$	117
4.2.4.4.1	Machine Mixer Blocks, Feed, WG, Lenses																					
4.2.4.4.2	Assemble Modules																					
4.2.4.5	Install SIS Mixer and Test Modules			18		36	\$	351	\$	40			\$	4	\$	63	\$	387	\$	68	\$	416
4.2.4.6	Deliver 91-119 GHz Receiver Modules																					
4.2.4.6.1	Deliver Modules #1-5																					
4.2.4.6.2	Deliver Modules #6-30																					
4.2.4.6.3	Deliver Modules # 31-40																					
4.2.5	163-211 GHz Receiver Module																					
4.2.5.1	SIS Mixer			36		24	\$	468	\$	100			\$	11	\$	97	\$	557	\$	104	\$	600
4.2.5.1.1	Design, Fabricate & Test Mixer Design																					
4.2.5.1.2	Deliver Production Design																					
4.2.5.1.3	Fabricate Production Mixers																					
4.2.5.2	Design & Verify Optics																					
4.2.5.3	Design Module																					
4.2.5.4	Contract Fabrication					4	\$	20	\$	100			\$	11	\$	30	\$	108	\$	32	\$	117
4.2.5.4.1	Machine Mixer Blocks, Feed, WG, Lenses																					
4.2.5.4.2	Assemble Modules			6		12	\$	117	\$	20			\$	2	\$	23	\$	135	\$	25	\$	145
4.2.5.5	Install SIS Mixer and Test																					
4.2.5.6	Deliver 163-211 GHz Receiver Modules																					
4.2.5.6.1	Deliver Modules #1-5																					
4.2.5.6.2	Deliver Modules #6-30																					
4.2.5.6.3	Deliver Modules #31-40																					
4.2.6	385-500 GHz Receiver Module																					
4.2.6.1	SIS Mixer			36		24	\$	468	\$	100			\$	568	\$	-	\$	-	\$	-	\$	-
4.2.6.1.1	Design, Fabricate & Test Mixer Design																					
4.2.6.1.2	Deliver Production Design																					
4.2.6.1.3	Fabricate Production Mixers																					
4.2.6.2	Design and Verify Optics																					
4.2.6.3	Design Module																					
4.2.6.4	Contract Fabrication					4	\$	20	\$	100			\$	120	\$	-	\$	-	\$	-	\$	-
4.2.6.4.1	Machine Mixer Blocks, Feed, WG, Lenses																					
4.2.6.4.2	Assemble Modules																					
4.2.6.5	Install SIS Mixer and Test			6		12	\$	117	\$	20			\$	137	\$	-	\$	-	\$	-	\$	-
4.2.6.6	Deliver 385-500 GHz Receiver Modules																					
4.2.6.6.1	Deliver Modules #1-5																					
4.2.6.6.2	Deliver Modules #6-30																					
4.2.6.6.3	Deliver Modules #31-40																					
4.2.7	125-163 GHz Receiver Module																					
4.2.7.1	SIS Mixer			6		6	\$	88	\$	400			\$	46	\$	119	\$	442	\$	129	\$	476
4.2.7.1.1	Design, Fabricate & Test Mixer Design																					
4.2.7.1.2	Deliver Production Design																					
4.2.7.1.3	Fabricate Production Mixers																					

4.2.7.2	Design & Verify Optics													
4.2.7.3	Design Module													
4.2.7.4	Contract Fabrication													
4.2.7.4.1	Machine Mixer Blocks, Feed, WG, Lenses													
4.2.7.4.2	Assemble Modules				2	\$ 10	\$ 50		\$ 7	\$ 14	\$ 53	\$ 15	\$ 57	
4.2.7.5	Install SIS Mixer and Test													
4.2.7.6	Deliver 125-163 GHz Receiver Modules													
4.2.7.6.1	Deliver 125-163 GHz Modules #1-5													
4.2.7.6.2	Deliver 125-163 GHz Modules #6-30													
4.2.7.6.3	Deliver 125-163 GHz Modules #31-40													
4.3	HFET Receiver Modules			6	12	\$ 117	\$ 50		\$ 6	\$ 24	\$ 161	\$ 26	\$ 174	
4.3.1	Contract for HFET Wafer													
4.3.2	Receive Diced HFET Wafer													
4.3.3	33-45 GHz Module													
4.3.3.1	Design Module													
4.3.3.2	Design & Verify Optics													
4.3.3.3	Contract Fabrication													
4.3.3.3.1	Machine Blocks, Feed, WG, Lenses													
4.3.3.3.2	Assemble Modules													
4.3.3.3.3	Flip-in Mirror													
4.3.4	Install HFET & Test Modules													
4.3.5	Deliver 33-45 GHz Receiver Modules													
4.3.5.1	Deliver Modules #1-20													
4.3.5.2	Deliver Modules #21-40													
4.3.6	67-95 GHz Module													
4.3.6.1	Design Amplifier													
4.3.6.2	Design Module													
4.3.6.3	Design & Verify Optics													
4.3.6.4	Contract Fabrication													
4.3.6.4.1	Machine Blocks, Feed, WG, Lenses													
4.3.6.4.2	Assemble Modules													
4.3.6.5	Install HFET & Test Modules													
4.3.6.6	Deliver 67-95 GHz Receiver Modules													
4.3.6.6.1	Deliver Modules 67-95GHz #1-20													
4.3.6.6.2	Deliver Modules 67-95GHz #21-40													
5	LO System													
5.1	LO Reference: Prototype Systems													
5.1.1	Deliver: Bench Prototype													
5.1.2	Testing and Design Refinement													
5.1.3	Procure/Fab Field Prototypes													
5.1.4	Deliver: LO Ref Field Prototypes													
5.1.5	Field Prototype testing and Design Refinement													
5.1.6	Preproduction Review													
5.1.7	Final Documentation and Design Modifications													
5.1.8	Release for Manufacture													
5.2	LO Reference: Production System			12	48	\$ 351			\$ 53	\$ 351	\$ 57	\$ 378		
5.1.1	Production test and lab equipment													
5.1.2	H-maser Frequency Standard (& Rb)													
5.1.3	8 GHz PL Oscillator & Distributor					\$ 1		\$ 0	\$ 0	\$ 1	\$ 0	\$ 1		
5.1.4	10 GHz PL Oscillator & Distributor					\$ 1		\$ 0	\$ 0	\$ 1	\$ 0	\$ 1		

5.1.5	12 GHz PL Oscillator & Distributor						\$ 1		\$ 0	\$ 0	\$ 1	\$ 0	\$ 1
5.1.6	14 GHz PL Oscillator & Distributor						\$ 1		\$ 0	\$ 0	\$ 1	\$ 0	\$ 1
5.1.7	3.2-5.2 GHz Synthesizer						\$ 8		\$ 1	\$ 1	\$ 7	\$ 1	\$ 8
5.1.8	3.2 -5.2 GHz PLO and Fringe Generator						\$ 160		\$ 18	\$ 21	\$ 142	\$ 23	\$ 153
5.1.9	Sampler Clock 4 GHz PL Osc & Distributor						\$ 1		\$ 0	\$ 0	\$ 1	\$ 0	\$ 1
5.1.10	LO Ref Generator						\$ 2		\$ 0	\$ 0	\$ 2	\$ 0	\$ 2
5.1.11	LO Ref Distributor - Control Bldg						\$ 1		\$ 0	\$ 0	\$ 1	\$ 0	\$ 1
5.1.12	Microwave Round-trip Phase Measurement						\$ 60		\$ 7	\$ 8	\$ 53	\$ 9	\$ 57
5.1.13	10-15 GHz Frequency Synthesizer						\$ 100		\$ 11	\$ 13	\$ 89	\$ 14	\$ 96
5.1.14	First LO Fringe Generator						\$ 20		\$ 2	\$ 3	\$ 18	\$ 3	\$ 19
5.1.15	16 GHz PL Oscillator						\$ 40		\$ 4	\$ 5	\$ 36	\$ 6	\$ 38
5.1.16	26 GHz PL Oscillator						\$ 40		\$ 4	\$ 5	\$ 36	\$ 6	\$ 38
5.1.17	LO Ref Distributor - Antenna						\$ 20		\$ 2	\$ 3	\$ 18	\$ 3	\$ 19
5.1.18	VXCO Clean-up Loop						\$ 20		\$ 2	\$ 3	\$ 18	\$ 3	\$ 19
5.1.19	Power supply module						\$ 60		\$ 7	\$ 8	\$ 53	\$ 9	\$ 57
5.1.20	Bins / Racks (assemble and test)						\$ 16		\$ 2	\$ 2	\$ 14	\$ 2	\$ 15
5.3	Millimeter LO Drivers												
5.3.1	Design and System Integration			3		\$ 29				\$ 4	\$ 29	\$ 5	\$ 31
5.3.2	72-95 GHz Source				3	\$ 15			\$ 2	\$ 2	\$ 13	\$ 2	\$ 14
5.3.2.1	Contract Procurement and Fabrication												
5.3.2.1.1	YIG-tuned Oscillator												
5.3.2.1.2	18.00 - 23.75 GHz 10 db Amplifier												
5.3.2.1.3	18.00 - 23.75 GHz x2 Multiplier												
5.3.2.1.4	36.0 - 47.5 GHz 10 db Amplifier												
5.3.2.1.5	36.0 - 47.5 GHz x2 Multiplier												
5.3.2.1.6	Mount and Tuning circuitry												
5.3.2.2	Assembly and Test												
5.3.2.3	Deliver 72 - 95 GHz LO Sources												
5.3.2.3.1	Deliver Modules #1-6												
5.3.2.3.2	Deliver Modules #7-24												
5.3.2.3.3	Deliver Modules #25-40												
5.3.3	100-120 GHz Source				3	\$ 15			\$ 15	\$ -	\$ -	\$ -	\$ -
5.3.3.1	Contract Procurement and Fabrication												
5.3.3.1.1	YIG-tuned Oscillator												
5.3.3.1.2	25.00 - 30.00 GHz 10 db Amplifier												
5.3.3.1.3	15.00 - 30.00 GHz x2 Multiplier												
5.3.3.1.4	50.0 - 60.0 GHz 10 db Amplifier												
5.3.3.1.5	50-60 GHz x2 Multiplier												
5.3.3.1.6	Mount and Tuning circuitry												
5.3.3.2	Assembly and Test												
5.3.3.3	Deliver 100 - 120 GHz LO Sources												
5.3.3.3.1	Deliver Modules #1-3												
5.3.3.3.2	Deliver Modules #4-21												
5.3.3.3.3	Deliver Modules #22-40												
5.3.4	87 - 108 GHz Source			6	8	\$ 98	\$ 240		\$ 38	\$ 75	\$ 300	\$ 81	\$ 323
5.3.4.1	Contract Procurement and Fabrication												
5.3.4.1.1	YIG-tuned Oscillator												
5.3.4.1.2	21.75-27.00 GHz 10 db Amplifier												
5.3.4.1.3	21.75-27.00 GHz x2 Multiplier												
5.3.4.1.4	43.5-54.0 GHz 10 db Amplifier												
5.3.4.1.5	43.5-54.0 GHz x2 Multiplier												

5.3.4.1.6	Mount and Tuning Circuitry													
5.3.4.2	Assembly and Test													
5.3.4.3	Deliver 87 - 108 GHz LO Sources													
5.3.4.3.1	Deliver Modules #1-6													
5.3.4.3.2	Deliver Modules #7-20													
5.3.4.3.3	Deliver Modules #21-35													
5.3.4.3.4	Deliver Modules #36-40													
5.3.5	65 - 85 GHz Source		6	8	\$ 98	\$ 240		\$ 38	\$ 75	\$ 300	\$ 81	\$ 323		
5.3.5.1	Contract Procurement and Fabrication													
5.3.5.1.1	YIG-tuned Oscillator													
5.3.5.1.2	16.25-21.25 GHz 10 db Amplifier													
5.3.5.1.3	16.25-21.25 GHz x2 Multiplier													
5.3.5.1.4	32.5-42.5 GHz 10 db Amplifier													
5.3.5.1.5	32.5-42.5 GHz x2 Multiplier													
5.3.5.1.6	Mount and Tuning Circuitry													
5.3.5.2	Assembly and Test													
5.3.5.3	Deliver 65 - 85 GHz LO Sources													
5.3.5.3.1	Deliver Modules #1-6													
5.3.5.3.2	Deliver Modules #7-20													
5.3.5.3.3	Deliver Modules #21-35													
5.3.5.3.4	Deliver Modules #36-40													
5.4	Millimeter LO Multiplier Chains													
5.4.1	Design and System Integration		2		\$ 20				\$ 3	\$ 20	\$ 3	\$ 21		
5.4.2	211 - 275 GHz Receiver LO		3	18	\$ 117	\$ 50		\$ 19	\$ 27	\$ 148	\$ 29	\$ 160		
5.4.2.1	Contract Fabrication													
5.4.2.1.1	X3 Diode for 72-95 GHz Source													
5.4.2.1.2	Machine Mount													
5.4.2.1.3	Bias and Control circuits													
5.4.2.2	Assemble Multiplier and Test													
5.4.2.3	Integrate Source and Multiplier; test													
5.4.2.4	Deliver 211-275 GHz Rcvr LO Modules													
5.4.2.4.1	Deliver Modules #1-3													
5.4.2.4.2	Deliver Modules #4-21													
5.4.2.4.3	Deliver Modules #22-40													
5.4.3	602 - 720 GHz Receiver LO		3	18	\$ 117	\$ 50		\$ 167	\$ -	\$ -	\$ -	\$ -		
5.4.3.1	Contract Fabrication													
5.4.3.1.1	X2 Diode for 100-120 GHz Source													
5.4.3.1.2	X3 Diode for 200-240 GHz Input													
5.4.3.1.3	Machine Mount													
5.4.3.1.4	Bias and Control circuits													
5.4.3.2	Assemble Multipliers and Test													
5.4.3.3	Integrate Source and Multipliers; test													
5.4.3.4	Deliver 602-720 GHz Rcvr LO Modules													
5.4.3.4.1	Deliver Modules #1-6													
5.4.3.4.2	Deliver Modules #7-18													
5.4.3.4.3	Deliver Modules #19-34													
5.4.3.4.4	Deliver Modules #35-40													
5.4.4	275 - 370 GHz Receiver LO		3	18	\$ 117	\$ 50		\$ 19	\$ 27	\$ 148	\$ 29	\$ 160		
5.4.4.1	Contract Fabrication													
5.4.4.1.1	X2 Diode for 72-95 GHz Source													

5.4.4.1.2	X2 Diode for 144-190 GHz Input																				
5.4.4.1.3	Machine Mount																				
5.4.4.1.4	Bias and Control Circuits																				
5.4.4.2	Assemble Multipliers and Test																				
5.4.4.3	Integrate Source and Multipliers; test																				
5.4.4.4	Deliver 275-370 GHz Rcvr LO Modules																				
5.4.4.4.1	Deliver Modules #1-6																				
5.4.4.4.2	Deliver Modules #7-27																				
5.4.4.4.3	Deliver Modules #28-40																				
5.4.5	163 - 211 GHz Receiver LO		3		18	\$	117	\$	50			\$	19	\$	27	\$	148	\$	29	\$	160
5.4.5.1	Contract Fabrication																				
5.4.5.1.1	X2 Diode for 87-108 GHz Source																				
5.4.5.1.2	Machine Mount																				
5.4.5.1.3	Bias and Control Circuits																				
5.4.5.2	Assemble Multiplier and Test																				
5.4.5.3	Integrate Source and Multiplier; test																				
5.4.5.4	Deliver 163 - 211 GHz Rcvr LO Modules																				
5.4.5.4.1	Deliver Modules #1-6																				
5.4.5.4.2	Deliver Modules #7-24																				
5.4.5.4.3	Deliver Modules #25-40																				
5.4.6	385 - 500 GHz Receiver LO		3		18	\$	117	\$	50			\$	19	\$	27	\$	148	\$	29	\$	160
5.4.6.1	Contract Fabrication																				
5.4.6.1.1	X3 Diode for 65-85 GHz Source																				
5.4.6.1.2	X2 Diode for 130-170 GHz Input																				
5.4.6.1.3	Machine Mount																				
5.4.6.1.4	Bias and Control Circuits																				
5.4.6.2	Assemble Multiplier and test																				
5.4.6.3	Integrate source and Multiplier; test																				
5.4.6.4	Deliver 385-500 GHz Rcvr LO Modules																				
5.4.6.4.1	Deliver Modules #1-6																				
5.4.6.4.2	Deliver Modules #7-24																				
5.4.6.4.3	Deliver Modules #25-40																				
5.4.7	125 - 163 GHz Receiver LO		6		24	\$	176	\$	75			\$	28	\$	40	\$	223	\$	44	\$	240
5.4.7.1	Contract Fabrication																				
5.4.7.1.1	X2 Diode for 65 - 85 GHz Source																				
5.4.7.1.2	Machine Mount																				
5.4.7.1.3	Bias and Control Circuits																				
5.4.7.2	Assemble Multiplier and test																				
5.4.7.3	Integrate Source and Multiplier; test																				
5.4.7.4	Deliver 125-163 GHz Rcvr LO Modules																				
5.4.7.4.1	Deliver Modules #1-6																				
5.4.7.4.2	Deliver Modules #7-18																				
5.4.7.4.3	Deliver Modules #19-34																				
5.4.7.4.4	Deliver Modules #35-40																				
5.4.8	33-45 GHz Receiver LO																				
5.4.8.1	Design & Fab Selection & Coupling from Sources																				
6	IF System		12		36	\$	293						\$	44	\$	293	\$	47	\$	315	
6.1	IF System: Prototype Systems																				

6.1.1	Deliver (Bench) Prototype IF System												
6.1.2	Testing and Design Refinement												
6.1.3	Procure/Fab Field Prototypes												
6.1.4	Deliver IF Field Prototypes to Test Interfeometer												
6.1.5	Field Prototype testing and Design Refinement												
6.1.6	Preproduction Review												
6.1.7	Final Documentation and Design Modifications												
6.1.8	Release for Manufacture												
6.2	Production test and lab equipment												
6.3	IF Multiplexer					\$ 160		\$ 18	\$ 21	\$ 142	\$ 23	\$ 153	
6.4	IF Demultiplexer					\$ 80		\$ 9	\$ 11	\$ 71	\$ 11	\$ 77	
6.5	IF Matrix Switch					\$ 64		\$ 7	\$ 9	\$ 57	\$ 9	\$ 61	
6.6	Baseband Converter					\$ 160		\$ 18	\$ 21	\$ 142	\$ 23	\$ 153	
6.7	Power supply module					\$ 40		\$ 4	\$ 5	\$ 36	\$ 6	\$ 38	
6.8	Bins / Racks (assemble and test)					\$ 16		\$ 2	\$ 2	\$ 14	\$ 2	\$ 15	
7	Optical Fiber System		12	36	\$ 293				\$ 44	\$ 293	\$ 47	\$ 315	
7.1	Optical Fiber System: Prototype Systems												
7.1.1	Deliver (Bench) Prototype FO System												
7.1.2	Testing and Design Refinement												
7.1.3	Procure/Fab Field Prototypes												
7.1.4	Deliver FO Field Prototypes to Test Interfeometer												
7.1.5	Field Prototype testing and Design Refinement												
7.1.6	Preproduction Review												
7.1.7	Final Documentation and Design Modifications												
7.1.8	Release for Manufacture												
7.1	Production test and lab equipment												
7.2	IF TX / RX					\$ 240		\$ 27	\$ 32	\$ 213	\$ 34	\$ 230	
7.3	LO Reference TX / RX					\$ 40		\$ 4	\$ 5	\$ 36	\$ 6	\$ 38	
7.4	Microwave Round-trip Phase TX / RX					\$ 40		\$ 4	\$ 5	\$ 36	\$ 6	\$ 38	
7.5	Monitor / Control TX / RX					\$ 20		\$ 2	\$ 3	\$ 18	\$ 3	\$ 19	
7.6	Power supply module					\$ 40		\$ 4	\$ 5	\$ 36	\$ 6	\$ 38	
7.7	Bins / Racks (assemble and test)					\$ 16		\$ 2	\$ 2	\$ 14	\$ 2	\$ 15	
										\$ -			
										\$ -			
8	Correlator		36	36	\$ 527	\$ 1,000		\$ 170	\$ 328	\$ 1,357	\$ 353	\$ 1,461	
8.1	Digital Sampler, 4 GHz												
8.1.1	Refine Design												
8.1.2	Release Digital Sampler for Manufacture												
8.1.3	Contract Materials												
8.1.4	Assembly												
8.1.5	Validation and Delivery												
8.2	Digital FIR Filter												
8.2.1	Prototype testing on Test Interferometer												
8.2.2	Design Refinement												
8.2.3	Release FIR Filter for manufacture												
8.2.4	Chip Fabrication												
8.2.5	Assembly												
8.2.6	Validation and Delivery												
8.3	Custom Boards												
8.3.1	Correlator Board												

8.3.1.1	Prototype assembly												
8.3.1.2	Prototype test												
8.3.1.3	Design modifications												
8.3.1.4	Fab, assemble and test with design mods												
8.4	Correlator Chip												
8.4.1	Prototype chip fabrication												
8.4.2	Prototype chip test												
8.4.3	Design modifications												
8.4.4	Fabricate and test design mods												
8.4.5	Fabricate production run												
8.5	Racks												
8.5.1	Design control wiring												
8.5.2	Design signal wiring												
8.5.3	Order parts												
8.5.4	Assemble prototypes												
8.6	Software												
8.7	Prototype Correlator Production												
8.7.1	Order parts												
8.7.2	Assemble												
8.7.3	Test												
8.7.4	Deliver Prototype Correlator to VLA site												
8.8	Site Correlator Production												
8.8.1	First 1/4 correlator												
8.8.1.1	Determine configuration												
8.8.1.2	Order parts												
8.8.1.3	Assemble												
8.8.1.4	Test												
8.8.1.5	Deliver 1/4 Correlator to MMA site												
8.8.2	Second 1/4 correlator												
8.8.2.1	Order parts												
8.8.2.2	Assemble												
8.8.2.3	Test												
8.8.2.4	Deliver 1/4 Correlator to MMA site												
8.8.3	Third 1/4 correlator												
8.8.3.1	Order parts												
8.8.3.2	Assemble												
8.8.3.3	Test												
8.8.3.4	Deliver 1/4 Correlator to MMA site												
8.8.4	Fourth 1/4 correlator												
8.8.4.1	Order parts												
8.8.4.2	Assemble												
8.8.4.3	Test												
8.8.4.4	Deliver 1/4 Correlator to MMA site												
8.9	Continued Support												
9	Computing						\$ 150			\$ 45	\$ 150	\$ 48	\$ 162
9.1	Control Software												
9.1.1	Test Interferometer Control & Analysis												
9.1.2	MMA correlator software												
9.1.3	Multi-antenna & sub-array control	33				\$ 286			\$ 43	\$ 286	\$ 46	\$ 308	
9.1.4	Operators & Observers interfaces	26				\$ 225			\$ 34	\$ 225	\$ 36	\$ 243	
9.1.5	Deliver Control Software	40				\$ 347			\$ 52	\$ 347	\$ 56	\$ 373	
9.1.6	Maintenance												

9.2	Scheduling												
9.2.1	Static scheduling system		9			\$	78				\$	12	\$ 78 \$ 13 \$ 84
9.2.2	Dynamic scheduling simulations												
9.2.3	Dynamic scheduling prototype		10			\$	87				\$	13	\$ 87 \$ 14 \$ 93
9.2.4	Dynamic scheduling implementation												
9.2.5	Initial Operations with Dynamic Scheduling												
9.3	Proposal Preparation Software												
9.3.1	Prototype		5			\$	43				\$	7	\$ 43 \$ 7 \$ 47
9.3.2	Production version		10			\$	87				\$	13	\$ 87 \$ 14 \$ 93
9.4	Image Pipeline												
9.4.1	Automated calibration & imaging heuristics												
9.4.2	Prototype image pipeline												
9.4.3	Parallelization studies and implementation		12			\$	104				\$	16	\$ 104 \$ 17 \$ 112
9.4.4	Initial Image Pipeline Operations												
9.4.5	Production image pipeline												
9.5	Archiving												
9.5.1	Prototype distributed archive												
9.5.2	Evaluate storage hardware												
9.5.3	Production archive		20			\$	173				\$	26	\$ 173 \$ 28 \$ 187
9.5.4	Data Archive operational												
9.6	Post-processing												
9.6.1	Define MMA Data formats												
9.6.2	MMA filler & format conversions		5			\$	43				\$	7	\$ 43 \$ 7 \$ 47
9.6.3	MMA-specific calibrations		5			\$	43				\$	7	\$ 43 \$ 7 \$ 47
9.6.4	MMA Post-processing begins					\$	-						
9.6.5	Maintenance		12			\$	104		\$ 104		\$ -	\$ -	\$ - \$ -
10	System Integration												
10.4	Test Interferometer Site Preparation												
10.4.1	Complete Office and Lab Space Preparation												
10.4.2	Cabling												
10.4.3	Test Interferometer Site Complete												
10.10.4	Prototype Antenna Outfitting												
10.10.4.1	Cabling												
10.10.4.2	Instrumentation												
10.10.4.3	Eval. Rcvr. #1 / Ant. #1 Integration												
10.10.4.4	Antenna #1 Outfitting Complete												
10.10.5	Integration Holography System/Antenna												
10.10.6	Integration Metrology/Antenna												
10.10.7	Antenna #1 Integration & Testing												
10.10.8	Prot. Rcvr. Test & Evaluation												
10.10.9	Antenna #2 Outfitting												
10.10.9.1	Cabling												
10.10.9.2	Instrumentation												
10.10.9.3	Eval. Rcvr. #2 / Ant. #2 Integration												
10.10.9.4	Antenna #2 Outfitting Complete												
10.11	Test Interferometer												
10.11.1	Antenna Evaluation & Characterization												
10.11.1.1	Antenna Verification												
10.11.1.4	Holography												
10.11.1.5	Beam and Sidelobes												
10.11.1.6	Gain vs. Elevation: Spillover Temp												
10.11.1.7	Effect of Sun in & Near the Beam												

10.11.2	Engineering Recommendations re Prod. Ant.												
10.11.3	Revise Interface Specifications												
10.11.5	Operations Personnel Training	6			72	\$ 400		\$ 400		\$ -	\$ -	\$ -	\$ -
10.11.5.1	Recruit Initial Chile Ops Staff												
10.11.5.2	Array Operations												
10.11.5.3	Engineering Maintenance												
10.11.5.4	Scientific Support & Analysis												
10.12.2	Relocate Ops Staff to Chile												
10.8.4.6	Start On-site Operations												
10.12	Disassemble Test Interferometer												
10.12.1	Prepare & Ship Antenna #1, #2												
10.12.3	Restore Facilities at VLA Site												
10.13	On Site System Integration			48	48	\$ 702		\$ 702		\$ -	\$ -	\$ -	\$ -
11	Calibration and Imaging												
11.1	Radiometric Phase Design & Prototype												
11.1.1	Complete 183GHz Phase Mon Prototype												
11.1.2	Demo 183 GHz Phase Monitor Radiometer on-Site												
11.1.3	Design Refinement												
11.1.4	Release Phase Mon Radiometer for manufacture												
11.2	Production Fab of Phase Monitor Radiometer			12	24	\$ 234	\$ 515		\$ 83	\$ 165	\$ 666	\$ 177	\$ 717
11.2.1	Contract Subassembly Fabrication												
11.2.1.1	Radiometer & Local Oscillator												
11.2.1.2	Spectrometer												
11.2.1.3	Feed, Window, lens, instrumentation												
11.2.1.4	M/C Interface												
11.2.2	Assembly & Test												
11.2.3	Deliver Production Radiometers												
11.2.4	Integration in Receiver Package												
11.2.5	Verification on-Site												
11.3	Production Fabrication of Dual-load Amp Cal Sys				6	\$ 29			\$ 3	\$ 3	\$ 26	\$ 4	\$ 28
11.3.1	Design Refinement												
11.3.2	Release Phase Mon Radiometer for manufacture												
11.3.3	Contract Subassembly												
11.3.3.1	Machining												
11.3.3.2	Load Fabrication												
11.3.3.3	Motors, Servo												
11.3.3.4	M/C Interface												
11.3.4	Assembly & Test												
11.3.5	Integration on Production Antennas												
11.4	Imaging Studies & Project Support	72				\$ 585		\$ 585		\$ -	\$ -	\$ -	\$ -
11.5	Imaging Algorithm Development	8	4			\$ 100				\$ 15	\$ 100	\$ 16	\$ 107
	TOTALS					\$ 12,205	\$ 41,781	\$ 5,455	\$ 2,418	\$ 11,707	\$ 46,113	\$ 12,607	\$ 49,659

Millimeter Array Construction 2005

WBS	Name	Scientists Work- Months	Programmers Work-Months	Engineers Work- Months	Technicians Work- Months	Personnel Cost	Materials and Supplies	Transfer to Operations	Adjustment to Scope	Contingency	Sum Cost	Inflated Contingency	Inflated Sum
1	Administration												
1.1	Project Management	72			48	\$ 819		\$ 215		\$ 91	\$ 605	\$ 100	\$ 667
1.1.1	Management, Planning, and Oversight						\$ 700			\$ 105	\$ 700	\$ 116	\$ 773
1.1.2	Business Operations						\$ 100			\$ 15	\$ 100	\$ 17	\$ 110
1.1.3	Chilean Operations						\$ 50			\$ 8	\$ 50	\$ 8	\$ 55
1.1.4	Safety and Health												
1.1.5	Personnel												
1.1.6	Project Science Office												
1.1.7	AUI Management						\$ 350			\$ -	\$ 350	\$ -	\$ 386
1.2	Engineering			24	12	\$ 293	\$ 20			\$ 47	\$ 313	\$ 52	\$ 345
1.2.1	System Engineering--Phase II												
1.2.2	Documentation System												
1.2.3	Production Engineering												
1.3	US Facilities												
1.3.1	CDL Permanent Facilities						\$ 600			\$ -	\$ 600	\$ -	\$ 662
1.3.2	Manufacturing Facilities						\$ 100			\$ 15	\$ 100	\$ 17	\$ 110
1.3.3	Common Infrastructure						\$ 200			\$ 30	\$ 200	\$ 33	\$ 221
2	Site Development			12		\$ 117	\$ 50			\$ 25	\$ 167	\$ 28	\$ 184
2.1	Review Legalities Regarding Array and OSF Sites												
2.2	Maintain Mining claims						\$ 25			\$ -	\$ 25	\$ -	\$ 28
2.3	Contract A&E Studies												
2.4	Hire Construction Manager for Chile												
2.5	Array Site												
2.5.1	Prepare Site Development Bid Packages												
2.5.1.1	Prepare Package for Array Site												
2.5.1.2	Review Bid Packages												
2.5.1.3	Bid Civil Works Construction												
2.5.2	Evaluate Array Site Bid Response												
2.5.2.1	Review Bids												
2.5.2.2	Recommend Contractors												
2.5.2.3	Award Array Site Contracts												
2.5.3	Contract Array Site Civil Works												
2.5.3.1	Array Site												
2.5.3.2	Inspect Completed Site Constr												
2.5.3.3	Accept Site Facility												
2.6	Operations Support Facility												
2.6.1	Prepare OSF Bid Packages												
2.6.1.1	Prepare Package for OSF												
2.6.1.2	Review Bid Packages												
2.6.1.3	Bid Civil Works Construction												
2.6.2	Evaluate OSF Bid Response												
2.6.2.1	Review Bids												
2.6.2.2	Recommend Contractors												
2.6.2.3	Award Contracts												

2.6.3	Contract OSF Civil Works																	
2.6.3.1	Operations Support Facility																	
2.6.3.2	Inspect Completed OSF Constr																	
2.6.3.3	Accept OSF Facility																	
2.7	OSF/Array Link																	
2.7.1	Prepare OSF/Array Link Bid Package																	
2.7.1.1	Prepare Package for OSF/Array F/O Link																	
2.7.1.2	Review Bid Package																	
2.7.1.3	Bid OSF/Array Link Construction																	
2.7.2	Evaluate Bid Response																	
2.7.2.1	Review Bids																	
2.7.2.2	Recommend Contractors																	
2.7.2.3	Award Contracts																	
2.7.3	Contract Civil Works																	
2.7.3.1	OSF/Array Link																	
2.7.3.2	Inspect Completed OSF/Array Link Constr																	
2.7.3.3	Accept OSF/Array Link																	
2.8	Prepare for Instrument Assembly																	
2.8.1	Equip Array Site																	
2.8.2	Equip Operations Support Facility																	
3	Antenna																	
3.1	Antenna Engineering Support																	
3.3.40	Acceptance Tests Antenna #1																	
3.3.45	Delivery of Antenna #1																	
3.8.10	Sign Transporter Contract																	
3.8.15	Transporter Acceptance tests																	
3.8.20	Deliver/Accept Transporter #1																	
3.7	Procurement of Antenna #2																	
3.7.1	Antenna #2 Contract Supervision																	
3.7.2	Antenna #2 Acceptance tests																	
3.8	Negotiate Production Antenna Contract																	
3.9	Sign Contract for Production Antennas																	
3.10	Antenna Contract Supervision																	
3.11	Accept Antenna #3 at OSF																	
3.12	Prepare Antenna #3																	
3.12.1	Outfit & Verify Ant #3 at OSF																	
3.12.2	Move, Install & Verify Ant #3 on Site																	
3.13	Accept Antenna #4 at OSF																	
3.14	Prepare Antenna #4																	
3.14.1	Outfit & Verify Ant #4 at OSF																	
3.14.2	Move, Install & Verify Ant #4 on Site																	
3.15	Accept Antenna#5 at OSF																	
3.16	Prepare Antenna #5																	
3.16.1	Outfit & Verify Ant #5 at OSF																	
3.16.2	Move, Install & Verify Ant #5 on Site																	
3.17	Accept Antenna#6 at OSF																	
3.18	Prepare Antenna #6																	
3.18.1	Outfit & Verify Ant #6 at OSF																	
3.18.2	Move, Install & Verify Ant #6 on Site																	
3.19	Accept Antenna #7 at OSF			1.5		\$	15				\$	2	\$	15	\$	2	\$	16

3.20	Prepare Antenna #7																			
3.20.1	Outfit & Verify Ant #7 at OSF			2		4	\$	39					\$	6	\$	39	\$	6	\$	43
3.20.2	Move, Install & Verify Ant #7 on Site			1		1	\$	15					\$	2	\$	15	\$	2	\$	16
3.21	Accept Antenna #8 at OSF			1.5			\$	15					\$	2	\$	15	\$	2	\$	16
3.22	Prepare Antenna #8																			
3.22.1	Outfit & Verify Ant #8 at OSF			2		4	\$	39					\$	6	\$	39	\$	6	\$	43
3.22.2	Move, Install & Verify Ant #8 on Site			1		1	\$	15					\$	2	\$	15	\$	2	\$	16
3.23	Accept Antenna #9 at OSF			1.5			\$	15					\$	2	\$	15	\$	2	\$	16
3.24	Prepare Antenna #9																			
3.24.1	Outfit & Verify Ant #9 at OSF			2		4	\$	39					\$	6	\$	39	\$	6	\$	43
3.24.2	Move, Install & Verify Ant #9 on Site			1		1	\$	15					\$	2	\$	15	\$	2	\$	16
3.25	Accept Antenna #10 at OSF			1.5			\$	15					\$	2	\$	15	\$	2	\$	16
3.26	Prepare Antenna #10																			
3.26.1	Outfit & Verify Ant #10 at OSF			2		4	\$	39					\$	6	\$	39	\$	6	\$	43
3.26.2	Move, Install and Verify Ant #10 on Site			1		1	\$	15					\$	2	\$	15	\$	2	\$	16
3.27	Accept Antenna #11 at OSF			1.5			\$	15					\$	2	\$	15	\$	2	\$	16
3.28	Prepare Antenna #11																			
3.28.1	Outfit & Verify Ant #11 at OSF			2		4	\$	39					\$	6	\$	39	\$	6	\$	43
3.28.2	Move, Install & Verify Ant #11 on Site			1		1	\$	15					\$	2	\$	15	\$	2	\$	16
3.29	Accept Antenna #12 at OSF			1.5			\$	15					\$	2	\$	15	\$	2	\$	16
3.30	Prepare Antenna #12																			
3.30.1	Outfit & Verify Ant #12 at OSF			2		4	\$	39					\$	6	\$	39	\$	6	\$	43
3.30.2	Move, Install & Verify Ant #12 on Site			1		1	\$	15					\$	2	\$	15	\$	2	\$	16
3.31	Accept Antenna #13 at OSF			1.5			\$	15					\$	2	\$	15	\$	2	\$	16
3.32	Prepare Antenna #13																			
3.32.1	Outfit & Verify Ant #13 at OSF			2		4	\$	39					\$	6	\$	39	\$	6	\$	43
3.32.2	Move, Install & Verify Ant #13 on Site			1		1	\$	15					\$	2	\$	15	\$	2	\$	16
3.33	Accept Antenna #14 at OSF			1.5			\$	15					\$	2	\$	15	\$	2	\$	16
3.34	Prepare Antenna #14																			
3.34.1	Outfit & Verify Ant #14 at OSF			2		4	\$	39					\$	6	\$	39	\$	6	\$	43
3.34.2	Move, Install & Verify Ant #14 on Site			1		1	\$	15					\$	2	\$	15	\$	2	\$	16
3.35	Accept Antenna #15 at OSF			1.5			\$	15					\$	2	\$	15	\$	2	\$	16
3.36	Prepare Antenna #15																			
3.36.1	Outfit & Verify Ant #15 at OSF			2		4	\$	39					\$	6	\$	39	\$	6	\$	43
3.36.2	Move, Install & Verify Ant #15 on Site			1		1	\$	15					\$	2	\$	15	\$	2	\$	16
3.37	Accept Antenna #16 at OSF			3			\$	29	\$	2,832			\$	854	\$	2,861	\$	943	\$	3,158
3.38	Prepare Antenna #16																			
3.38.1	Outfit & Verify Ant #16 at OSF																			
3.38.2	Move, Install & Verify Ant #16 on Site																			
3.39	Accept Antenna #17 at OSF			3			\$	29	\$	2,832			\$	854	\$	2,861	\$	943	\$	3,158
3.40	Prepare Antenna #17																			
3.40.1	Outfit & Verify Ant #17 at OSF																			
3.40.2	Move, Install & Verify Ant #17 on Site																			
3.41	Accept Antenna #18 at OSF			3			\$	29	\$	2,832			\$	854	\$	2,861	\$	943	\$	3,158
3.42	Prepare Antenna #18																			
3.42.1	Outfit & Verify Ant #18 at OSF																			
3.42.2	Move, Install & Verify Ant #18 on Site																			
3.43	Accept Antenna #19 at OSF			3			\$	29	\$	2,832			\$	854	\$	2,861	\$	943	\$	3,158
3.44	Prepare Antenna #19																			
3.44.1	Outfit & Verify Ant #19 at OSF																			
3.44.2	Move, Install & Verify Ant #19 on Site																			
3.45	Accept Antenna #20 at OSF			3			\$	29	\$	2,832			\$	854	\$	2,861	\$	943	\$	3,158
3.46	Prepare Antenna #20																			
3.46.1	Outfit & Verify Ant #20 at OSF																			

3.46.2	Move, Install & Verify Ant #20 on Site												
3.47	Accept Antenna #21 at OSF			3		\$ 29	\$ 2,832			\$ 854	\$ 2,861	\$ 943	\$ 3,158
3.48	Prepare Antenna #21												
3.48.1	Outfit & Verify Ant #21 at OSF												
3.48.2	Move, Install & Verify Ant #21 on Site												
3.49	Accept Antenna #22 at OSF			3		\$ 29	\$ 2,832			\$ 854	\$ 2,861	\$ 943	\$ 3,158
3.50	Prepare Antenna #22												
3.50.1	Outfit & Verify Ant #22 at OSF												
3.50.2	Move, Install & Verify Ant #22 on Site												
3.51	Accept Antenna #23 at OSF			3		\$ 29	\$ 2,832			\$ 854	\$ 2,861	\$ 943	\$ 3,158
3.52	Prepare Antenna #23												
3.52.1	Outfit & Verify Ant #23 at OSF												
3.52.2	Move, Install & Verify Ant #23 on Site												
3.53	Accept Antenna #24 at OSF			3		\$ 29	\$ 2,832			\$ 854	\$ 2,861	\$ 943	\$ 3,158
3.54	Prepare Antenna #24												
3.54.1	Outfit & Verify Ant #24 at OSF												
3.54.2	Move, Install & Verify Ant #24 on Site												
3.55	Accept Antenna #25 at OSF			3		\$ 29	\$ 2,832			\$ 854	\$ 2,861	\$ 943	\$ 3,158
3.56	Prepare Antenna #25												
3.56.1	Outfit & Verify Ant #25 at OSF												
3.56.2	Move, Install & Verify Ant #25 on Site												
3.57	Accept Antenna #26 at OSF			3		\$ 29	\$ 2,832			\$ 854	\$ 2,861	\$ 943	\$ 3,158
3.58	Prepare Antenna #26												
3.58.1	Outfit & Verify Ant #26 at OSF												
3.58.2	Move, Install & Verify Ant #26 on Site												
3.59	Accept Antenna #27 at OSF			3		\$ 29	\$ 2,832			\$ 854	\$ 2,861	\$ 943	\$ 3,158
3.60	Prepare Antenna #27												
3.60.1	Outfit & Verify Ant #27 at OSF												
3.60.2	Move, Install & Verify Ant #27 on Site												
3.61	Accept Antenna #28 at OSF												
3.62	Prepare Antenna #28												
3.62.1	Outfit & Verify Ant #28 at OSF												
3.62.2	Move, Install & Verify Ant #28 on Site												
3.63	Accept Antenna #29 at OSF												
3.64	Prepare Antenna #29												
3.64.1	Outfit & Verify Ant #29 at OSF												
3.64.2	Move, Install & Verify Ant #29 on Site												
3.65	Accept Antenna #30 at OSF												
3.66	Prepare Antenna #30												
3.66.1	Outfit & Verify Ant #30 at OSF												
3.66.2	Move, Install & Verify Ant #30 on Site												
3.67	Accept Antenna #31 at OSF												
3.68	Prepare Antenna #31												
3.68.1	Outfit & Verify Ant #31 at OSF												
3.68.2	Move, Install and Verify Ant #31 on Site												
3.69	Accept Antenna #32 at OSF												
3.70	Prepare Antenna #32												
3.70.1	Outfit & Verify Ant #32 at OSF												
3.70.2	Move, Install & Verify Ant #32 on Site												
3.71	Accept Antenna #33 at OSF												
3.72	Prepare Antenna #33												
3.72.1	Outfit & Verify Ant #33 at OSF												
3.72.2	Move, Install and Verify Ant #33 on Site												
3.73	Accept Antenna #34 at OSF												

3.74	Prepare Antenna #34												
3.74.1	Outfit & Verify Ant #34 at OSF												
3.74.2	Move, Install and Verify Ant #34 on Site												
3.75	Accept Antenna #35 at OSF												
3.76	Prepare Antenna #35												
3.76.1	Outfit & Verify Ant #35 at OSF												
3.76.2	Move, Install & Verify Ant #35 on Site												
3.77	Accept Antenna #36 at OSF												
3.78	Prepare Antenna #36												
3.78.1	Outfit & Verify Ant #36 at OSF												
3.78.2	Move, Install & Verify Ant #36 on Site												
3.79	Prepare Antenna #1												
3.79.1	Antenna #1 Reassembled at OSF						\$ 388			\$ 116	\$ 388	\$ 128	\$ 428
3.79.2	Outfit & Verify Ant #1 at OSF												
3.79.3	Move, Install & Verify Ant #1 on Site												
3.80	Prepare Antenna #2												
3.80.1	Antenna #2 Reassembled at OSF						\$ 388			\$ 116	\$ 388	\$ 128	\$ 428
3.80.2	Outfit & Verify Ant #2 at OSF												
3.80.3	Move, Install & Verify Ant #2 on Site												
3.81	Antenna Transporter												
3.81.1	Contract for Transporter #1, move to Site						\$ 60			\$ 18	\$ 60	\$ 20	\$ 66
3.81.2	Contract for Transporters #2, #3												
3.81.3	Accept Transporters #2, #3 at OSF												
4	Receivers												
4.1	Receiver Package												
4.1.1	Prototype Production Receiver Cryogenics												
4.1.1.1	CDR: Cryogenics Development												
4.1.1.2	Construct & test prototype cryogenics												
4.1.1.3	Deliver Prototype Cryogenics Subsystem												
4.1.2	Prototype Production Receiver Package												
4.1.2.1	Prototype Receiver Package Integration												
4.1.2.2	Prot. Rcvr. Pckg Lab Test & Evaluation												
4.1.2.3	Complete Prototype MMA Receiver Package												
4.1.3	MMA Rcvr Pckg Design Refinement												
4.1.4	Documentation												
4.1.5	Release MMA Receiver Pckg for manufacture												
4.1.6	Contract for Receiver Pckg Subassemblies												
4.1.6.1	Machine Dewars				30	\$ 146	\$ 50		\$ 22	\$ 30	\$ 174	\$ 34	\$ 193
4.1.6.2	Fabricate Cryogenics subsystems	6		24	\$ 176	\$ 240		\$ 46	\$ 84	\$ 369	\$ 93	\$ 408	
4.1.6.3	Fabricate windows, IR filters, etc	6		30	\$ 205	\$ 100		\$ 34	\$ 51	\$ 271	\$ 56	\$ 299	
4.1.7	Accept Receiver Pckg Subassemblies												
4.1.7.1	Subassemblies #1-6												
4.1.7.2	Subassemblies #7-16												
4.1.7.3	Subassemblies #17-26												
4.1.7.4	Subassemblies #27-36												
4.1.7.5	Subassemblies #37-40												
4.1.8	Fab Rcvr Pckg Instrumentation & Electronics	3		12	\$ 88	\$ 100		\$ 21	\$ 37	\$ 167	\$ 41	\$ 184	
4.1.9	Fabricate Receiver Inserts	18		30	\$ 322	\$ 100		\$ 47	\$ 64	\$ 375	\$ 71	\$ 414	
4.1.10	Assemble Receiver Package												
4.1.10.1	Integrate Rcvr Instrumentation & subass'y	12		48	\$ 351	\$ 80		\$ 48	\$ 62	\$ 383	\$ 69	\$ 423	

4.1.10.2	Deliver Receiver Package #1-6												
4.1.10.3	Deliver Receiver Package #7-16												
4.1.10.4	Deliver Receiver Package #17-26												
4.1.10.5	Deliver Receiver Package #27-36												
4.1.10.6	Deliver Receiver Package #37-40												
4.2	SIS Receiver Modules												
4.2.1	211-275 GHz Module												
4.2.1.1	SIS Mixer												
4.2.1.1.1	Design, Fab and Test Mixer Design												
4.2.1.1.2	Deliver Production Design												
4.2.1.1.3	Fabricate Production Mixers												
4.2.1.2	Design & Verify Optics												
4.2.1.3	Design Module												
4.2.1.4	Contract Fabrication												
4.2.1.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.1.4.2	Assemble Modules												
4.2.1.5	Install SIS Mixer & Test Modules												
4.2.1.6	Deliver 211-275 GHz Receiver Modules												
4.2.1.6.1	Deliver Modules #1-7												
4.2.1.6.2	Deliver Modules #8-26												
4.2.1.6.3	Deliver Modules #27-40												
4.2.2	602-720 GHz Module												
4.2.2.1	SIS Mixer												
4.2.2.1.1	Design, Fabricate and Test Mixer Design												
4.2.2.1.2	Deliver Production Design												
4.2.2.1.3	Fabricate Production Mixers												
4.2.2.2	Design & Verify Optics												
4.2.2.3	Design Module												
4.2.2.4	Contract Fabrication												
4.2.2.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.2.4.2	Assemble Modules												
4.2.2.5	Install SIS Mixer and Test Modules												
4.2.2.6	Deliver 602-720 GHz Receiver Modules												
4.2.2.6.1	Deliver Modules #1-7												
4.2.2.6.2	Deliver Modules #8-26												
4.2.2.6.3	Deliver Modules #27-40												
4.2.3	275-370 GHz Receiver Module												
4.2.3.1	SIS Mixer												
4.2.3.1.1	Design, Fabricate and Test Mixer Design												
4.2.3.1.2	Deliver Production Design												
4.2.3.1.3	Fabricate Production Mixers												
4.2.3.2	Design & Verify Optics												
4.2.3.3	Design Module												
4.2.3.4	Contract Fabrication												
4.2.3.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.3.4.2	Assemble Modules												
4.2.3.5	Install SIS Mixer and Test Modules			18	36	\$ 351	\$ 40		\$ 43	\$ 52	\$ 348	\$ 57	\$ 384
4.2.3.6	Deliver 275-370 GHz Receiver Module												
4.2.3.6.1	Deliver Modules #1-5												
4.2.3.6.2	Deliver Modules #6-30												
4.2.3.6.3	Deliver Modules #30-40												

4.2.4	91-119 GHz Receiver Module																		
4.2.4.1	SIS Mixer																		
4.2.4.1.1	Design, Fabricate & Test Mixer Design																		
4.2.4.1.2	Deliver Production Design																		
4.2.4.1.3	Fabricate Production Mixers																		
4.2.4.2	Design & Verify Optics																		
4.2.4.3	Design Module																		
4.2.4.4	Contract Fabrication																		
4.2.4.4.1	Machine Mixer Blocks, Feed, WG, Lenses																		
4.2.4.4.2	Assemble Modules																		
4.2.4.5	Install SIS Mixer and Test Modules		18	36	\$	351	\$	40		\$	43	\$	52	\$	348	\$	57	\$	384
4.2.4.6	Deliver 91-119 GHz Receiver Modules																		
4.2.4.6.1	Deliver Modules #1-5																		
4.2.4.6.2	Deliver Modules #6-30																		
4.2.4.6.3	Deliver Modules # 31-40																		
4.2.5	163-211 GHz Receiver Module																		
4.2.5.1	SIS Mixer																		
4.2.5.1.1	Design, Fabricate & Test Mixer Design																		
4.2.5.1.2	Deliver Production Design																		
4.2.5.1.3	Fabricate Production Mixers																		
4.2.5.2	Design & Verify Optics																		
4.2.5.3	Design Module																		
4.2.5.4	Contract Fabrication			4	\$	20	\$	50		\$	8	\$	16	\$	62	\$	17	\$	68
4.2.5.4.1	Machine Mixer Blocks, Feed, WG, Lenses																		
4.2.5.4.2	Assemble Modules																		
4.2.5.5	Install SIS Mixer and Test		18	36	\$	351	\$	30		\$	42	\$	49	\$	339	\$	54	\$	374
4.2.5.6	Deliver 163-211 GHz Receiver Modules																		
4.2.5.6.1	Deliver Modules #1-5																		
4.2.5.6.2	Deliver Modules #6-30																		
4.2.5.6.3	Deliver Modules #31-40																		
4.2.6	385-500 GHz Receiver Module																		
4.2.6.1	SIS Mixer																		
4.2.6.1.1	Design, Fabricate & Test Mixer Design																		
4.2.6.1.2	Deliver Production Design																		
4.2.6.1.3	Fabricate Production Mixers																		
4.2.6.2	Design and Verify Optics																		
4.2.6.3	Design Module																		
4.2.6.4	Contract Fabrication			4	\$	20	\$	50		\$	70	\$	-	\$	-	\$	-	\$	-
4.2.6.4.1	Machine Mixer Blocks, Feed, WG, Lenses																		
4.2.6.4.2	Assemble Modules																		
4.2.6.5	Install SIS Mixer and Test		18	36	\$	351	\$	30		\$	381	\$	-	\$	-	\$	-	\$	-
4.2.6.6	Deliver 385-500 GHz Receiver Modules																		
4.2.6.6.1	Deliver Modules #1-5																		
4.2.6.6.2	Deliver Modules #6-30																		
4.2.6.6.3	Deliver Modules #31-40																		
4.2.7	125-163 GHz Receiver Module																		
4.2.7.1	SIS Mixer		18	18	\$	263	\$	50		\$	35	\$	44	\$	278	\$	49	\$	307
4.2.7.1.1	Design, Fabricate & Test Mixer Design																		
4.2.7.1.2	Deliver Production Design																		
4.2.7.1.3	Fabricate Production Mixers																		

4.2.7.2	Design & Verify Optics																			
4.2.7.3	Design Module																			
4.2.7.4	Contract Fabrication				4	\$	20	\$	100		\$	13	\$	29	\$	106	\$	32	\$	117
4.2.7.4.1	Machine Mixer Blocks, Feed, WG, Lenses																			
4.2.7.4.2	Assemble Modules																			
4.2.7.5	Install SIS Mixer and Test																			
4.2.7.6	Deliver 125-163 GHz Receiver Modules																			
4.2.7.6.1	Deliver 125-163 GHz Modules #1-5																			
4.2.7.6.2	Deliver 125-163 GHz Modules #6-30																			
4.2.7.6.3	Deliver 125-163 GHz Modules #31-40																			
4.3	HFET Receiver Modules			6	12	\$	117	\$	50		\$	19	\$	22	\$	148	\$	25	\$	164
4.3.1	Contract for HFET Wafer																			
4.3.2	Receive Diced HFET Wafer																			
4.3.3	33-45 GHz Module																			
4.3.3.1	Design Module																			
4.3.3.2	Design & Verify Optics																			
4.3.3.3	Contract Fabrication																			
4.3.3.3.1	Machine Blocks, Feed, WG, Lenses																			
4.3.3.3.2	Assemble Modules																			
4.3.3.3.3	Flip-in Mirror																			
4.3.4	Install HFET & Test Modules																			
4.3.5	Deliver 33-45 GHz Receiver Modules																			
4.3.5.1	Deliver Modules #1-20																			
4.3.5.2	Deliver Modules #21-40																			
4.3.6	67-95 GHz Module																			
4.3.6.1	Design Amplifer																			
4.3.6.2	Design Module																			
4.3.6.3	Design & Verify Optics																			
4.3.6.4	Contract Fabrication																			
4.3.6.4.1	Machine Blocks, Feed, WG, Lenses																			
4.3.6.4.2	Assemble Modules																			
4.3.6.5	Install HFET & Test Modules																			
4.3.6.6	Deliver 67-95 GHz Receiver Modules																			
4.3.6.6.1	Deliver Modules 67-95GHz #1-20																			
4.3.6.6.2	Deliver Modules 67-95GHz #21-40																			
5	LO System																			
5.1	LO Reference: Prototype Systems																			
5.1.1	Deliver: Bench Prototype																			
5.1.2	Testing and Design Refinement																			
5.1.3	Procure/Fab Field Prototypes																			
5.1.4	Deliver: LO Ref Field Prototypes																			
5.1.5	Field Prototype testing and Design Refinement																			
5.1.6	Preproduction Review																			
5.1.7	Final Documentation and Design Modifications																			
5.1.8	Release for Manufacture																			
5.2	LO Reference: Production System			12	48	\$	351				\$	53	\$	351	\$	58	\$	387		
5.1.1	Production test and lab equipment																			
5.1.2	H-maser Frequency Standard (& Rb)																			
5.1.3	8 GHz PL Oscillator & Distributor						\$	1		\$	0	\$	0	\$	1	\$	0	\$	1	
5.1.4	10 GHz PL Oscillator & Distributor						\$	1		\$	0	\$	0	\$	1	\$	0	\$	1	

5.1.5	12 GHz PL Oscillator & Distributor					\$ 1		\$ 0	\$ 0	\$ 1	\$ 0	\$ 1
5.1.6	14 GHz PL Oscillator & Distributor					\$ 1		\$ 0	\$ 0	\$ 1	\$ 0	\$ 1
5.1.7	3.2-5.2 GHz Synthesizer					\$ 8		\$ 1	\$ 1	\$ 7	\$ 1	\$ 8
5.1.8	3.2 -5.2 GHz PLO and Fringe Generator					\$ 160		\$ 18	\$ 21	\$ 142	\$ 24	\$ 157
5.1.9	Sampler Clock 4 GHz PL Osc & Distributor					\$ 1		\$ 0	\$ 0	\$ 1	\$ 0	\$ 1
5.1.10	LO Ref Generator					\$ 2		\$ 0	\$ 0	\$ 2	\$ 0	\$ 2
5.1.11	LO Ref Distributor - Control Bldg					\$ 1		\$ 0	\$ 0	\$ 1	\$ 0	\$ 1
5.1.12	Microwave Round-trip Phase Measurement					\$ 60		\$ 7	\$ 8	\$ 53	\$ 9	\$ 59
5.1.13	10-15 GHz Frequency Synthesizer					\$ 100		\$ 11	\$ 13	\$ 89	\$ 15	\$ 98
5.1.14	First LO Fringe Generator					\$ 20		\$ 2	\$ 3	\$ 18	\$ 3	\$ 20
5.1.15	16 GHz PL Oscillator					\$ 40		\$ 4	\$ 5	\$ 36	\$ 6	\$ 39
5.1.16	26 GHz PL Oscillator					\$ 40		\$ 4	\$ 5	\$ 36	\$ 6	\$ 39
5.1.17	LO Ref Distributor - Antenna					\$ 20		\$ 2	\$ 3	\$ 18	\$ 3	\$ 20
5.1.18	VXCO Clean-up Loop					\$ 20		\$ 2	\$ 3	\$ 18	\$ 3	\$ 20
5.1.19	Power supply module					\$ 60		\$ 7	\$ 8	\$ 53	\$ 9	\$ 59
5.1.20	Bins / Racks (assemble and test)					\$ 16		\$ 2	\$ 2	\$ 14	\$ 2	\$ 16
5.3	Millimeter LO Drivers											
5.3.1	Design and System Integration			3	\$ 29	\$ 50			\$ 19	\$ 79	\$ 21	\$ 87
5.3.2	72-95 GHz Source											
5.3.2.1	Contract Procurement and Fabrication											
5.3.2.1.1	YIG-tuned Oscillator											
5.3.2.1.2	18.00 - 23.75 GHz 10 db Amplifier											
5.3.2.1.3	18.00 - 23.75 GHz x2 Multiplier											
5.3.2.1.4	36.0 - 47.5 GHz 10 db Amplifier											
5.3.2.1.5	36.0 - 47.5 GHz x2 Multiplier											
5.3.2.1.6	Mount and Tuning circuitry											
5.3.2.2	Assembly and Test											
5.3.2.3	Deliver 72 - 95 GHz LO Sources											
5.3.2.3.1	Deliver Modules #1-6											
5.3.2.3.2	Deliver Modules #7-24											
5.3.2.3.3	Deliver Modules #25-40											
5.3.3	100-120 GHz Source											
5.3.3.1	Contract Procurement and Fabrication											
5.3.3.1.1	YIG-tuned Oscillator											
5.3.3.1.2	25.00 - 30.00 GHz 10 db Amplifier											
5.3.3.1.3	15.00 - 30.00 GHz x2 Multiplier											
5.3.3.1.4	50.0 - 60.0 GHz 10 db Amplifier											
5.3.3.1.5	50-60 GHz x2 Multiplier											
5.3.3.1.6	Mount and Tuning circuitry											
5.3.3.2	Assembly and Test											
5.3.3.3	Deliver 100 - 120 GHz LO Sources											
5.3.3.3.1	Deliver Modules #1-3											
5.3.3.3.2	Deliver Modules #4-21											
5.3.3.3.3	Deliver Modules #22-40											
5.3.4	87 - 108 GHz Source			3	\$ 15			\$ 2	\$ 15	\$ 2	\$ 16	
5.3.4.1	Contract Procurement and Fabrication											
5.3.4.1.1	YIG-tuned Oscillator											
5.3.4.1.2	21.75-27.00 GHz 10 db Amplifier											
5.3.4.1.3	21.75-27.00 GHz x2 Multiplier											
5.3.4.1.4	43.5-54.0 GHz 10 db Amplifier											
5.3.4.1.5	43.5-54.0 GHz x2 Multiplier											

5.3.4.1.6	Mount and Tuning Circuitry																				
5.3.4.2	Assembly and Test																				
5.3.4.3	Deliver 87 - 108 GHz LO Sources																				
5.3.4.3.1	Deliver Modules #1-6																				
5.3.4.3.2	Deliver Modules #7-20																				
5.3.4.3.3	Deliver Modules #21-35																				
5.3.4.3.4	Deliver Modules #36-40																				
5.3.5	65 - 85 GHz Source					3	\$	15						\$	2	\$	15	\$	2	\$	16
5.3.5.1	Contract Procurement and Fabrication																				
5.3.5.1.1	YIG-tuned Oscillator																				
5.3.5.1.2	16.25-21.25 GHz 10 db Amplifier																				
5.3.5.1.3	16.25-21.25 GHz x2 Multiplier																				
5.3.5.1.4	32.5-42.5 GHz 10 db Amplifier																				
5.3.5.1.5	32.5-42.5 GHz x2 Multiplier																				
5.3.5.1.6	Mount and Tuning Circuitry																				
5.3.5.2	Assembly and Test																				
5.3.5.3	Deliver 65 - 85 GHz LO Sources																				
5.3.5.3.1	Deliver Modules #1-6																				
5.3.5.3.2	Deliver Modules #7-20																				
5.3.5.3.3	Deliver Modules #21-35																				
5.3.5.3.4	Deliver Modules #36-40																				
5.4	Millimeter LO Multiplier Chains				2		\$	20						\$	3	\$	20	\$	3	\$	22
5.4.1	Design and System Integration																				
5.4.2	211 - 275 GHz Receiver LO																				
5.4.2.1	Contract Fabrication																				
5.4.2.1.1	X3 Diode for 72-95 GHz Source																				
5.4.2.1.2	Machine Mount																				
5.4.2.1.3	Bias and Control circuits																				
5.4.2.2	Assemble Multiplier and Test																				
5.4.2.3	Integrate Source and Multiplier; test																				
5.4.2.4	Deliver 211-275 GHz Rcvr LO Modules																				
5.4.2.4.1	Deliver Modules #1-3																				
5.4.2.4.2	Deliver Modules #4-21																				
5.4.2.4.3	Deliver Modules #22-40																				
5.4.3	602 - 720 GHz Receiver LO																				
5.4.3.1	Contract Fabrication																				
5.4.3.1.1	X2 Diode for 100-120 GHz Source																				
5.4.3.1.2	X3 Diode for 200-240 GHz Input																				
5.4.3.1.3	Machine Mount																				
5.4.3.1.4	Bias and Control circuits																				
5.4.3.2	Assemble Multipliers and Test																				
5.4.3.3	Integrate Source and Multipliers; test																				
5.4.3.4	Deliver 602-720 GHz Rcvr LO Modules																				
5.4.3.4.1	Deliver Modules #1-6																				
5.4.3.4.2	Deliver Modules #7-18																				
5.4.3.4.3	Deliver Modules #19-34																				
5.4.3.4.4	Deliver Modules #35-40																				
5.4.4	275 - 370 GHz Receiver LO																				
5.4.4.1	Contract Fabrication																				
5.4.4.1.1	X2 Diode for 72-95 GHz Source																				

5.4.4.1.2	X2 Diode for 144-190 GHz Input																		
5.4.4.1.3	Machine Mount																		
5.4.4.1.4	Bias and Control Circuits																		
5.4.4.2	Assemble Multipliers and Test																		
5.4.4.3	Integrate Source and Multipliers; test																		
5.4.4.4	Deliver 275-370 GHz Rcvr LO Modules																		
5.4.4.4.1	Deliver Modules #1-6																		
5.4.4.4.2	Deliver Modules #7-27																		
5.4.4.4.3	Deliver Modules #28-40																		
5.4.5	163 - 211 GHz Receiver LO		3	18	\$	117	\$	50		\$	19	\$	27	\$	148	\$	30	\$	164
5.4.5.1	Contract Fabrication																		
5.4.5.1.1	X2 Diode for 87-108 GHz Source																		
5.4.5.1.2	Machine Mount																		
5.4.5.1.3	Bias and Control Circuits																		
5.4.5.2	Assemble Multiplier and Test																		
5.4.5.3	Integrate Source and Multiplier; test																		
5.4.5.4	Deliver 163 - 211 GHz Rcvr LO Modules																		
5.4.5.4.1	Deliver Modules #1-6																		
5.4.5.4.2	Deliver Modules #7-24																		
5.4.5.4.3	Deliver Modules #25-40																		
5.4.6	385 - 500 GHz Receiver LO		3	18	\$	117	\$	50		\$	19	\$	27	\$	148	\$	30	\$	164
5.4.6.1	Contract Fabrication																		
5.4.6.1.1	X3 Diode for 65-85 GHz Source																		
5.4.6.1.2	X2 Diode for 130-170 GHz Input																		
5.4.6.1.3	Machine Mount																		
5.4.6.1.4	Bias and Control Circuits																		
5.4.6.2	Assemble Multiplier and test																		
5.4.6.3	Integrate source and Multiplier; test																		
5.4.6.4	Deliver 385-500 GHz Rcvr LO Modules																		
5.4.6.4.1	Deliver Modules #1-6																		
5.4.6.4.2	Deliver Modules #7-24																		
5.4.6.4.3	Deliver Modules #25-40																		
5.4.7	125 - 163 GHz Receiver LO		3	18	\$	117	\$	50		\$	19	\$	27	\$	148	\$	30	\$	164
5.4.7.1	Contract Fabrication																		
5.4.7.1.1	X2 Diode for 65 - 85 GHz Source																		
5.4.7.1.2	Machine Mount																		
5.4.7.1.3	Bias and Control Circuits																		
5.4.7.2	Assemble Multiplier and test																		
5.4.7.3	Integrate Source and Multiplier; test																		
5.4.7.4	Deliver 125-163 GHz Rcvr LO Modules																		
5.4.7.4.1	Deliver Modules #1-6																		
5.4.7.4.2	Deliver Modules #7-18																		
5.4.7.4.3	Deliver Modules #19-34																		
5.4.7.4.4	Deliver Modules #35-40																		
5.4.8	33-45 GHz Receiver LO																		
5.4.8.1	Design & Fab Selection & Coupling from Sources																		
6	IF System		12	36	\$	293					\$	44	\$	293	\$	48	\$	323	
6.1	IF System: Prototype Systems																		

6.1.1	Deliver (Bench) Prototype IF System												
6.1.2	Testing and Design Refinement												
6.1.3	Procure/Fab Field Prototypes												
6.1.4	Deliver IF Field Prototypes to Test Interfeometer												
6.1.5	Field Prototype testing and Design Refinement												
6.1.6	Preproduction Review												
6.1.7	Final Documentation and Design Modifications												
6.1.8	Release for Manufacture												
6.2	Production test and lab equipment												
6.3	IF Multiplexer					\$ 160		\$ 18	\$ 21	\$ 142	\$ 24	\$ 157	
6.4	IF Demultiplexer					\$ 80		\$ 9	\$ 11	\$ 71	\$ 12	\$ 78	
6.5	IF Matrix Switch					\$ 64		\$ 7	\$ 9	\$ 57	\$ 9	\$ 63	
6.6	Baseband Converter					\$ 160		\$ 18	\$ 21	\$ 142	\$ 24	\$ 157	
6.7	Power supply module					\$ 40		\$ 4	\$ 5	\$ 36	\$ 6	\$ 39	
6.8	Bins / Racks (assemble and test)					\$ 16		\$ 2	\$ 2	\$ 14	\$ 2	\$ 16	
7	Optical Fiber System		12	36	\$ 293				\$ 44	\$ 293	\$ 48	\$ 323	
7.1	Optical Fiber System: Prototype Systems												
7.1.1	Deliver (Bench) Prototype FO System												
7.1.2	Testing and Design Refinement												
7.1.3	Procure/Fab Field Prototypes												
7.1.4	Deliver FO Field Prototypes to Test Interfeometer												
7.1.5	Field Prototype testing and Design Refinement												
7.1.6	Preproduction Review												
7.1.7	Final Documentation and Design Modifications												
7.1.8	Release for Manufacture												
7.1	Production test and lab equipment												
7.2	IF TX / RX					\$ 240		\$ 27	\$ 32	\$ 213	\$ 35	\$ 235	
7.3	LO Reference TX / RX					\$ 40		\$ 4	\$ 5	\$ 36	\$ 6	\$ 39	
7.4	Microwave Round-trip Phase TX / RX					\$ 40		\$ 4	\$ 5	\$ 36	\$ 6	\$ 39	
7.5	Monitor / Control TX / RX					\$ 20		\$ 2	\$ 3	\$ 18	\$ 3	\$ 20	
7.6	Power supply module					\$ 40		\$ 4	\$ 5	\$ 36	\$ 6	\$ 39	
7.7	Bins / Racks (assemble and test)					\$ 16		\$ 2	\$ 2	\$ 14	\$ 2	\$ 16	
8	Correlator		36	36	\$ 527	\$ 1,000		\$ 170	\$ 328	\$ 1,357	\$ 362	\$ 1,498	
8.1	Digital Sampler, 4 GHz												
8.1.1	Refine Design												
8.1.2	Release Digital Sampler for Manufacture												
8.1.3	Contract Materials												
8.1.4	Assembly												
8.1.5	Validation and Delivery												
8.2	Digital FIR Filter												
8.2.1	Prototype testing on Test Interferometer												
8.2.2	Design Refinement												
8.2.3	Release FIR Filter for manufacture												
8.2.4	Chip Fabrication												
8.2.5	Assembly												
8.2.6	Validation and Delivery												
8.3	Custom Boards												
8.3.1	Correlator Board												

8.3.1.1	Prototype assembly												
8.3.1.2	Prototype test												
8.3.1.3	Design modifications												
8.3.1.4	Fab, assemble and test with design mods												
8.4	Correlator Chip												
8.4.1	Prototype chip fabrication												
8.4.2	Prototype chip test												
8.4.3	Design modifications												
8.4.4	Fabricate and test design mods												
8.4.5	Fabricate production run												
8.5	Racks												
8.5.1	Design control wiring												
8.5.2	Design signal wiring												
8.5.3	Order parts												
8.5.4	Assemble prototypes												
8.6	Software												
8.7	Prototype Correlator Production												
8.7.1	Order parts												
8.7.2	Assemble												
8.7.3	Test												
8.7.4	Deliver Prototype Correlator to VLA site												
8.8	Site Correlator Production												
8.8.1	First 1/4 correlator												
8.8.1.1	Determine configuration												
8.8.1.2	Order parts												
8.8.1.3	Assemble												
8.8.1.4	Test												
8.8.1.5	Deliver 1/4 Correlator to MMA site												
8.8.2	Second 1/4 correlator												
8.8.2.1	Order parts												
8.8.2.2	Assemble												
8.8.2.3	Test												
8.8.2.4	Deliver 1/4 Correlator to MMA site												
8.8.3	Third 1/4 correlator												
8.8.3.1	Order parts												
8.8.3.2	Assemble												
8.8.3.3	Test												
8.8.3.4	Deliver 1/4 Correlator to MMA site												
8.8.4	Fourth 1/4 correlator												
8.8.4.1	Order parts												
8.8.4.2	Assemble												
8.8.4.3	Test												
8.8.4.4	Deliver 1/4 Correlator to MMA site												
8.9	Continued Support												
9	Computing						\$ 400			\$ 120	\$ 400	\$ 132	\$ 442
9.1	Control Software												
9.1.1	Test Interferometer Control & Analysis												
9.1.2	MMA correlator software												
9.1.3	Multi-antenna & sub-array control												
9.1.4	Operators & Observers interfaces												
9.1.5	Deliver Control Software												
9.1.6	Maintenance		40			\$ 347		\$ 347		\$ -	\$ -	\$ -	\$ -

9.2	Scheduling																		
9.2.1	Static scheduling system																		
9.2.2	Dynamic scheduling simulations																		
9.2.3	Dynamic scheduling prototype																		
9.2.4	Dynamic scheduling implementation		26			\$	225				\$	34	\$	225	\$	37	\$	249	
9.2.5	Initial Operations with Dynamic Scheduling																		
9.3	Proposal Preparation Software																		
9.3.1	Prototype																		
9.3.2	Production version		10			\$	87				\$	13	\$	87	\$	14	\$	96	
9.4	Image Pipeline																		
9.4.1	Automated calibration & imaging heuristics																		
9.4.2	Prototype image pipeline																		
9.4.3	Parallelization studies and implementation		12			\$	104				\$	16	\$	104	\$	17	\$	115	
9.4.4	Initial Image Pipeline Operations		20			\$	173				\$	26	\$	173	\$	29	\$	191	
9.4.5	Production image pipeline																		
9.5	Archiving																		
9.5.1	Prototype distributed archive																		
9.5.2	Evaluate storage hardware																		
9.5.3	Production archive		20			\$	173				\$	26	\$	173	\$	29	\$	191	
9.5.4	Data Archive operational																		
9.6	Post-processing																		
9.6.1	Define MMA Data formats																		
9.6.2	MMA filler & format conversions																		
9.6.3	MMA-specific calibrations																		
9.6.4	MMA Post-processing begins																		
9.6.5	Maintenance		26			\$	225		\$	225		\$	-	\$	-	\$	-	\$	-
10	System Integration																		
10.4	Test Interferometer Site Preparation																		
10.4.1	Complete Office and Lab Space Preparation																		
10.4.2	Cabling																		
10.4.3	Test Interferometer Site Complete																		
10.10.4	Prototype Antenna Outfitting																		
10.10.4.1	Cabling																		
10.10.4.2	Instrumentation																		
10.10.4.3	Eval. Rcvr. #1 / Ant. #1 Integration																		
10.10.4.4	Antenna #1 Outfitting Complete																		
10.10.5	Integration Holography System/Antenna																		
10.10.6	Integration Metrology/Antenna																		
10.10.7	Antenna #1 Integration & Testing																		
10.10.8	Prot. Rcvr. Test & Evaluation																		
10.10.9	Antenna #2 Outfitting																		
10.10.9.1	Cabling																		
10.10.9.2	Instrumentation																		
10.10.9.3	Eval. Rcvr. #2 / Ant. #2 Integration																		
10.10.9.4	Antenna #2 Outfitting Complete																		
10.11	Test Interferometer																		
10.11.1	Antenna Evaluation & Characterization																		
10.11.1.1	Antenna Verification																		
10.11.1.4	Holography																		
10.11.1.5	Beam and Sidelobes																		
10.11.1.6	Gain vs. Elevation: Spillover Temp																		
10.11.1.7	Effect of Sun in & Near the Beam																		

10.11.2	Engineering Recommendations re Prod. Ant.																				
10.11.3	Revise Interface Specifications																				
10.11.5	Operations Personnel Training																				
10.11.5.1	Recruit Initial Chile Ops Staff																				
10.11.5.2	Array Operations																				
10.11.5.3	Engineering Maintenance																				
10.11.5.4	Scientific Support & Analysis																				
10.12.2	Relocate Ops Staff to Chile																				
10.8.4.6	Start On-site Operations																				
10.12	Disassemble Test Interferometer				24	\$	117				\$	18	\$	117	\$	19	\$	129			
10.12.1	Prepare & Ship Antenna #1, #2																				
10.12.3	Restore Facilities at VLA Site																				
10.13	On Site System Integration			48	48	\$	702		\$	702		\$	-	\$	-	\$	-	\$	-		
11	Calibration and Imaging																				
11.1	Radiometric Phase Design & Prototype																				
11.1.1	Complete 183GHz Phase Mon Prototype																				
11.1.2	Demo 183 GHz Phase Monitor Radiometer on-Site																				
11.1.3	Design Refinement																				
11.1.4	Release Phase Mon Radiometer for manufacture																				
11.2	Production Fab of Phase Monitor Radiometer				24	\$	117			\$	13	\$	14	\$	104	\$	15	\$	115		
11.2.1	Contract Subassembly Fabrication																				
11.2.1.1	Radiometer & Local Oscillator																				
11.2.1.2	Spectrometer																				
11.2.1.3	Feed, Window, lens, instrumentation																				
11.2.1.4	M/C Interface																				
11.2.2	Assembly & Test																				
11.2.3	Deliver Production Radiometers																				
11.2.4	Integration in Receiver Package																				
11.2.5	Verification on-Site																				
11.3	Production Fabrication of Dual-load Amp Cal Sys				2	\$	10			\$	1	\$	1	\$	9	\$	1	\$	10		
11.3.1	Design Refinement																				
11.3.2	Release Phase Mon Radiometer for manufacture																				
11.3.3	Contract Subassembly																				
11.3.3.1	Machining																				
11.3.3.2	Load Fabrication																				
11.3.3.3	Motors, Servo																				
11.3.3.4	M/C Interface																				
11.3.4	Assembly & Test																				
11.3.5	Integration on Production Antennas																				
11.4	Imaging Studies & Project Support	72				\$	585		\$	585		\$	-	\$	-	\$	-	\$	-		
11.5	Imaging Algorithm Development	8	4			\$	100					\$	15	\$	100	\$	17	\$	110		
	TOTALS					\$	10,180	\$	41,193	\$	2,074	\$	1,274	\$	12,571	\$	48,026	\$	13,876	\$	53,011

Millimeter Array Construction 2006

WBS	Name	Scientists Work- Months	Programmers Work-Months	Engineers Work- Months	Technicians Work Months	Personnel Cost	Materials and Supplies	Transfer to Operations	Adjustment to Scope	Contingency	Sum Cost	Inflated Contingency	Inflated Sum
1	Administration												
1.1	Project Management	72			48	\$ 819		\$ 215		\$ 91	\$ 605	\$ 103	\$ 684
1.1.1	Management, Planning, and Oversight						\$ 700			\$ 105	\$ 700	\$ 119	\$ 792
1.1.2	Business Operations						\$ 100			\$ 15	\$ 100	\$ 17	\$ 113
1.1.3	Chilean Operations						\$ 50			\$ 8	\$ 50	\$ 8	\$ 57
1.1.4	Safety and Health												
1.1.5	Personnel												
1.1.6	Project Science Office												
1.1.7	AUI Management						\$ 350			\$ -	\$ 350	\$ -	\$ 396
1.2	Engineering			24	12	\$ 293	\$ 20			\$ 47	\$ 313	\$ 53	\$ 354
1.2.1	System Engineering--Phase II												
1.2.2	Documentation System												
1.2.3	Production Engineering												
1.3	US Facilities												
1.3.1	CDL Permanent Facilities												
1.3.2	Manufacturing Facilities						\$ 100			\$ 15	\$ 100	\$ 17	\$ 113
1.3.3	Common Infrastructure						\$ 200			\$ 30	\$ 200	\$ 34	\$ 226
2	Site Development			12		\$ 117	\$ 50			\$ 25	\$ 167	\$ 28	\$ 189
2.1	Review Legalities Regarding Array and OSF Sites												
2.2	Maintain Mining claims						\$ 25			\$ -	\$ 25	\$ -	\$ 28
2.3	Contract A&E Studies												
2.4	Hire Construction Manager for Chile												
2.5	Array Site												
2.5.1	Prepare Site Development Bid Packages												
2.5.1.1	Prepare Package for Array Site												
2.5.1.2	Review Bid Packages												
2.5.1.3	Bid Civil Works Construction												
2.5.2	Evaluate Array Site Bid Response												
2.5.2.1	Review Bids												
2.5.2.2	Recommend Contractors												
2.5.2.3	Award Array Site Contracts												
2.5.3	Contract Array Site Civil Works												
2.5.3.1	Array Site												
2.5.3.2	Inspect Completed Site Constr												
2.5.3.3	Accept Site Facility												
2.6	Operations Support Facility												
2.6.1	Prepare OSF Bid Packages												
2.6.1.1	Prepare Package for OSF												
2.6.1.2	Review Bid Packages												
2.6.1.3	Bid Civil Works Construction												
2.6.2	Evaluate OSF Bid Response												
2.6.2.1	Review Bids												
2.6.2.2	Recommend Contractors												
2.6.2.3	Award Contracts												

2.6.3	Contract OSF Civil Works												
2.6.3.1	Operations Support Facility												
2.6.3.2	Inspect Completed OSF Constr												
2.6.3.3	Accept OSF Facility												
2.7	OSF/Array Link												
2.7.1	Prepare OSF/Array Link Bid Package												
2.7.1.1	Prepare Package for OSF/Array F/O Link												
2.7.1.2	Review Bid Package												
2.7.1.3	Bid OSF/Array Link Construction												
2.7.2	Evaluate Bid Response												
2.7.2.1	Review Bids												
2.7.2.2	Recommend Contractors												
2.7.2.3	Award Contracts												
2.7.3	Contract Civil Works												
2.7.3.1	OSF/Array Link												
2.7.3.2	Inspect Completed OSF/Array Link Constr												
2.7.3.3	Accept OSF/Array Link												
2.8	Prepare for Instrument Assembly												
2.8.1	Equip Array Site												
2.8.2	Equip Operations Support Facility												
3	Antenna												
3.1	Antenna Engineering Support												
3.3.40	Acceptance Tests Antenna #1												
3.3.45	Delivery of Antenna #1												
3.8.10	Sign Transporter Contract												
3.8.15	Transporter Acceptance tests												
3.8.20	Deliver/Accept Transporter #1												
3.7	Procurement of Antenna #2												
3.7.1	Antenna #2 Contract Supervision												
3.7.2	Antenna #2 Acceptance tests												
3.8	Negotiate Production Antenna Contract												
3.9	Sign Contract for Production Antennas												
3.10	Antenna Contract Supervision												
3.11	Accept Antenna #3 at OSF												
3.12	Prepare Antenna #3												
3.12.1	Outfit & Verify Ant #3 at OSF												
3.12.2	Move, Install & Verify Ant #3 on Site												
3.13	Accept Antenna #4 at OSF												
3.14	Prepare Antenna #4												
3.14.1	Outfit & Verify Ant #4 at OSF												
3.14.2	Move, Install & Verify Ant #4 on Site												
3.15	Accept Antenna#5 at OSF												
3.16	Prepare Antenna #5												
3.16.1	Outfit & Verify Ant #5 at OSF												
3.16.2	Move, Install & Verify Ant #5 on Site												
3.17	Accept Antenna#6 at OSF												
3.18	Prepare Antenna #6												
3.18.1	Outfit & Verify Ant #6 at OSF												
3.18.2	Move, Install & Verify Ant #6 on Site												
3.19	Accept Antenna #7 at OSF												

3.20	Prepare Antenna #7																
3.20.1	Outfit & Verify Ant #7 at OSF																
3.20.2	Move, Install & Verify Ant #7 on Site																
3.21	Accept Antenna #8 at OSF																
3.22	Prepare Antenna #8																
3.22.1	Outfit & Verify Ant #8 at OSF																
3.22.2	Move, Install & Verify Ant #8 on Site																
3.23	Accept Antenna #9 at OSF																
3.24	Prepare Antenna #9																
3.24.1	Outfit & Verify Ant #9 at OSF																
3.24.2	Move, Install & Verify Ant #9 on Site																
3.25	Accept Antenna #10 at OSF																
3.26	Prepare Antenna #10																
3.26.1	Outfit & Verify Ant #10 at OSF																
3.26.2	Move, Install and Verify Ant #10 on Site																
3.27	Accept Antenna #11 at OSF																
3.28	Prepare Antenna #11																
3.28.1	Outfit & Verify Ant #11 at OSF																
3.28.2	Move, Install & Verify Ant #11 on Site																
3.29	Accept Antenna #12 at OSF																
3.30	Prepare Antenna #12																
3.30.1	Outfit & Verify Ant #12 at OSF																
3.30.2	Move, Install & Verify Ant #12 on Site																
3.31	Accept Antenna #13 at OSF																
3.32	Prepare Antenna #13																
3.32.1	Outfit & Verify Ant #13 at OSF																
3.32.2	Move, Install & Verify Ant #13 on Site																
3.33	Accept Antenna #14 at OSF																
3.34	Prepare Antenna #14																
3.34.1	Outfit & Verify Ant #14 at OSF																
3.34.2	Move, Install & Verify Ant #14 on Site																
3.35	Accept Antenna #15 at OSF																
3.36	Prepare Antenna #15																
3.36.1	Outfit & Verify Ant #15 at OSF																
3.36.2	Move, Install & Verify Ant #15 on Site																
3.37	Accept Antenna #16 at OSF		1.5		\$	15				\$	2	\$	15	\$	2	\$	17
3.38	Prepare Antenna #16																
3.38.1	Outfit & Verify Ant #16 at OSF		2		4	\$	39			\$	6	\$	39	\$	7	\$	44
3.38.2	Move, Install & Verify Ant #16 on Site		1		1	\$	15			\$	2	\$	15	\$	2	\$	17
3.39	Accept Antenna #17 at OSF		1.5			\$	15			\$	2	\$	15	\$	2	\$	17
3.40	Prepare Antenna #17																
3.40.1	Outfit & Verify Ant #17 at OSF		2		4	\$	39			\$	6	\$	39	\$	7	\$	44
3.40.2	Move, Install & Verify Ant #17 on Site		1		1	\$	15			\$	2	\$	15	\$	2	\$	17
3.41	Accept Antenna #18 at OSF		1.5			\$	15			\$	2	\$	15	\$	2	\$	17
3.42	Prepare Antenna #18																
3.42.1	Outfit & Verify Ant #18 at OSF		2		4	\$	39			\$	6	\$	39	\$	7	\$	44
3.42.2	Move, Install & Verify Ant #18 on Site		1		1	\$	15			\$	2	\$	15	\$	2	\$	17
3.43	Accept Antenna #19 at OSF		1.5			\$	15			\$	2	\$	15	\$	2	\$	17
3.44	Prepare Antenna #19																
3.44.1	Outfit & Verify Ant #19 at OSF		2		4	\$	39			\$	6	\$	39	\$	7	\$	44
3.44.2	Move, Install & Verify Ant #19 on Site		1		1	\$	15			\$	2	\$	15	\$	2	\$	17
3.45	Accept Antenna #20 at OSF		1.5			\$	15			\$	2	\$	15	\$	2	\$	17
3.46	Prepare Antenna #20																
3.46.1	Outfit & Verify Ant #20 at OSF		2		4	\$	39			\$	6	\$	39	\$	7	\$	44

3.46.2	Move, Install & Verify Ant #20 on Site			1	1	\$ 15				\$ 2	\$ 15	\$ 2	\$ 17
3.47	Accept Antenna #21 at OSF			1.5		\$ 15				\$ 2	\$ 15	\$ 2	\$ 17
3.48	Prepare Antenna #21												
3.48.1	Outfit & Verify Ant #21 at OSF			2	4	\$ 39				\$ 6	\$ 39	\$ 7	\$ 44
3.48.2	Move, Install & Verify Ant #21 on Site			1	1	\$ 15				\$ 2	\$ 15	\$ 2	\$ 17
3.49	Accept Antenna #22 at OSF			1.5		\$ 15				\$ 2	\$ 15	\$ 2	\$ 17
3.50	Prepare Antenna #22												
3.50.1	Outfit & Verify Ant #22 at OSF			2	4	\$ 39				\$ 6	\$ 39	\$ 7	\$ 44
3.50.2	Move, Install & Verify Ant #22 on Site			1	1	\$ 15				\$ 2	\$ 15	\$ 2	\$ 17
3.51	Accept Antenna #23 at OSF			1.5		\$ 15				\$ 2	\$ 15	\$ 2	\$ 17
3.52	Prepare Antenna #23												
3.52.1	Outfit & Verify Ant #23 at OSF			2	4	\$ 39				\$ 6	\$ 39	\$ 7	\$ 44
3.52.2	Move, Install & Verify Ant #23 on Site			1	1	\$ 15				\$ 2	\$ 15	\$ 2	\$ 17
3.53	Accept Antenna #24 at OSF			1.5		\$ 15				\$ 2	\$ 15	\$ 2	\$ 17
3.54	Prepare Antenna #24												
3.54.1	Outfit & Verify Ant #24 at OSF			2	4	\$ 39				\$ 6	\$ 39	\$ 7	\$ 44
3.54.2	Move, Install & Verify Ant #24 on Site			1	1	\$ 15				\$ 2	\$ 15	\$ 2	\$ 17
3.55	Accept Antenna #25 at OSF			1.5		\$ 15				\$ 2	\$ 15	\$ 2	\$ 17
3.56	Prepare Antenna #25												
3.56.1	Outfit & Verify Ant #25 at OSF			2	4	\$ 39				\$ 6	\$ 39	\$ 7	\$ 44
3.56.2	Move, Install & Verify Ant #25 on Site			1	1	\$ 15				\$ 2	\$ 15	\$ 2	\$ 17
3.57	Accept Antenna #26 at OSF			1.5		\$ 15				\$ 2	\$ 15	\$ 2	\$ 17
3.58	Prepare Antenna #26												
3.58.1	Outfit & Verify Ant #26 at OSF			2	4	\$ 39				\$ 6	\$ 39	\$ 7	\$ 44
3.58.2	Move, Install & Verify Ant #26 on Site			1	1	\$ 15				\$ 2	\$ 15	\$ 2	\$ 17
3.59	Accept Antenna #27 at OSF			1.5		\$ 15				\$ 2	\$ 15	\$ 2	\$ 17
3.60	Prepare Antenna #27												
3.60.1	Outfit & Verify Ant #27 at OSF			2	4	\$ 39				\$ 6	\$ 39	\$ 7	\$ 44
3.60.2	Move, Install & Verify Ant #27 on Site			1	1	\$ 15				\$ 2	\$ 15	\$ 2	\$ 17
3.61	Accept Antenna #28 at OSF			3		\$ 29	\$ 2,832			\$ 854	\$ 2,861	\$ 966	\$ 3,237
3.62	Prepare Antenna #28												
3.62.1	Outfit & Verify Ant #28 at OSF												
3.62.2	Move, Install & Verify Ant #28 on Site												
3.63	Accept Antenna #29 at OSF			3		\$ 29	\$ 2,832			\$ 854	\$ 2,861	\$ 966	\$ 3,237
3.64	Prepare Antenna #29												
3.64.1	Outfit & Verify Ant #29 at OSF												
3.64.2	Move, Install & Verify Ant #29 on Site												
3.65	Accept Antenna #30 at OSF			3		\$ 29	\$ 2,832			\$ 854	\$ 2,861	\$ 966	\$ 3,237
3.66	Prepare Antenna #30												
3.66.1	Outfit & Verify Ant #30 at OSF												
3.66.2	Move, Install & Verify Ant #30 on Site												
3.67	Accept Antenna #31 at OSF			3		\$ 29	\$ 2,832			\$ 854	\$ 2,861	\$ 966	\$ 3,237
3.68	Prepare Antenna #31												
3.68.1	Outfit & Verify Ant #31 at OSF												
3.68.2	Move, Install and Verify Ant #31 on Site												
3.69	Accept Antenna #32 at OSF			3		\$ 29	\$ 2,832			\$ 854	\$ 2,861	\$ 966	\$ 3,237
3.70	Prepare Antenna #32												
3.70.1	Outfit & Verify Ant #32 at OSF												
3.70.2	Move, Install & Verify Ant #32 on Site												
3.71	Accept Antenna #33 at OSF			3		\$ 29	\$ 2,832		\$ 2,861	\$ -	\$ -	\$ -	\$ -
3.72	Prepare Antenna #33												
3.72.1	Outfit & Verify Ant #33 at OSF												
3.72.2	Move, Install and Verify Ant #33 on Site												
3.73	Accept Antenna #34 at OSF			3		\$ 29	\$ 2,832		\$ 2,861	\$ -	\$ -	\$ -	\$ -

3.74	Prepare Antenna #34												
3.74.1	Outfit & Verify Ant #34 at OSF												
3.74.2	Move, Install and Verify Ant #34 on Site												
3.75	Accept Antenna #35 at OSF		3		\$ 29	\$ 2,832		\$ 2,861	\$ -	\$ -	\$ -	\$ -	\$ -
3.76	Prepare Antenna #35												
3.76.1	Outfit & Verify Ant #35 at OSF												
3.76.2	Move, Install & Verify Ant #35 on Site												
3.77	Accept Antenna #36 at OSF		3		\$ 29	\$ 2,832		\$ 2,861	\$ -	\$ -	\$ -	\$ -	\$ -
3.78	Prepare Antenna #36												
3.78.1	Outfit & Verify Ant #36 at OSF												
3.78.2	Move, Install & Verify Ant #36 on Site												
3.79	Prepare Antenna #1												
3.79.1	Antenna #1 Reassembled at OSF												
3.79.2	Outfit & Verify Ant #1 at OSF												
3.79.3	Move, Install & Verify Ant #1 on Site												
3.80	Prepare Antenna #2												
3.80.1	Antenna #2 Reassembled at OSF												
3.80.2	Outfit & Verify Ant #2 at OSF												
3.80.3	Move, Install & Verify Ant #2 on Site												
3.81	Antenna Transporter												
3.81.1	Contract for Transporter #1, move to Site												
3.81.2	Contract for Transporters #2, #3												
3.81.3	Accept Transporters #2, #3 at OSF												
4	Receivers												
4.1	Receiver Package												
4.1.1	Prototype Production Receiver Cryogenics												
4.1.1.1	CDR: Cryogenics Development												
4.1.1.2	Construct & test prototype cryogenics												
4.1.1.3	Deliver Prototype Cryogenics Subsystem												
4.1.2	Prototype Production Receiver Package												
4.1.2.1	Prototype Receiver Package Integration												
4.1.2.2	Prot. Rcvr. Pckg Lab Test & Evaluation												
4.1.2.3	Complete Prototype MMA Receiver Package												
4.1.3	MMA Rcvr Pckg Design Refinement												
4.1.4	Documentation												
4.1.5	Release MMA Receiver Pckg for manufacture												
4.1.6	Contract for Receiver Pckg Subassemblies												
4.1.6.1	Machine Dewars			30	\$ 146	\$ 50		\$ 22	\$ 30	\$ 174	\$ 34	\$ 197	
4.1.6.2	Fabricate Cryogenics subsystems		6	24	\$ 176	\$ 240		\$ 46	\$ 84	\$ 369	\$ 96	\$ 418	
4.1.6.3	Fabricate windows, IR filters, etc		6	30	\$ 205	\$ 100		\$ 34	\$ 51	\$ 271	\$ 57	\$ 306	
4.1.7	Accept Receiver Pckg Subassemblies												
4.1.7.1	Subassemblies #1-6												
4.1.7.2	Subassemblies #7-16												
4.1.7.3	Subassemblies #17-26												
4.1.7.4	Subassemblies #27-36												
4.1.7.5	Subassemblies #37-40												
4.1.8	Fab Rcvr Pckg Instrumentation & Electronics		3	12	\$ 88	\$ 75		\$ 18	\$ 30	\$ 145	\$ 34	\$ 164	
4.1.9	Fabricate Receiver Inserts		18	30	\$ 322	\$ 100		\$ 47	\$ 64	\$ 375	\$ 73	\$ 424	
4.1.10	Assemble Receiver Package				\$ -								
4.1.10.1	Integrate Rcvr Instrumentation & subass'y		12	48	\$ 351	\$ 80		\$ 48	\$ 62	\$ 383	\$ 70	\$ 433	

4.1.10.2	Deliver Receiver Package #1-6												
4.1.10.3	Deliver Receiver Package #7-16												
4.1.10.4	Deliver Receiver Package #17-26												
4.1.10.5	Deliver Receiver Package #27-36												
4.1.10.6	Deliver Receiver Package #37-40												
4.2	SIS Receiver Modules												
4.2.1	211-275 GHz Module												
4.2.1.1	SIS Mixer												
4.2.1.1.1	Design, Fab and Test Mixer Design												
4.2.1.1.2	Deliver Production Design												
4.2.1.1.3	Fabricate Production Mixers												
4.2.1.2	Design & Verify Optics												
4.2.1.3	Design Module												
4.2.1.4	Contract Fabrication												
4.2.1.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.1.4.2	Assemble Modules												
4.2.1.5	Install SIS Mixer & Test Modules												
4.2.1.6	Deliver 211-275 GHz Receiver Modules												
4.2.1.6.1	Deliver Modules #1-7												
4.2.1.6.2	Deliver Modules #8-26												
4.2.1.6.3	Deliver Modules #27-40												
4.2.2	602-720 GHz Module												
4.2.2.1	SIS Mixer												
4.2.2.1.1	Design, Fabricate and Test Mixer Design												
4.2.2.1.2	Deliver Production Design												
4.2.2.1.3	Fabricate Production Mixers												
4.2.2.2	Design & Verify Optics												
4.2.2.3	Design Module												
4.2.2.4	Contract Fabrication												
4.2.2.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.2.4.2	Assemble Modules												
4.2.2.5	Install SIS Mixer and Test Modules												
4.2.2.6	Deliver 602-720 GHz Receiver Modules												
4.2.2.6.1	Deliver Modules #1-7												
4.2.2.6.2	Deliver Modules #8-26												
4.2.2.6.3	Deliver Modules #27-40												
4.2.3	275-370 GHz Receiver Module												
4.2.3.1	SIS Mixer												
4.2.3.1.1	Design, Fabricate and Test Mixer Design												
4.2.3.1.2	Deliver Production Design												
4.2.3.1.3	Fabricate Production Mixers												
4.2.3.2	Design & Verify Optics												
4.2.3.3	Design Module												
4.2.3.4	Contract Fabrication												
4.2.3.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.3.4.2	Assemble Modules												
4.2.3.5	Install SIS Mixer and Test Modules												
4.2.3.6	Deliver 275-370 GHz Receiver Module												
4.2.3.6.1	Deliver Modules #1-5												
4.2.3.6.2	Deliver Modules #6-30												
4.2.3.6.3	Deliver Modules #30-40												

4.2.4	91-119 GHz Receiver Module																	
4.2.4.1	SIS Mixer																	
4.2.4.1.1	Design, Fabricate & Test Mixer Design																	
4.2.4.1.2	Deliver Production Design																	
4.2.4.1.3	Fabricate Production Mixers																	
4.2.4.2	Design & Verify Optics																	
4.2.4.3	Design Module																	
4.2.4.4	Contract Fabrication																	
4.2.4.4.1	Machine Mixer Blocks, Feed, WG, Lenses																	
4.2.4.4.2	Assemble Modules																	
4.2.4.5	Install SIS Mixer and Test Modules																	
4.2.4.6	Deliver 91-119 GHz Receiver Modules																	
4.2.4.6.1	Deliver Modules #1-5																	
4.2.4.6.2	Deliver Modules #6-30																	
4.2.4.6.3	Deliver Modules # 31-40																	
4.2.5	163-211 GHz Receiver Module																	
4.2.5.1	SIS Mixer																	
4.2.5.1.1	Design, Fabricate & Test Mixer Design																	
4.2.5.1.2	Deliver Production Design																	
4.2.5.1.3	Fabricate Production Mixers																	
4.2.5.2	Design & Verify Optics																	
4.2.5.3	Design Module																	
4.2.5.4	Contract Fabrication																	
4.2.5.4.1	Machine Mixer Blocks, Feed, WG, Lenses																	
4.2.5.4.2	Assemble Modules																	
4.2.5.5	Install SIS Mixer and Test	18	36	\$	351	\$	30		\$	42	\$	49	\$	339	\$	55	\$	383
4.2.5.6	Deliver 163-211 GHz Receiver Modules																	
4.2.5.6.1	Deliver Modules #1-5																	
4.2.5.6.2	Deliver Modules #6-30																	
4.2.5.6.3	Deliver Modules #31-40																	
4.2.6	385-500 GHz Receiver Module																	
4.2.6.1	SIS Mixer																	
4.2.6.1.1	Design, Fabricate & Test Mixer Design																	
4.2.6.1.2	Deliver Production Design																	
4.2.6.1.3	Fabricate Production Mixers																	
4.2.6.2	Design and Verify Optics																	
4.2.6.3	Design Module																	
4.2.6.4	Contract Fabrication																	
4.2.6.4.1	Machine Mixer Blocks, Feed, WG, Lenses																	
4.2.6.4.2	Assemble Modules																	
4.2.6.5	Install SIS Mixer and Test	18	36	\$	351	\$	30		\$	381	\$	-	\$	-	\$	-	\$	-
4.2.6.6	Deliver 385-500 GHz Receiver Modules																	
4.2.6.6.1	Deliver Modules #1-5																	
4.2.6.6.2	Deliver Modules #6-30																	
4.2.6.6.3	Deliver Modules #31-40																	
4.2.7	125-163 GHz Receiver Module																	
4.2.7.1	SIS Mixer	24	24	\$	351	\$	50		\$	45	\$	54	\$	356	\$	61	\$	403
4.2.7.1.1	Design, Fabricate & Test Mixer Design																	
4.2.7.1.2	Deliver Production Design																	
4.2.7.1.3	Fabricate Production Mixers																	

4.2.7.2	Design & Verify Optics																				
4.2.7.3	Design Module																				
4.2.7.4	Contract Fabrication				4	\$	20	\$	100			\$	13	\$	29	\$	106	\$	33	\$	120
4.2.7.4.1	Machine Mixer Blocks, Feed, WG, Lenses																				
4.2.7.4.2	Assemble Modules																				
4.2.7.5	Install SIS Mixer and Test			24	48	\$	468	\$	50			\$	58	\$	68	\$	460	\$	77	\$	521
4.2.7.6	Deliver 125-163 GHz Receiver Modules																				
4.2.7.6.1	Deliver 125-163 GHz Modules #1-5																				
4.2.7.6.2	Deliver 125-163 GHz Modules #6-30																				
4.2.7.6.3	Deliver 125-163 GHz Modules #31-40																				
4.3	HFET Receiver Modules																				
4.3.1	Contract for HFET Wafer																				
4.3.2	Receive Diced HFET Wafer																				
4.3.3	33-45 GHz Module																				
4.3.3.1	Design Module																				
4.3.3.2	Design & Verify Optics																				
4.3.3.3	Contract Fabrication																				
4.3.3.3.1	Machine Blocks, Feed, WG, Lenses																				
4.3.3.3.2	Assemble Modules																				
4.3.3.3.3	Flip-in Mirror																				
4.3.4	Install HFET & Test Modules																				
4.3.5	Deliver 33-45 GHz Receiver Modules																				
4.3.5.1	Deliver Modules #1-20																				
4.3.5.2	Deliver Modules #21-40																				
4.3.6	67-95 GHz Module																				
4.3.6.1	Design Amplifier																				
4.3.6.2	Design Module																				
4.3.6.3	Design & Verify Optics																				
4.3.6.4	Contract Fabrication																				
4.3.6.4.1	Machine Blocks, Feed, WG, Lenses																				
4.3.6.4.2	Assemble Modules																				
4.3.6.5	Install HFET & Test Modules																				
4.3.6.6	Deliver 67-95 GHz Receiver Modules																				
4.3.6.6.1	Deliver Modules 67-95GHz #1-20																				
4.3.6.6.2	Deliver Modules 67-95GHz #21-40																				
5	LO System																				
5.1	LO Reference: Prototype Systems																				
5.1.1	Deliver: Bench Prototype																				
5.1.2	Testing and Design Refinement																				
5.1.3	Procure/Fab Field Prototypes																				
5.1.4	Deliver: LO Ref Field Prototypes																				
5.1.5	Field Prototype testing and Design Refinement																				
5.1.6	Preproduction Review																				
5.1.7	Final Documentation and Design Modifications																				
5.1.8	Release for Manufacture																				
5.2	LO Reference: Production System			12	48	\$	351					\$	53	\$	351	\$	60	\$	397		
5.1.1	Production test and lab equipment																				
5.1.2	H-maser Frequency Standard (& Rb)																				
5.1.3	8 GHz PL Oscillator & Distributor							\$	1			\$	0	\$	0	\$	1	\$	0	\$	1
5.1.4	10 GHz PL Oscillator & Distributor							\$	1			\$	0	\$	0	\$	1	\$	0	\$	1

5.1.5	12 GHz PL Oscillator & Distributor						\$ 1		\$ 0	\$ 0	\$ 1	\$ 0	\$ 1
5.1.6	14 GHz PL Oscillator & Distributor						\$ 1		\$ 0	\$ 0	\$ 1	\$ 0	\$ 1
5.1.7	3.2-5.2 GHz Synthesizer						\$ 8		\$ 1	\$ 1	\$ 7	\$ 1	\$ 8
5.1.8	3.2 -5.2 GHz PLO and Fringe Generator						\$ 160		\$ 18	\$ 21	\$ 142	\$ 24	\$ 161
5.1.9	Sampler Clock 4 GHz PL Osc & Distributor						\$ 1		\$ 0	\$ 0	\$ 1	\$ 0	\$ 1
5.1.10	LO Ref Generator						\$ 2		\$ 0	\$ 0	\$ 2	\$ 0	\$ 2
5.1.11	LO Ref Distributor - Control Bldg						\$ 1		\$ 0	\$ 0	\$ 1	\$ 0	\$ 1
5.1.12	Microwave Round-trip Phase Measurement						\$ 60		\$ 7	\$ 8	\$ 53	\$ 9	\$ 60
5.1.13	10-15 GHz Frequency Synthesizer						\$ 100		\$ 11	\$ 13	\$ 89	\$ 15	\$ 101
5.1.14	First LO Fringe Generator						\$ 20		\$ 2	\$ 3	\$ 18	\$ 3	\$ 20
5.1.15	16 GHz PL Oscillator						\$ 40		\$ 4	\$ 5	\$ 36	\$ 6	\$ 40
5.1.16	26 GHz PL Oscillator						\$ 40		\$ 4	\$ 5	\$ 36	\$ 6	\$ 40
5.1.17	LO Ref Distributor - Antenna						\$ 20		\$ 2	\$ 3	\$ 18	\$ 3	\$ 20
5.1.18	VXCO Clean-up Loop						\$ 20		\$ 2	\$ 3	\$ 18	\$ 3	\$ 20
5.1.19	Power supply module						\$ 60		\$ 7	\$ 8	\$ 53	\$ 9	\$ 60
5.1.20	Bins / Racks (assemble and test)						\$ 16		\$ 2	\$ 2	\$ 14	\$ 2	\$ 16
5.3	Millimeter LO Drivers			3		\$ 29	\$ 50			\$ 19	\$ 79	\$ 22	\$ 90
5.3.1	Design and System Integration												
5.3.2	72-95 GHz Source												
5.3.2.1	Contract Procurement and Fabrication												
5.3.2.1.1	YIG-tuned Oscillator												
5.3.2.1.2	18.00 - 23.75 GHz 10 db Amplifier												
5.3.2.1.3	18.00 - 23.75 GHz x2 Multiplier												
5.3.2.1.4	36.0 - 47.5 GHz 10 db Amplifier												
5.3.2.1.5	36.0 - 47.5 GHz x2 Multiplier												
5.3.2.1.6	Mount and Tuning circuitry												
5.3.2.2	Assembly and Test												
5.3.2.3	Deliver 72 - 95 GHz LO Sources												
5.3.2.3.1	Deliver Modules #1-6												
5.3.2.3.2	Deliver Modules #7-24												
5.3.2.3.3	Deliver Modules #25-40												
5.3.3	100-120 GHz Source												
5.3.3.1	Contract Procurement and Fabrication												
5.3.3.1.1	YIG-tuned Oscillator												
5.3.3.1.2	25.00 - 30.00 GHz 10 db Amplifier												
5.3.3.1.3	15.00 - 30.00 GHz x2 Multiplier												
5.3.3.1.4	50.0 - 60.0 GHz 10 db Amplifier												
5.3.3.1.5	50-60 GHz x2 Multiplier												
5.3.3.1.6	Mount and Tuning circuitry												
5.3.3.2	Assembly and Test												
5.3.3.3	Deliver 100 - 120 GHz LO Sources												
5.3.3.3.1	Deliver Modules #1-3												
5.3.3.3.2	Deliver Modules #4-21												
5.3.3.3.3	Deliver Modules #22-40												
5.3.4	87 - 108 GHz Source			3		\$ 29			\$ 4	\$ 29	\$ 5	\$ 33	
5.3.4.1	Contract Procurement and Fabrication												
5.3.4.1.1	YIG-tuned Oscillator												
5.3.4.1.2	21.75-27.00 GHz 10 db Amplifier												
5.3.4.1.3	21.75-27.00 GHz x2 Multiplier												
5.3.4.1.4	43.5-54.0 GHz 10 db Amplifier												
5.3.4.1.5	43.5-54.0 GHz x2 Multiplier												

5.3.4.1.6	Mount and Tuning Circuitry																			
5.3.4.2	Assembly and Test																			
5.3.4.3	Deliver 87 - 108 GHz LO Sources																			
5.3.4.3.1	Deliver Modules #1-6																			
5.3.4.3.2	Deliver Modules #7-20																			
5.3.4.3.3	Deliver Modules #21-35																			
5.3.4.3.4	Deliver Modules #36-40																			
5.3.5	65 - 85 GHz Source			3		\$	29					\$	4	\$	29	\$	5	\$	33	
5.3.5.1	Contract Procurement and Fabrication																			
5.3.5.1.1	YIG-tuned Oscillator																			
5.3.5.1.2	16.25-21.25 GHz 10 db Amplifier																			
5.3.5.1.3	16.25-21.25 GHz x2 Multiplier																			
5.3.5.1.4	32.5-42.5 GHz 10 db Amplifier																			
5.3.5.1.5	32.5-42.5 GHz x2 Multiplier																			
5.3.5.1.6	Mount and Tuning Circuitry																			
5.3.5.2	Assembly and Test																			
5.3.5.3	Deliver 65 - 85 GHz LO Sources																			
5.3.5.3.1	Deliver Modules #1-6																			
5.3.5.3.2	Deliver Modules #7-20																			
5.3.5.3.3	Deliver Modules #21-35																			
5.3.5.3.4	Deliver Modules #36-40																			
5.4	Millimeter LO Multiplier Chains																			
5.4.1	Design and System Integration			2		\$	20						\$	3	\$	20	\$	3	\$	22
5.4.2	211 - 275 GHz Receiver LO																			
5.4.2.1	Contract Fabrication																			
5.4.2.1.1	X3 Diode for 72-95 GHz Source																			
5.4.2.1.2	Machine Mount																			
5.4.2.1.3	Bias and Control circuits																			
5.4.2.2	Assemble Multiplier and Test																			
5.4.2.3	Integrate Source and Multiplier; test																			
5.4.2.4	Deliver 211-275 GHz Rcvr LO Modules																			
5.4.2.4.1	Deliver Modules #1-3																			
5.4.2.4.2	Deliver Modules #4-21																			
5.4.2.4.3	Deliver Modules #22-40																			
5.4.3	602 - 720 GHz Receiver LO																			
5.4.3.1	Contract Fabrication																			
5.4.3.1.1	X2 Diode for 100-120 GHz Source																			
5.4.3.1.2	X3 Diode for 200-240 GHz Input																			
5.4.3.1.3	Machine Mount																			
5.4.3.1.4	Bias and Control circuits																			
5.4.3.2	Assemble Multipliers and Test																			
5.4.3.3	Integrate Source and Multipliers; test																			
5.4.3.4	Deliver 602-720 GHz Rcvr LO Modules																			
5.4.3.4.1	Deliver Modules #1-6																			
5.4.3.4.2	Deliver Modules #7-18																			
5.4.3.4.3	Deliver Modules #19-34																			
5.4.3.4.4	Deliver Modules #35-40																			
5.4.4	275 - 370 GHz Receiver LO																			
5.4.4.1	Contract Fabrication																			
5.4.4.1.1	X2 Diode for 72-95 GHz Source																			

5.4.4.1.2	X2 Diode for 144-190 GHz Input												
5.4.4.1.3	Machine Mount												
5.4.4.1.4	Bias and Control Circuits												
5.4.4.2	Assemble Multipliers and Test												
5.4.4.3	Integrate Source and Multipliers; test												
5.4.4.4	Deliver 275-370 GHz Rcvr LO Modules												
5.4.4.4.1	Deliver Modules #1-6												
5.4.4.4.2	Deliver Modules #7-27												
5.4.4.4.3	Deliver Modules #28-40												
5.4.5	163 - 211 GHz Receiver LO		3	12	\$ 88	\$ 50		\$ 15	\$ 24	\$ 122	\$ 27	\$ 139	
5.4.5.1	Contract Fabrication												
5.4.5.1.1	X2 Diode for 87-108 GHz Source												
5.4.5.1.2	Machine Mount												
5.4.5.1.3	Bias and Control Circuits												
5.4.5.2	Assemble Multiplier and Test												
5.4.5.3	Integrate Source and Multiplier; test												
5.4.5.4	Deliver 163 - 211 GHz Rcvr LO Modules												
5.4.5.4.1	Deliver Modules #1-6												
5.4.5.4.2	Deliver Modules #7-24												
5.4.5.4.3	Deliver Modules #25-40												
5.4.6	385 - 500 GHz Receiver LO		3	12	\$ 88	\$ 50		\$ 15	\$ 24	\$ 122	\$ 27	\$ 139	
5.4.6.1	Contract Fabrication												
5.4.6.1.1	X3 Diode for 65-85 GHz Source												
5.4.6.1.2	X2 Diode for 130-170 GHz Input												
5.4.6.1.3	Machine Mount												
5.4.6.1.4	Bias and Control Circuits												
5.4.6.2	Assemble Multiplier and test												
5.4.6.3	Integrate source and Multiplier; test												
5.4.6.4	Deliver 385-500 GHz Rcvr LO Modules												
5.4.6.4.1	Deliver Modules #1-6												
5.4.6.4.2	Deliver Modules #7-24												
5.4.6.4.3	Deliver Modules #25-40												
5.4.7	125 - 163 GHz Receiver LO		12	36	\$ 293	\$ 75		\$ 41	\$ 54	\$ 327	\$ 61	\$ 370	
5.4.7.1	Contract Fabrication												
5.4.7.1.1	X2 Diode for 65 - 85 GHz Source												
5.4.7.1.2	Machine Mount												
5.4.7.1.3	Bias and Control Circuits												
5.4.7.2	Assemble Multiplier and test												
5.4.7.3	Integrate Source and Multiplier; test												
5.4.7.4	Deliver 125-163 GHz Rcvr LO Modules												
5.4.7.4.1	Deliver Modules #1-6												
5.4.7.4.2	Deliver Modules #7-18												
5.4.7.4.3	Deliver Modules #19-34												
5.4.7.4.4	Deliver Modules #35-40												
5.4.8	33-45 GHz Receiver LO												
5.4.8.1	Design & Fab Selection & Coupling from Sources												
6	IF System		12	36	\$ 293			\$ 44	\$ 293	\$ 50	\$ 331		
6.1	IF System: Prototype Systems												

6.1.1	Deliver (Bench) Prototype IF System												
6.1.2	Testing and Design Refinement												
6.1.3	Procure/Fab Field Prototypes												
6.1.4	Deliver IF Field Prototypes to Test Interfeometer												
6.1.5	Field Prototype testing and Design Refinement												
6.1.6	Preproduction Review												
6.1.7	Final Documentation and Design Modifications												
6.1.8	Release for Manufacture												
6.2	Production test and lab equipment												
6.3	IF Multiplexer					\$ 160		\$ 18	\$ 21	\$ 142	\$ 24	\$ 161	
6.4	IF Demultiplexer					\$ 80		\$ 9	\$ 11	\$ 71	\$ 12	\$ 80	
6.5	IF Matrix Switch					\$ 64		\$ 7	\$ 9	\$ 57	\$ 10	\$ 64	
6.6	Baseband Converter					\$ 160		\$ 18	\$ 21	\$ 142	\$ 24	\$ 161	
6.7	Power supply module					\$ 40		\$ 4	\$ 5	\$ 36	\$ 6	\$ 40	
6.8	Bins / Racks (assemble and test)					\$ 16		\$ 2	\$ 2	\$ 14	\$ 2	\$ 16	
7	Optical Fiber System		12	36	\$ 293				\$ 44	\$ 293	\$ 50	\$ 331	
7.1	Optical Fiber System: Prototype Systems												
7.1.1	Deliver (Bench) Prototype FO System												
7.1.2	Testing and Design Refinement												
7.1.3	Procure/Fab Field Prototypes												
7.1.4	Deliver FO Field Prototypes to Test Interfeometer												
7.1.5	Field Prototype testing and Design Refinement												
7.1.6	Preproduction Review												
7.1.7	Final Documentation and Design Modifications												
7.1.8	Release for Manufacture												
7.1	Production test and lab equipment												
7.2	IF TX / RX					\$ 240		\$ 27	\$ 32	\$ 213	\$ 36	\$ 241	
7.3	LO Reference TX / RX					\$ 40		\$ 4	\$ 5	\$ 36	\$ 6	\$ 40	
7.4	Microwave Round-trip Phase TX / RX					\$ 40		\$ 4	\$ 5	\$ 36	\$ 6	\$ 40	
7.5	Monitor / Control TX / RX					\$ 20		\$ 2	\$ 3	\$ 18	\$ 3	\$ 20	
7.6	Power supply module					\$ 40		\$ 4	\$ 5	\$ 36	\$ 6	\$ 40	
7.7	Bins / Racks (assemble and test)					\$ 16		\$ 2	\$ 2	\$ 14	\$ 2	\$ 16	
8	Correlator		36	36	\$ 527	\$ 1,000		\$ 170	\$ 328	\$ 1,357	\$ 371	\$ 1,535	
8.1	Digital Sampler, 4 GHz												
8.1.1	Refine Design												
8.1.2	Release Digital Sampler for Manufacture												
8.1.3	Contract Materials												
8.1.4	Assembly												
8.1.5	Validation and Delivery												
8.2	Digital FIR Filter												
8.2.1	Prototype testing on Test Interferometer												
8.2.2	Design Refinement												
8.2.3	Release FIR Filter for manufacture												
8.2.4	Chip Fabrication												
8.2.5	Assembly												
8.2.6	Validation and Delivery												
8.3	Custom Boards												
8.3.1	Correlator Board												

8.3.1.1	Prototype assembly												
8.3.1.2	Prototype test												
8.3.1.3	Design modifications												
8.3.1.4	Fab, assemble and test with design mods												
8.4	Correlator Chip												
8.4.1	Prototype chip fabrication												
8.4.2	Prototype chip test												
8.4.3	Design modifications												
8.4.4	Fabricate and test design mods												
8.4.5	Fabricate production run												
8.5	Racks												
8.5.1	Design control wiring												
8.5.2	Design signal wiring												
8.5.3	Order parts												
8.5.4	Assemble prototypes												
8.6	Software												
8.7	Prototype Correlator Production												
8.7.1	Order parts												
8.7.2	Assemble												
8.7.3	Test												
8.7.4	Deliver Prototype Correlator to VLA site												
8.8	Site Correlator Production												
8.8.1	First 1/4 correlator												
8.8.1.1	Determine configuration												
8.8.1.2	Order parts												
8.8.1.3	Assemble												
8.8.1.4	Test												
8.8.1.5	Deliver 1/4 Correlator to MMA site												
8.8.2	Second 1/4 correlator												
8.8.2.1	Order parts												
8.8.2.2	Assemble												
8.8.2.3	Test												
8.8.2.4	Deliver 1/4 Correlator to MMA site												
8.8.3	Third 1/4 correlator												
8.8.3.1	Order parts												
8.8.3.2	Assemble												
8.8.3.3	Test												
8.8.3.4	Deliver 1/4 Correlator to MMA site												
8.8.4	Fourth 1/4 correlator												
8.8.4.1	Order parts												
8.8.4.2	Assemble												
8.8.4.3	Test												
8.8.4.4	Deliver 1/4 Correlator to MMA site												
8.9	Continued Support												
9	Computing						\$ 400			\$ 120	\$ 400	\$ 136	\$ 453
9.1	Control Software												
9.1.1	Test Interferometer Control & Analysis												
9.1.2	MMA correlator software												
9.1.3	Multi-antenna & sub-array control												
9.1.4	Operators & Observers interfaces												
9.1.5	Deliver Control Software												
9.1.6	Maintenance		40			\$ 347		\$ 347		\$ -	\$ -	\$ -	\$ -

9.2	Scheduling																
9.2.1	Static scheduling system																
9.2.2	Dynamic scheduling simulations																
9.2.3	Dynamic scheduling prototype																
9.2.4	Dynamic scheduling implementation		26			\$	225			\$	34	\$	225	\$	38	\$	255
9.2.5	Initial Operations with Dynamic Scheduling																
9.3	Proposal Preparation Software																
9.3.1	Prototype																
9.3.2	Production version		10			\$	87			\$	13	\$	87	\$	15	\$	98
9.4	Image Pipeline																
9.4.1	Automated calibration & imaging heuristics																
9.4.2	Prototype image pipeline																
9.4.3	Parallelization studies and implementation																
9.4.4	Initial Image Pipeline Operations																
9.4.5	Production image pipeline		20			\$	173			\$	26	\$	173	\$	29	\$	196
9.5	Archiving																
9.5.1	Prototype distributed archive																
9.5.2	Evaluate storage hardware																
9.5.3	Production archive		20			\$	173			\$	26	\$	173	\$	29	\$	196
9.5.4	Data Archive operational																
9.6	Post-processing																
9.6.1	Define MMA Data formats																
9.6.2	MMA filler & format conversions																
9.6.3	MMA-specific calibrations																
9.6.4	MMA Post-processing begins																
9.6.5	Maintenance		12			\$	104		\$	104		\$	-	\$	-	\$	-
10	System Integration																
10.4	Test Interferometer Site Preparation																
10.4.1	Complete Office and Lab Space Preparation																
10.4.2	Cabling																
10.4.3	Test Interferometer Site Complete																
10.10.4	Prototype Antenna Outfitting																
10.10.4.1	Cabling																
10.10.4.2	Instrumentation																
10.10.4.3	Eval. Rcvr. #1 / Ant. #1 Integration																
10.10.4.4	Antenna #1 Outfitting Complete																
10.10.5	Integration Holography System/Antenna																
10.10.6	Integration Metrology/Antenna																
10.10.7	Antenna #1 Integration & Testing																
10.10.8	Prot. Rcvr. Test & Evaluation																
10.10.9	Antenna #2 Outfitting																
10.10.9.1	Cabling																
10.10.9.2	Instrumentation																
10.10.9.3	Eval. Rcvr. #2 / Ant. #2 Integration																
10.10.9.4	Antenna #2 Outfitting Complete																
10.11	Test Interferometer																
10.11.1	Antenna Evaluation & Characterization																
10.11.1.1	Antenna Verification																
10.11.1.4	Holography																
10.11.1.5	Beam and Sidelobes																
10.11.1.6	Gain vs. Elevation: Spillover Temp																
10.11.1.7	Effect of Sun in & Near the Beam																

10.11.2	Engineering Recommendations re Prod. Ant.												
10.11.3	Revise Interface Specifications												
10.11.5	Operations Personnel Training												
10.11.5.1	Recruit Initial Chile Ops Staff												
10.11.5.2	Array Operations												
10.11.5.3	Engineering Maintenance												
10.11.5.4	Scientific Support & Analysis												
10.12.2	Relocate Ops Staff to Chile												
10.8.4.6	Start On-site Operations												
10.12	Disassemble Test Interferometer												
10.12.1	Prepare & Ship Antenna #1, #2												
10.12.3	Restore Facilities at VLA Site												
10.13	On Site System Integration			48	48	\$ 702		\$ 702		\$ -	\$ -	\$ -	\$ -
11	Calibration and Imaging												
11.1	Radiometric Phase Design & Prototype												
11.1.1	Complete 183GHz Phase Mon Prototype												
11.1.2	Demo 183 GHz Phase Monitor Radiometer on-Site												
11.1.3	Design Refinement												
11.1.4	Release Phase Mon Radiometer for manufacture												
11.2	Production Fab of Phase Monitor Radiometer				18	\$ 88				\$ 13	\$ 88	\$ 15	\$ 99
11.2.1	Contract Subassembly Fabrication												
11.2.1.1	Radiometer & Local Oscillator												
11.2.1.2	Spectrometer												
11.2.1.3	Feed, Window, lens, instrumentation												
11.2.1.4	M/C Interface												
11.2.2	Assembly & Test												
11.2.3	Deliver Production Radiometers												
11.2.4	Integration in Receiver Package												
11.2.5	Verification on-Site				3	\$ 15				\$ 2	\$ 15	\$ 2	\$ 17
11.3	Production Fabrication of Dual-load Amp Cal Sys												
11.3.1	Design Refinement												
11.3.2	Release Phase Mon Radiometer for manufacture												
11.3.3	Contract Subassembly												
11.3.3.1	Machining												
11.3.3.2	Load Fabrication												
11.3.3.3	Motors, Servo												
11.3.3.4	M/C Interface												
11.3.4	Assembly & Test												
11.3.5	Integration on Production Antennas												
11.4	Imaging Studies & Project Support	72				\$ 585		\$ 585		\$ -	\$ -	\$ -	\$ -
11.5	Imaging Algorithm Development	8	4			\$ 100				\$ 15	\$ 100	\$ 17	\$ 113
	TOTALS					\$ 9,774	\$ 31,081	\$ 1,952	\$ 12,603	\$ 6,296	\$ 26,301	\$ 7,123	\$ 29,757

Millimeter Array Construction 2007

WBS	Name	Scientists Work- Months	Programmer Work-Months	Engineers Work- Months	Technicians Work- Months	Personnel Cost	Materials and Supplies	Transfer to Operations	Adjustment to Scope	Contingency	Sum Cost	Inflated Contingency	Inflated Sum
1	Administration												
1.1	Project Management	72			48	\$ 819		\$ 215		\$ 91	\$ 605	\$ 105	\$ 701
1.1.1	Management, Planning, and Oversight						\$ 700			\$ 105	\$ 700	\$ 122	\$ 812
1.1.2	Business Operations						\$ 100			\$ 15	\$ 100	\$ 17	\$ 116
1.1.3	Chilean Operations						\$ 50			\$ 8	\$ 50	\$ 9	\$ 58
1.1.4	Safety and Health												
1.1.5	Personnel												
1.1.6	Project Science Office												
1.1.7	AUI Management						\$ 350			\$ -	\$ 350	\$ -	\$ 406
1.2	Engineering			24	12	\$ 293	\$ 20			\$ 47	\$ 313	\$ 54	\$ 362
1.2.1	System Engineering--Phase II												
1.2.2	Documentation System												
1.2.3	Production Engineering												
1.3	US Facilities												
1.3.1	CDL Permanent Facilities												
1.3.2	Manufacturing Facilities						\$ 100			\$ 15	\$ 100	\$ 17	\$ 116
1.3.3	Common Infrastructure						\$ 200			\$ 30	\$ 200	\$ 35	\$ 232
2	Site Development			12		\$ 117	\$ 50			\$ 25	\$ 167	\$ 29	\$ 194
2.1	Review Legalities Regarding Array and OSF Sites												
2.2	Maintain Mining claims												
2.3	Contract A&E Studies												
2.4	Hire Construction Manager for Chile												
2.5	Array Site												
2.5.1	Prepare Site Development Bid Packages												
2.5.1.1	Prepare Package for Array Site												
2.5.1.2	Review Bid Packages												
2.5.1.3	Bid Civil Works Construction												
2.5.2	Evaluate Array Site Bid Response												
2.5.2.1	Review Bids												
2.5.2.2	Recommend Contractors												
2.5.2.3	Award Array Site Contracts												
2.5.3	Contract Array Site Civil Works												
2.5.3.1	Array Site												
2.5.3.2	Inspect Completed Site Constr												
2.5.3.3	Accept Site Facility												
2.6	Operations Support Facility												
2.6.1	Prepare OSF Bid Packages												
2.6.1.1	Prepare Package for OSF												
2.6.1.2	Review Bid Packages												
2.6.1.3	Bid Civil Works Construction												
2.6.2	Evaluate OSF Bid Response												
2.6.2.1	Review Bids												
2.6.2.2	Recommend Contractors												
2.6.2.3	Award Contracts												

2.6.3	Contract OSF Civil Works												
2.6.3.1	Operations Support Facility												
2.6.3.2	Inspect Completed OSF Constr												
2.6.3.3	Accept OSF Facility												
2.7	OSF/Array Link												
2.7.1	Prepare OSF/Array Link Bid Package												
2.7.1.1	Prepare Package for OSF/Array F/O Link												
2.7.1.2	Review Bid Package												
2.7.1.3	Bid OSF/Array Link Construction												
2.7.2	Evaluate Bid Response												
2.7.2.1	Review Bids												
2.7.2.2	Recommend Contractors												
2.7.2.3	Award Contracts												
2.7.3	Contract Civil Works												
2.7.3.1	OSF/Array Link												
2.7.3.2	Inspect Completed OSF/Array Link Constr												
2.7.3.3	Accept OSF/Array Link												
2.8	Prepare for Instrument Assembly												
2.8.1	Equip Array Site												
2.8.2	Equip Operations Support Facility												
3	Antenna												
3.1	Antenna Engineering Support												
3.3.40	Acceptance Tests Antenna #1												
3.3.45	Delivery of Antenna #1												
3.8.10	Sign Transporter Contract												
3.8.15	Transporter Acceptance tests												
3.8.20	Deliver/Accept Transporter #1												
3.7	Procurement of Antenna #2												
3.7.1	Antenna #2 Contract Supervision												
3.7.2	Antenna #2 Acceptance tests												
3.8	Negotiate Production Antenna Contract												
3.9	Sign Contract for Production Antennas												
3.10	Antenna Contract Supervision												
3.11	Accept Antenna #3 at OSF												
3.12	Prepare Antenna #3												
3.12.1	Outfit & Verify Ant #3 at OSF												
3.12.2	Move, Install & Verify Ant #3 on Site												
3.13	Accept Antenna #4 at OSF												
3.14	Prepare Antenna #4												
3.14.1	Outfit & Verify Ant #4 at OSF												
3.14.2	Move, Install & Verify Ant #4 on Site												
3.15	Accept Antenna#5 at OSF												
3.16	Prepare Antenna #5												
3.16.1	Outfit & Verify Ant #5 at OSF												
3.16.2	Move, Install & Verify Ant #5 on Site												
3.17	Accept Antenna#6 at OSF												
3.18	Prepare Antenna #6												
3.18.1	Outfit & Verify Ant #6 at OSF												
3.18.2	Move, Install & Verify Ant #6 on Site												
3.19	Accept Antenna #7 at OSF												

3.20	Prepare Antenna #7												
3.20.1	Outfit & Verify Ant #7 at OSF												
3.20.2	Move, Install & Verify Ant #7 on Site												
3.21	Accept Antenna #8 at OSF												
3.22	Prepare Antenna #8												
3.22.1	Outfit & Verify Ant #8 at OSF												
3.22.2	Move, Install & Verify Ant #8 on Site												
3.23	Accept Antenna #9 at OSF												
3.24	Prepare Antenna #9												
3.24.1	Outfit & Verify Ant #9 at OSF												
3.24.2	Move, Install & Verify Ant #9 on Site												
3.25	Accept Antenna #10 at OSF												
3.26	Prepare Antenna #10												
3.26.1	Outfit & Verify Ant #10 at OSF												
3.26.2	Move, Install and Verify Ant #10 on Site												
3.27	Accept Antenna #11 at OSF												
3.28	Prepare Antenna #11												
3.28.1	Outfit & Verify Ant #11 at OSF												
3.28.2	Move, Install & Verify Ant #11 on Site												
3.29	Accept Antenna #12 at OSF												
3.30	Prepare Antenna #12												
3.30.1	Outfit & Verify Ant #12 at OSF												
3.30.2	Move, Install & Verify Ant #12 on Site												
3.31	Accept Antenna #13 at OSF												
3.32	Prepare Antenna #13												
3.32.1	Outfit & Verify Ant #13 at OSF												
3.32.2	Move, Install & Verify Ant #13 on Site												
3.33	Accept Antenna #14 at OSF												
3.34	Prepare Antenna #14												
3.34.1	Outfit & Verify Ant #14 at OSF												
3.34.2	Move, Install & Verify Ant #14 on Site												
3.35	Accept Antenna #15 at OSF												
3.36	Prepare Antenna #15												
3.36.1	Outfit & Verify Ant #15 at OSF												
3.36.2	Move, Install & Verify Ant #15 on Site												
3.37	Accept Antenna #16 at OSF												
3.38	Prepare Antenna #16												
3.38.1	Outfit & Verify Ant #16 at OSF												
3.38.2	Move, Install & Verify Ant #16 on Site												
3.39	Accept Antenna #17 at OSF												
3.40	Prepare Antenna #17												
3.40.1	Outfit & Verify Ant #17 at OSF												
3.40.2	Move, Install & Verify Ant #17 on Site												
3.41	Accept Antenna #18 at OSF												
3.42	Prepare Antenna #18												
3.42.1	Outfit & Verify Ant #18 at OSF												
3.42.2	Move, Install & Verify Ant #18 on Site												
3.43	Accept Antenna #19 at OSF												
3.44	Prepare Antenna #19												
3.44.1	Outfit & Verify Ant #19 at OSF												
3.44.2	Move, Install & Verify Ant #19 on Site												
3.45	Accept Antenna #20 at OSF												
3.46	Prepare Antenna #20												
3.46.1	Outfit & Verify Ant #20 at OSF												

3.46.2	Move, Install & Verify Ant #20 on Site																			
3.47	Accept Antenna #21 at OSF																			
3.48	Prepare Antenna #21																			
3.48.1	Outfit & Verify Ant #21 at OSF																			
3.48.2	Move, Install & Verify Ant #21 on Site																			
3.49	Accept Antenna #22 at OSF																			
3.50	Prepare Antenna #22																			
3.50.1	Outfit & Verify Ant #22 at OSF																			
3.50.2	Move, Install & Verify Ant #22 on Site																			
3.51	Accept Antenna #23 at OSF																			
3.52	Prepare Antenna #23																			
3.52.1	Outfit & Verify Ant #23 at OSF																			
3.52.2	Move, Install & Verify Ant #23 on Site																			
3.53	Accept Antenna #24 at OSF																			
3.54	Prepare Antenna #24																			
3.54.1	Outfit & Verify Ant #24 at OSF																			
3.54.2	Move, Install & Verify Ant #24 on Site																			
3.55	Accept Antenna #25 at OSF																			
3.56	Prepare Antenna #25																			
3.56.1	Outfit & Verify Ant #25 at OSF																			
3.56.2	Move, Install & Verify Ant #25 on Site																			
3.57	Accept Antenna #26 at OSF																			
3.58	Prepare Antenna #26																			
3.58.1	Outfit & Verify Ant #26 at OSF																			
3.58.2	Move, Install & Verify Ant #26 on Site																			
3.59	Accept Antenna #27 at OSF																			
3.60	Prepare Antenna #27																			
3.60.1	Outfit & Verify Ant #27 at OSF																			
3.60.2	Move, Install & Verify Ant #27 on Site																			
3.61	Accept Antenna #28 at OSF			1.5			\$	15				\$	2	\$	15	\$	3	\$	17	
3.62	Prepare Antenna #28						\$	-												
3.62.1	Outfit & Verify Ant #28 at OSF			2		4	\$	39				\$	6	\$	39	\$	7	\$	45	
3.62.2	Move, Install & Verify Ant #28 on Site			1		1	\$	15				\$	2	\$	15	\$	3	\$	17	
3.63	Accept Antenna #29 at OSF			1.5			\$	15				\$	2	\$	15	\$	3	\$	17	
3.64	Prepare Antenna #29																			
3.64.1	Outfit & Verify Ant #29 at OSF			2		4	\$	39				\$	6	\$	39	\$	7	\$	45	
3.64.2	Move, Install & Verify Ant #29 on Site			1		1	\$	15				\$	2	\$	15	\$	3	\$	17	
3.65	Accept Antenna #30 at OSF			1.5			\$	15				\$	2	\$	15	\$	3	\$	17	
3.66	Prepare Antenna #30																			
3.66.1	Outfit & Verify Ant #30 at OSF			2		4	\$	39				\$	6	\$	39	\$	7	\$	45	
3.66.2	Move, Install & Verify Ant #30 on Site			1		1	\$	15				\$	2	\$	15	\$	3	\$	17	
3.67	Accept Antenna #31 at OSF			1.5			\$	15				\$	2	\$	15	\$	3	\$	17	
3.68	Prepare Antenna #31																			
3.68.1	Outfit & Verify Ant #31 at OSF			2		4	\$	39				\$	6	\$	39	\$	7	\$	45	
3.68.2	Move, Install and Verify Ant #31 on Site			1		1	\$	15				\$	2	\$	15	\$	3	\$	17	
3.69	Accept Antenna #32 at OSF			1.5			\$	15				\$	2	\$	15	\$	3	\$	17	
3.70	Prepare Antenna #32																			
3.70.1	Outfit & Verify Ant #32 at OSF			2		4	\$	39				\$	6	\$	39	\$	7	\$	45	
3.70.2	Move, Install & Verify Ant #32 on Site			1		1	\$	15				\$	2	\$	15	\$	3	\$	17	
3.71	Accept Antenna #33 at OSF			1.5			\$	15				\$	2	\$	15	\$	3	\$	17	
3.72	Prepare Antenna #33																			
3.72.1	Outfit & Verify Ant #33 at OSF			2		4	\$	39			\$	39	\$	-	\$	-	\$	-	\$	-
3.72.2	Move, Install and Verify Ant #33 on Site			1		1	\$	15			\$	15	\$	-	\$	-	\$	-	\$	-
3.73	Accept Antenna #34 at OSF			1.5			\$	15			\$	15	\$	-	\$	-	\$	-	\$	-

3.74	Prepare Antenna #34												
3.74.1	Outfit & Verify Ant #34 at OSF	2	4	\$	39			\$	39	\$	-	\$	-
3.74.2	Move, Install and Verify Ant #34 on Site	1	1	\$	15			\$	15	\$	-	\$	-
3.75	Accept Antenna #35 at OSF	1.5		\$	15			\$	15	\$	-	\$	-
3.76	Prepare Antenna #35												
3.76.1	Outfit & Verify Ant #35 at OSF	2	4	\$	39			\$	39	\$	-	\$	-
3.76.2	Move, Install & Verify Ant #35 on Site	1	1	\$	15			\$	15	\$	-	\$	-
3.77	Accept Antenna #36 at OSF	1.5		\$	15			\$	15	\$	-	\$	-
3.78	Prepare Antenna #36												
3.78.1	Outfit & Verify Ant #36 at OSF	2	4	\$	39			\$	39	\$	-	\$	-
3.78.2	Move, Install & Verify Ant #36 on Site	1	1	\$	15			\$	15	\$	-	\$	-
									\$	-	\$	-	\$
3.79	Prepare Antenna #1												
3.79.1	Antenna #1 Reassembled at OSF	1.5		\$	15				\$	2	\$	15	\$
3.79.2	Outfit & Verify Ant #1 at OSF	2	4	\$	39			\$	-	\$	6	\$	39
3.79.3	Move, Install & Verify Ant #1 on Site	1	1	\$	15			\$	-	\$	2	\$	15
3.80	Prepare Antenna #2												
3.80.1	Antenna #2 Reassembled at OSF	1.5		\$	15				\$	2	\$	15	\$
3.80.2	Outfit & Verify Ant #2 at OSF	2	4	\$	39				\$	6	\$	39	\$
3.80.3	Move, Install & Verify Ant #2 on Site	1	1	\$	15				\$	2	\$	15	\$
3.81	Antenna Transporter												
3.81.1	Contract for Transporter #1, move to Site												
3.81.2	Contract for Transporters #2, #3												
3.81.3	Accept Transporters #2, #3 at OSF												
4	Receivers												
4.1	Receiver Package												
4.1.1	Prototype Production Receiver Cryogenics												
4.1.1.1	CDR: Cryogenics Development												
4.1.1.2	Construct & test prototype cryogenics												
4.1.1.3	Deliver Prototype Cryogenics Subsystem												
4.1.2	Prototype Production Receiver Package												
4.1.2.1	Prototype Receiver Package Integration												
4.1.2.2	Prot. Rcvr. Pckg Lab Test & Evaluation												
4.1.2.3	Complete Prototype MMA Receiver Package												
4.1.3	MMA Rcvr Pckg Design Refinement												
4.1.4	Documentation												
4.1.5	Release MMA Receiver Pckg for manufacture												
4.1.6	Contract for Receiver Pckg Subassemblies												
4.1.6.1	Machine Dewars		30	\$	146	\$	50		\$	22	\$	30	\$
4.1.6.2	Fabricate Cryogenics subsystems	6	24	\$	176	\$	240		\$	46	\$	84	\$
4.1.6.3	Fabricate windows, IR filters, etc	6	30	\$	205	\$	100		\$	34	\$	51	\$
4.1.7	Accept Receiver Pckg Subassemblies												
4.1.7.1	Subassemblies #1-6												
4.1.7.2	Subassemblies #7-16												
4.1.7.3	Subassemblies #17-26												
4.1.7.4	Subassemblies #27-36												
4.1.7.5	Subassemblies #37-40												
4.1.8	Fab Rcvr Pckg Instrumentation & Electronics	3	12	\$	88	\$	75		\$	18	\$	30	\$
4.1.9	Fabricate Receiver Inserts	18	30	\$	322	\$	100		\$	47	\$	64	\$
4.1.10	Assemble Receiver Package												
4.1.10.1	Integrate Rcvr Instrumentation & subass'y	12	48	\$	351	\$	80		\$	48	\$	62	\$

4.1.10.2	Deliver Receiver Package #1-6												
4.1.10.3	Deliver Receiver Package #7-16												
4.1.10.4	Deliver Receiver Package #17-26												
4.1.10.5	Deliver Receiver Package #27-36												
4.1.10.6	Deliver Receiver Package #37-40												
4.2	SIS Receiver Modules												
4.2.1	211-275 GHz Module												
4.2.1.1	SIS Mixer												
4.2.1.1.1	Design, Fab and Test Mixer Design												
4.2.1.1.2	Deliver Production Design												
4.2.1.1.3	Fabricate Production Mixers												
4.2.1.2	Design & Verify Optics												
4.2.1.3	Design Module												
4.2.1.4	Contract Fabrication												
4.2.1.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.1.4.2	Assemble Modules												
4.2.1.5	Install SIS Mixer & Test Modules												
4.2.1.6	Deliver 211-275 GHz Receiver Modules												
4.2.1.6.1	Deliver Modules #1-7												
4.2.1.6.2	Deliver Modules #8-26												
4.2.1.6.3	Deliver Modules #27-40												
4.2.2	602-720 GHz Module												
4.2.2.1	SIS Mixer												
4.2.2.1.1	Design, Fabricate and Test Mixer Design												
4.2.2.1.2	Deliver Production Design												
4.2.2.1.3	Fabricate Production Mixers												
4.2.2.2	Design & Verify Optics												
4.2.2.3	Design Module												
4.2.2.4	Contract Fabrication												
4.2.2.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.2.4.2	Assemble Modules												
4.2.2.5	Install SIS Mixer and Test Modules												
4.2.2.6	Deliver 602-720 GHz Receiver Modules												
4.2.2.6.1	Deliver Modules #1-7												
4.2.2.6.2	Deliver Modules #8-26												
4.2.2.6.3	Deliver Modules #27-40												
4.2.3	275-370 GHz Receiver Module												
4.2.3.1	SIS Mixer												
4.2.3.1.1	Design, Fabricate and Test Mixer Design												
4.2.3.1.2	Deliver Production Design												
4.2.3.1.3	Fabricate Production Mixers												
4.2.3.2	Design & Verify Optics												
4.2.3.3	Design Module												
4.2.3.4	Contract Fabrication												
4.2.3.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.3.4.2	Assemble Modules												
4.2.3.5	Install SIS Mixer and Test Modules												
4.2.3.6	Deliver 275-370 GHz Receiver Module												
4.2.3.6.1	Deliver Modules #1-5												
4.2.3.6.2	Deliver Modules #6-30												
4.2.3.6.3	Deliver Modules #30-40												

4.2.4	91-119 GHz Receiver Module												
4.2.4.1	SIS Mixer												
4.2.4.1.1	Design, Fabricate & Test Mixer Design												
4.2.4.1.2	Deliver Production Design												
4.2.4.1.3	Fabricate Production Mixers												
4.2.4.2	Design & Verify Optics												
4.2.4.3	Design Module												
4.2.4.4	Contract Fabrication												
4.2.4.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.4.4.2	Assemble Modules												
4.2.4.5	Install SIS Mixer and Test Modules												
4.2.4.6	Deliver 91-119 GHz Receiver Modules												
4.2.4.6.1	Deliver Modules #1-5												
4.2.4.6.2	Deliver Modules #6-30												
4.2.4.6.3	Deliver Modules # 31-40												
4.2.5	163-211 GHz Receiver Module												
4.2.5.1	SIS Mixer												
4.2.5.1.1	Design, Fabricate & Test Mixer Design												
4.2.5.1.2	Deliver Production Design												
4.2.5.1.3	Fabricate Production Mixers												
4.2.5.2	Design & Verify Optics												
4.2.5.3	Design Module												
4.2.5.4	Contract Fabrication												
4.2.5.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.5.4.2	Assemble Modules												
4.2.5.5	Install SIS Mixer and Test	6	12	\$	117	\$	20		\$	15	\$	19	\$ 122 \$ 22 \$ 141
4.2.5.6	Deliver 163-211 GHz Receiver Modules												
4.2.5.6.1	Deliver Modules #1-5												
4.2.5.6.2	Deliver Modules #6-30												
4.2.5.6.3	Deliver Modules #31-40												
4.2.6	385-500 GHz Receiver Module												
4.2.6.1	SIS Mixer												
4.2.6.1.1	Design, Fabricate & Test Mixer Design												
4.2.6.1.2	Deliver Production Design												
4.2.6.1.3	Fabricate Production Mixers												
4.2.6.2	Design and Verify Optics												
4.2.6.3	Design Module												
4.2.6.4	Contract Fabrication												
4.2.6.4.1	Machine Mixer Blocks, Feed, WG, Lenses												
4.2.6.4.2	Assemble Modules												
4.2.6.5	Install SIS Mixer and Test	6	12	\$	117	\$	20		\$	137	\$	-	\$ - \$ - \$ -
4.2.6.6	Deliver 385-500 GHz Receiver Modules												
4.2.6.6.1	Deliver Modules #1-5												
4.2.6.6.2	Deliver Modules #6-30												
4.2.6.6.3	Deliver Modules #31-40												
4.2.7	125-163 GHz Receiver Module												
4.2.7.1	SIS Mixer												
4.2.7.1.1	Design, Fabricate & Test Mixer Design												
4.2.7.1.2	Deliver Production Design												
4.2.7.1.3	Fabricate Production Mixers												

4.2.7.2	Design & Verify Optics													
4.2.7.3	Design Module													
4.2.7.4	Contract Fabrication													
4.2.7.4.1	Machine Mixer Blocks, Feed, WG, Lenses													
4.2.7.4.2	Assemble Modules													
4.2.7.5	Install SIS Mixer and Test		24	48	\$ 468	\$ 50		\$ 58	\$ 68	\$ 460	\$ 79	\$ 534		
4.2.7.6	Deliver 125-163 GHz Receiver Modules													
4.2.7.6.1	Deliver 125-163 GHz Modules #1-5													
4.2.7.6.2	Deliver 125-163 GHz Modules #6-30													
4.2.7.6.3	Deliver 125-163 GHz Modules #31-40													
4.3	HFET Receiver Modules													
4.3.1	Contract for HFET Wafer													
4.3.2	Receive Diced HFET Wafer													
4.3.3	33-45 GHz Module													
4.3.3.1	Design Module													
4.3.3.2	Design & Verify Optics													
4.3.3.3	Contract Fabrication													
4.3.3.3.1	Machine Blocks, Feed, WG, Lenses													
4.3.3.3.2	Assemble Modules													
4.3.3.3.3	Flip-in Mirror													
4.3.4	Install HFET & Test Modules													
4.3.5	Deliver 33-45 GHz Receiver Modules													
4.3.5.1	Deliver Modules #1-20													
4.3.5.2	Deliver Modules #21-40													
4.3.6	67-95 GHz Module													
4.3.6.1	Design Amplifier													
4.3.6.2	Design Module													
4.3.6.3	Design & Verify Optics													
4.3.6.4	Contract Fabrication													
4.3.6.4.1	Machine Blocks, Feed, WG, Lenses													
4.3.6.4.2	Assemble Modules													
4.3.6.5	Install HFET & Test Modules													
4.3.6.6	Deliver 67-95 GHz Receiver Modules													
4.3.6.6.1	Deliver Modules 67-95GHz #1-20													
4.3.6.6.2	Deliver Modules 67-95GHz #21-40													
5	LO System													
5.1	LO Reference: Prototype Systems													
5.1.1	Deliver: Bench Prototype													
5.1.2	Testing and Design Refinement													
5.1.3	Procure/Fab Field Prototypes													
5.1.4	Deliver: LO Ref Field Prototypes													
5.1.5	Field Prototype testing and Design Refinement													
5.1.6	Preproduction Review													
5.1.7	Final Documentation and Design Modifications													
5.1.8	Release for Manufacture													
5.2	LO Reference: Production System		12	48	\$ 351			\$ 53	\$ 351	\$ 61	\$ 407			
5.1.1	Production test and lab equipment													
5.1.2	H-maser Frequency Standard (& Rb)													
5.1.3	8 GHz PL Oscillator & Distributor					\$ 1	\$ 0	\$ 0	\$ 1	\$ 0	\$ 1			
5.1.4	10 GHz PL Oscillator & Distributor					\$ 1	\$ 0	\$ 0	\$ 1	\$ 0	\$ 1			

5.1.5	12 GHz PL Oscillator & Distributor						\$ 1		\$ 0	\$ 0	\$ 1	\$ 0	\$ 1
5.1.6	14 GHz PL Oscillator & Distributor						\$ 1		\$ 0	\$ 0	\$ 1	\$ 0	\$ 1
5.1.7	3.2-5.2 GHz Synthesizer						\$ 8		\$ 1	\$ 1	\$ 7	\$ 1	\$ 8
5.1.8	3.2 -5.2 GHz PLO and Fringe Generator						\$ 160		\$ 18	\$ 24	\$ 142	\$ 28	\$ 165
5.1.9	Sampler Clock 4 GHz PL Osc & Distributor						\$ 1		\$ 0	\$ 0	\$ 1	\$ 0	\$ 1
5.1.10	LO Ref Generator						\$ 2		\$ 0	\$ 0	\$ 2	\$ 0	\$ 2
5.1.11	LO Ref Distributor - Control Bldg						\$ 1		\$ 0	\$ 0	\$ 1	\$ 0	\$ 1
5.1.12	Microwave Round-trip Phase Measurement						\$ 60		\$ 7	\$ 9	\$ 53	\$ 10	\$ 62
5.1.13	10-15 GHz Frequency Synthesizer						\$ 100		\$ 11	\$ 15	\$ 89	\$ 17	\$ 103
5.1.14	First LO Fringe Generator						\$ 20		\$ 2	\$ 3	\$ 18	\$ 3	\$ 21
5.1.15	16 GHz PL Oscillator						\$ 40		\$ 4	\$ 6	\$ 36	\$ 7	\$ 41
5.1.16	26 GHz PL Oscillator						\$ 40		\$ 4	\$ 6	\$ 36	\$ 7	\$ 41
5.1.17	LO Ref Distributor - Antenna						\$ 20		\$ 2	\$ 3	\$ 18	\$ 3	\$ 21
5.1.18	VXCO Clean-up Loop						\$ 20		\$ 2	\$ 3	\$ 18	\$ 3	\$ 21
5.1.19	Power supply module						\$ 60		\$ 7	\$ 9	\$ 53	\$ 10	\$ 62
5.1.20	Bins / Racks (assemble and test)						\$ 16		\$ 2	\$ 2	\$ 14	\$ 3	\$ 16
5.3	Millimeter LO Drivers												
5.3.1	Design and System Integration												
5.3.2	72-95 GHz Source												
5.3.2.1	Contract Procurement and Fabrication												
5.3.2.1.1	YIG-tuned Oscillator												
5.3.2.1.2	18.00 - 23.75 GHz 10 db Amplifier												
5.3.2.1.3	18.00 - 23.75 GHz x2 Multiplier												
5.3.2.1.4	36.0 - 47.5 GHz 10 db Amplifier												
5.3.2.1.5	36.0 - 47.5 GHz x2 Multiplier												
5.3.2.1.6	Mount and Tuning circuitry												
5.3.2.2	Assembly and Test												
5.3.2.3	Deliver 72 - 95 GHz LO Sources												
5.3.2.3.1	Deliver Modules #1-6												
5.3.2.3.2	Deliver Modules #7-24												
5.3.2.3.3	Deliver Modules #25-40												
5.3.3	100-120 GHz Source												
5.3.3.1	Contract Procurement and Fabrication												
5.3.3.1.1	YIG-tuned Oscillator												
5.3.3.1.2	25.00 - 30.00 GHz 10 db Amplifier												
5.3.3.1.3	15.00 - 30.00 GHz x2 Multiplier												
5.3.3.1.4	50.0 - 60.0 GHz 10 db Amplifier												
5.3.3.1.5	50-60 GHz x2 Multiplier												
5.3.3.1.6	Mount and Tuning circuitry												
5.3.3.2	Assembly and Test												
5.3.3.3	Deliver 100 - 120 GHz LO Sources												
5.3.3.3.1	Deliver Modules #1-3												
5.3.3.3.2	Deliver Modules #4-21												
5.3.3.3.3	Deliver Modules #22-40												
5.3.4	87 - 108 GHz Source												
5.3.4.1	Contract Procurement and Fabrication												
5.3.4.1.1	YIG-tuned Oscillator												
5.3.4.1.2	21.75-27.00 GHz 10 db Amplifier												
5.3.4.1.3	21.75-27.00 GHz x2 Multiplier												
5.3.4.1.4	43.5-54.0 GHz 10 db Amplifier												
5.3.4.1.5	43.5-54.0 GHz x2 Multiplier												

5.3.4.1.6	Mount and Tuning Circuitry												
5.3.4.2	Assembly and Test												
5.3.4.3	Deliver 87 - 108 GHz LO Sources												
5.3.4.3.1	Deliver Modules #1-6												
5.3.4.3.2	Deliver Modules #7-20												
5.3.4.3.3	Deliver Modules #21-35												
5.3.4.3.4	Deliver Modules #36-40												
5.3.5	65 - 85 GHz Source												
5.3.5.1	Contract Procurement and Fabrication												
5.3.5.1.1	YIG-tuned Oscillator												
5.3.5.1.2	16.25-21.25 GHz 10 db Amplifier												
5.3.5.1.3	16.25-21.25 GHz x2 Multiplier												
5.3.5.1.4	32.5-42.5 GHz 10 db Amplifier												
5.3.5.1.5	32.5-42.5 GHz x2 Multiplier												
5.3.5.1.6	Mount and Tuning Circuitry												
5.3.5.2	Assembly and Test												
5.3.5.3	Deliver 65 - 85 GHz LO Sources												
5.3.5.3.1	Deliver Modules #1-6												
5.3.5.3.2	Deliver Modules #7-20												
5.3.5.3.3	Deliver Modules #21-35												
5.3.5.3.4	Deliver Modules #36-40												
5.4	Millimeter LO Multiplier Chains												
5.4.1	Design and System Integration		6	12	\$ 117	\$ 50	\$ 167		\$ 8	\$ -	\$ 9	\$ -	
5.4.2	211 - 275 GHz Receiver LO												
5.4.2.1	Contract Fabrication												
5.4.2.1.1	X3 Diode for 72-95 GHz Source												
5.4.2.1.2	Machine Mount												
5.4.2.1.3	Bias and Control circuits												
5.4.2.2	Assemble Multiplier and Test												
5.4.2.3	Integrate Source and Multiplier; test												
5.4.2.4	Deliver 211-275 GHz Rcvr LO Modules												
5.4.2.4.1	Deliver Modules #1-3												
5.4.2.4.2	Deliver Modules #4-21												
5.4.2.4.3	Deliver Modules #22-40												
5.4.3	602 - 720 GHz Receiver LO												
5.4.3.1	Contract Fabrication												
5.4.3.1.1	X2 Diode for 100-120 GHz Source												
5.4.3.1.2	X3 Diode for 200-240 GHz Input												
5.4.3.1.3	Machine Mount												
5.4.3.1.4	Bias and Control circuits												
5.4.3.2	Assemble Multipliers and Test												
5.4.3.3	Integrate Source and Multipliers; test												
5.4.3.4	Deliver 602-720 GHz Rcvr LO Modules												
5.4.3.4.1	Deliver Modules #1-6												
5.4.3.4.2	Deliver Modules #7-18												
5.4.3.4.3	Deliver Modules #19-34												
5.4.3.4.4	Deliver Modules #35-40												
5.4.4	275 - 370 GHz Receiver LO												
5.4.4.1	Contract Fabrication												
5.4.4.1.1	X2 Diode for 72-95 GHz Source												

5.4.4.1.2	X2 Diode for 144-190 GHz Input																	
5.4.4.1.3	Machine Mount																	
5.4.4.1.4	Bias and Control Circuits																	
5.4.4.2	Assemble Multipliers and Test																	
5.4.4.3	Integrate Source and Multipliers; test																	
5.4.4.4	Deliver 275-370 GHz Rcvr LO Modules																	
5.4.4.4.1	Deliver Modules #1-6																	
5.4.4.4.2	Deliver Modules #7-27																	
5.4.4.4.3	Deliver Modules #28-40																	
5.4.5	163 - 211 GHz Receiver LO																	
5.4.5.1	Contract Fabrication																	
5.4.5.1.1	X2 Diode for 87-108 GHz Source																	
5.4.5.1.2	Machine Mount																	
5.4.5.1.3	Bias and Control Circuits																	
5.4.5.2	Assemble Multiplier and Test																	
5.4.5.3	Integrate Source and Multplier; test																	
5.4.5.4	Deliver 163 - 211 GHz Rcvr LO Modules																	
5.4.5.4.1	Deliver Modules #1-6																	
5.4.5.4.2	Deliver Modules #7-24																	
5.4.5.4.3	Deliver Modules #25-40																	
5.4.6	385 - 500 GHz Receiver LO																	
5.4.6.1	Contract Fabrication																	
5.4.6.1.1	X3 Diode for 65-85 GHz Source																	
5.4.6.1.2	X2 Diode for 130-170 GHz Input																	
5.4.6.1.3	Machine Mount																	
5.4.6.1.4	Bias and Control Circuits																	
5.4.6.2	Assemble Multiplier and test																	
5.4.6.3	Integrate source and Multiplier; test																	
5.4.6.4	Deliver 385-500 GHz Rcvr LO Modules																	
5.4.6.4.1	Deliver Modules #1-6																	
5.4.6.4.2	Deliver Modules #7-24																	
5.4.6.4.3	Deliver Modules #25-40																	
5.4.7	125 - 163 GHz Receiver LO																	
5.4.7.1	Contract Fabrication																	
5.4.7.1.1	X2 Diode for 65 - 85 GHz Source																	
5.4.7.1.2	Machine Mount																	
5.4.7.1.3	Bias and Control Circuits																	
5.4.7.2	Assemble Multiplier and test																	
5.4.7.3	Integrate Source and Multiplier; test																	
5.4.7.4	Deliver 125-163 GHz Rcvr LO Modules																	
5.4.7.4.1	Deliver Modules #1-6																	
5.4.7.4.2	Deliver Modules #7-18																	
5.4.7.4.3	Deliver Modules #19-34																	
5.4.7.4.4	Deliver Modules #35-40																	
5.4.8	33-45 GHz Receiver LO																	
5.4.8.1	Design & Fab Selection & Coupling from Sources																	
6	IF System			12	36	\$	293				\$	44	\$	293	\$	51	\$	339
6.1	IF System: Prototype Systems																	

6.1.1	Deliver (Bench) Prototype IF System												
6.1.2	Testing and Design Refinement												
6.1.3	Procure/Fab Field Prototypes												
6.1.4	Deliver IF Field Prototypes to Test Interfeometer												
6.1.5	Field Prototype testing and Design Refinement												
6.1.6	Preproduction Review												
6.1.7	Final Documentation and Design Modifications												
6.1.8	Release for Manufacture												
6.2	Production test and lab equipment												
6.3	IF Multiplexer					\$ 160		\$ 18	\$ 21	\$ 142	\$ 25	\$ 165	
6.4	IF Demultiplexer					\$ 80		\$ 9	\$ 11	\$ 71	\$ 12	\$ 82	
6.5	IF Matrix Switch					\$ 64		\$ 7	\$ 9	\$ 57	\$ 10	\$ 66	
6.6	Baseband Converter					\$ 160		\$ 18	\$ 21	\$ 142	\$ 25	\$ 165	
6.7	Power supply module					\$ 40		\$ 4	\$ 5	\$ 36	\$ 6	\$ 41	
6.8	Bins / Racks (assemble and test)					\$ 16		\$ 2	\$ 2	\$ 14	\$ 2	\$ 16	
7	Optical Fiber System		12	36	\$ 293				\$ 44	\$ 293	\$ 51	\$ 339	
7.1	Optical Fiber System: Prototype Systems												
7.1.1	Deliver (Bench) Prototype FO System												
7.1.2	Testing and Design Refinement												
7.1.3	Procure/Fab Field Prototypes												
7.1.4	Deliver FO Field Prototypes to Test Interfeometer												
7.1.5	Field Prototype testing and Design Refinement												
7.1.6	Preproduction Review												
7.1.7	Final Documentation and Design Modifications												
7.1.8	Release for Manufacture												
7.1	Production test and lab equipment												
7.2	IF TX / RX					\$ 240		\$ 27	\$ 32	\$ 213	\$ 37	\$ 247	
7.3	LO Reference TX / RX					\$ 40		\$ 4	\$ 5	\$ 36	\$ 6	\$ 41	
7.4	Microwave Round-trip Phase TX / RX					\$ 40		\$ 4	\$ 5	\$ 36	\$ 6	\$ 41	
7.5	Monitor / Control TX / RX					\$ 20		\$ 2	\$ 3	\$ 18	\$ 3	\$ 21	
7.6	Power supply module					\$ 40		\$ 4	\$ 5	\$ 36	\$ 6	\$ 41	
7.7	Bins / Racks (assemble and test)					\$ 16		\$ 2	\$ 2	\$ 14	\$ 2	\$ 16	
8	Correlator												
8.1	Digital Sampler, 4 GHz												
8.1.1	Refine Design												
8.1.2	Release Digital Sampler for Manufacture												
8.1.3	Contract Materials												
8.1.4	Assembly												
8.1.5	Validation and Delivery												
8.2	Digital FIR Filter												
8.2.1	Prototype testing on Test Interferometer												
8.2.2	Design Refinement												
8.2.3	Release FIR Filter for manufacture												
8.2.4	Chip Fabrication												
8.2.5	Assembly												
8.2.6	Validation and Delivery												
8.3	Custom Boards												
8.3.1	Correlator Board												

8.3.1.1	Prototype assembly												
8.3.1.2	Prototype test												
8.3.1.3	Design modifications												
8.3.1.4	Fab, assemble and test with design mods												
8.4	Correlator Chip												
8.4.1	Prototype chip fabrication												
8.4.2	Prototype chip test												
8.4.3	Design modifications												
8.4.4	Fabricate and test design mods												
8.4.5	Fabricate production run												
8.5	Racks												
8.5.1	Design control wiring												
8.5.2	Design signal wiring												
8.5.3	Order parts												
8.5.4	Assemble prototypes												
8.6	Software												
8.7	Prototype Correlator Production												
8.7.1	Order parts												
8.7.2	Assemble												
8.7.3	Test												
8.7.4	Deliver Prototype Correlator to VLA site												
8.8	Site Correlator Production												
8.8.1	First 1/4 correlator												
8.8.1.1	Determine configuration												
8.8.1.2	Order parts												
8.8.1.3	Assemble												
8.8.1.4	Test												
8.8.1.5	Deliver 1/4 Correlator to MMA site												
8.8.2	Second 1/4 correlator												
8.8.2.1	Order parts												
8.8.2.2	Assemble												
8.8.2.3	Test												
8.8.2.4	Deliver 1/4 Correlator to MMA site												
8.8.3	Third 1/4 correlator												
8.8.3.1	Order parts												
8.8.3.2	Assemble												
8.8.3.3	Test												
8.8.3.4	Deliver 1/4 Correlator to MMA site												
8.8.4	Fourth 1/4 correlator												
8.8.4.1	Order parts												
8.8.4.2	Assemble												
8.8.4.3	Test												
8.8.4.4	Deliver 1/4 Correlator to MMA site												
8.9	Continued Support												
9	Computing						\$ 150			\$ 45	\$ 150	\$ 52	\$ 174
9.1	Control Software												
9.1.1	Test Interferometer Control & Analysis												
9.1.2	MMA correlator software												
9.1.3	Multi-antenna & sub-array control												
9.1.4	Operators & Observers interfaces												
9.1.5	Deliver Control Software												
9.1.6	Maintenance			40			\$ 347		\$ 347	\$ -	\$ -	\$ -	\$ -

9.2	Scheduling																	
9.2.1	Static scheduling system																	
9.2.2	Dynamic scheduling simulations																	
9.2.3	Dynamic scheduling prototype																	
9.2.4	Dynamic scheduling implementation		26			\$	225			\$	34	\$	225	\$	39	\$	261	
9.2.5	Initial Operations with Dynamic Scheduling																	
9.3	Proposal Preparation Software																	
9.3.1	Prototype																	
9.3.2	Production version		10			\$	87			\$	13	\$	87	\$	15	\$	101	
9.4	Image Pipeline																	
9.4.1	Automated calibration & imaging heuristics																	
9.4.2	Prototype image pipeline		40			\$	347			\$	52	\$	347	\$	60	\$	402	
9.4.3	Parallelization studies and implementation																	
9.4.4	Initial Image Pipeline Operations																	
9.4.5	Production image pipeline																	
9.5	Archiving																	
9.5.1	Prototype distributed archive																	
9.5.2	Evaluate storage hardware		6			\$	52			\$	8	\$	52	\$	9	\$	60	
9.5.3	Production archive		20			\$	173			\$	26	\$	173	\$	30	\$	201	
9.5.4	Data Archive operational																	
9.6	Post-processing																	
9.6.1	Define MMA Data formats																	
9.6.2	MMA filler & format conversions																	
9.6.3	MMA-specific calibrations																	
9.6.4	MMA Post-processing begins																	
9.6.5	Maintenance		12			\$	104		\$	104	\$	-	\$	-	\$	-	\$	-
10	System Integration																	
10.4	Test Interferometer Site Preparation																	
10.4.1	Complete Office and Lab Space Preparation																	
10.4.2	Cabling																	
10.4.3	Test Interferometer Site Complete																	
10.10.4	Prototype Antenna Outfitting																	
10.10.4.1	Cabling																	
10.10.4.2	Instrumentation																	
10.10.4.3	Eval. Rcvr. #1 / Ant. #1 Integration																	
10.10.4.4	Antenna #1 Outfitting Complete																	
10.10.5	Integration Holography System/Antenna																	
10.10.6	Integration Metrology/Antenna																	
10.10.7	Antenna #1 Integration & Testing																	
10.10.8	Prot. Rcvr. Test & Evaluation																	
10.10.9	Antenna #2 Outfitting																	
10.10.9.1	Cabling																	
10.10.9.2	Instrumentation																	
10.10.9.3	Eval. Rcvr. #2 / Ant. #2 Integration																	
10.10.9.4	Antenna #2 Outfitting Complete																	
10.11	Test Interferometer																	
10.11.1	Antenna Evaluation & Characterization																	
10.11.1.1	Antenna Verification																	
10.11.1.4	Holography																	
10.11.1.5	Beam and Sidelobes																	
10.11.1.6	Gain vs. Elevation: Spillover Temp																	
10.11.1.7	Effect of Sun in & Near the Beam																	

10.11.2	Engineering Recommendations re Prod. Ant.												
10.11.3	Revise Interface Specifications												
10.11.5	Operations Personnel Training												
10.11.5.1	Recruit Initial Chile Ops Staff												
10.11.5.2	Array Operations												
10.11.5.3	Engineering Maintenance												
10.11.5.4	Scientific Support & Analysis												
10.12.2	Relocate Ops Staff to Chile												
10.8.4.6	Start On-site Operations												
10.12	Disassemble Test Interferometer												
10.12.1	Prepare & Ship Antenna #1, #2												
10.12.3	Restore Facilities at VLA Site												
10.13	On Site System Integration			48	48	\$ 702		\$ 702		\$ -	\$ -	\$ -	\$ -
11	Calibration and Imaging												
11.1	Radiometric Phase Design & Prototype												
11.1.1	Complete 183GHz Phase Mon Prototype												
11.1.2	Demo 183 GHz Phase Monitor Radiometer on-Site												
11.1.3	Design Refinement												
11.1.4	Release Phase Mon Radiometer for manufacture												
11.2	Production Fab of Phase Monitor Radiometer				18	\$ 88				\$ 13	\$ 88	\$ 15	\$ 102
11.2.1	Contract Subassembly Fabrication												
11.2.1.1	Radiometer & Local Oscillator												
11.2.1.2	Spectrometer												
11.2.1.3	Feed, Window, lens, instrumentation												
11.2.1.4	M/C Interface												
11.2.2	Assembly & Test												
11.2.3	Deliver Production Radiometers												
11.2.4	Integration in Receiver Package												
11.2.5	Verification on-Site												
11.3	Production Fabrication of Dual-load Amp Cal Sys				3	\$ 15				\$ 2	\$ 15	\$ 3	\$ 17
11.3.1	Design Refinement												
11.3.2	Release Phase Mon Radiometer for manufacture												
11.3.3	Contract Subassembly												
11.3.3.1	Machining												
11.3.3.2	Load Fabrication												
11.3.3.3	Motors, Servo												
11.3.3.4	M/C Interface												
11.3.4	Assembly & Test												
11.3.5	Integration on Production Antennas												
11.4	Imaging Studies & Project Support	72				\$ 585		\$ 585		\$ -	\$ -	\$ -	\$ -
11.5	Imaging Algorithm Development	8	4			\$ 100				\$ 15	\$ 100	\$ 17	\$ 116
	TOTALS					\$ 7,845	\$ 3,973	\$ 2,119	\$ 846	\$ 1,379	\$ 8,853	\$ 1,599	\$ 10,267