ANNEX D: WORK BREAKDOWN STRUCTURE, ASSIGNMENT OF DELIVERABLES AND SCHEDULE OF VALUES

Work Breakdown Structure

The ALMA Work Breakdown Structure (WBS) is a detailed description of all the tasks necessary to construct the instruments and software required for ALMA; to construct the buildings, roads, antenna foundations, utilities and infrastructure needed for the support of those instruments and software; to integrate the whole into a properly functioning synthesis array telescope on the Chajnantor site in northern Chile; and to manage the construction project on behalf of the two sponsoring ALMA Parties via work carried out through NRAO ("North America") and ESO ("Europe").

The ALMA construction project has adopted a management structure based on the Integrated Product Team (IPT) concept. The IPT concept provides a method of managing tasks carried out across multiple organizations and locations. Each ~~Level One~~level-1 WBS element is managed by an IPT responsible for delivering the required products on time, within the specified cost and meeting the project requirements. The implementation of the IPT concept is described~~in detail~~ in the ALMA Management Plan.

The ALMA WBS was derived in three steps. First, the scientific requirements for ALMA were specified by the ALMA Science Advisory Committee (ASAC). Second, a technical description of an array capable of meeting those requirements was outlined by the technical leaders of the ALMA Project in North America and Europe. Close and frequent interaction was required between the ASAC and the technical project leadership to assure that the planned technical capabilities met the science requirement priorities. Third, a plan for design and fabrication, or procurement, of all the hardware modules and subsystems was established. Costs were estimated for all tasks and subtasks. The process was informed and constrained by the estimated resources the sponsors were intending to commit to ALMA. The resulting project description was organized into the WBS which specifies in sufficient detail the tasks and the resources, both personnel and financial, required to realize those tasks for the completed project.

The WBS for the ALMA construction project down to level 3 is included ~~below.~~in the following pages. The WBS is organized into nine level-1 tasks:

1. Management/Administration (*)
2. Site Development
3. Antenna Subsystem
4. Front End Subsystem
5. Back End Subsystem
6. Correlator
7. Computing Subsystem
8. System Engineering and Integration
9. Science (*)

* Note: Education and Public Outreach is a functional task of the Science IPT and Safety is a task of Management/Administration.

Atacama Large Millimeter Array

ALMA Construction Plan 2002-Mar-12

All Tasks selected

ALMA_Project_2002Mar12r06.mpp
View: Import Gantt View
Construction Plan: Page 1 of 5

WBS	Task	NA %	Eur %	Responsibility
	ALMA Project Plan 2002Mar12			
1	**Management / Admin.**			
1.010	Management And Administration			JAO
1.010.0100	North American Project Office	100%		
1.010.0120	European Project Office		100%	
1.015	Joint ALMA Office			JAO
1.015.0160	Joint ALMA Office (including safety)	50%	50%	
2	**Site Development**			
2.020	Site Construction Management			Site IPT
2.020.0200	Site Development Management	35%	65%	
2.025	Site Development			Site IPT
2.025.0210	Site Infrastructure	71%	29%	
2.025.0220	Array Site	49%	51%	
2.025.0240	Operations Support Facility (OSF)	0%	100%	
2.025.0260	Array/OSF Access Roads	33%	67%	
2.025.0280	Array/OSF Communication Links	100%	0%	
2.025.0300	Chilean Phase 2 Facilities	0%	100%	
3	**Antenna Subsystem**			
3.030	Antenna Management/Engineering			Ant IPT
3.030.0320	Antenna Management Phase 2	50%	50%	
3.030.0340	Production Antenna Engineering Support	50%	50%	
3.035	Prototype Antenna Evaluation Support			Ant IPT
3.035.0360	North Am. Post Acceptance Evaluation	100%		
3.035.0380	Euro Post Acceptance Evaluation		100%	
3.036	European Prototype Antenna Phase 2			Europe
3.036.0410	European Phase 2 Prototype Antenna		100%	
3.045	Antenna Contract Tendering/Supervision			Ant IPT
3.045.0440	Final Design Mods & Documentation; Prepare Bid Package	50%	50%	
3.045.0460	Production Antenna Contracting	50%	50%	
3.045.0480	Final Foundation Design	50%	50%	
3.050	Antenna Procurement			Ant IPT
3.050.0500	Production Antennas	49%	51%	
3.060	Production Antenna Acceptance at OSF			Ant IPT
3.060.0560	Production Antenna Acceptance at OSF	50%	50%	
3.065	Nutator Design/Fabricate			N. Am.
3.065.0580	Production Antenna Nutator	100%		
3.070	Transporter Design/Fabricate			Europe
3.070.0600	Transporter Design / Fabrication		100%	
4	**Front End Subsystem**			
4.075	Frontend Management/Subsystem Engineering			FE IPT
4.075.0620	Front End Subsystem Management	50%	50%	
4.075.0640	Front End Subsystem Engineering	50%	50%	
4.080	Cryostat Design/Prototype			Europe
4.080.0660	Cryostat Design/Prototype		100%	
4.085	Cryostat Production			Europe
4.085.0680	Cryostat construction		100%	

ALMA Construction Plan 2002-Mar-12

All Tasks selected

WBS	Task	NA %	Eur %	Responsibility
4.085.0700	Cryocooler		100%	
4.090	Windows/IR/Common Optics Design/Prototype			Europe
4.090.0720	Windows/IR/Common Optics Design/Prototype		100%	
4.095	Windows/IR/Common Optics Production			Europe
4.095.0740	Common Optics		100%	
4.095.0760	Windows and IR Filters		100%	
4.100	Electronics/M&C Design/Prototype			N. Am.
4.100.0780	FE Electronics / M&C Design/Prototype	100%		
4.105	Electronics/M&C Production			N. Am.
4.105.0800	Production Front End Electronics	100%		
4.105.0820	Front-end IF Selection Switch	100%		
4.105.0840	Front End Monitor and Control System	100%		
4.110	FE Subreflector Calibration System Development			N. Am.
4.110.0860	Photonic Phase Cal Development	100%		
4.115	FE Focal Plane Calibration System Development			Europe
4.115.0880	Calibration System Development		100%	
4.120	FE Subreflector Calibration System Production			N. Am.
4.120.0900	Photonic Phase Cal Production	100%		
4.120.0940	Subreflector Calibration System - control s/w and h/w	100%		
4.120.0960	Subreflector Calibration System - hardware at subreflector	100%		
4.125	FE Focal Plane Calibration System Production			Europe
4.125.0920	Calibration System		100%	
4.125.0980	Solar Filter		100%	
4.140	Band 3 Cartridge Design/ Prototype			N. Am.
4.140.1003	Band 3 Cartridge Design / Development	100%		
4.145	Band 3 Cartridge Production			N. Am.
4.145.1063	Signal and LO Sources Band 3	100%		
4.145.1080	Band 3 SIS Mixer	100%		
4.145.1103	LO Production Band 3	100%		
4.145.1123	SIS Mixer Production Equipment Band 3	100%		
4.145.1140	IF amplifier 4-12 GHz (Band 3 SIS option only)	100%		
4.145.1163	Build SIS mixer fabrication equipment Band 3	100%		
4.145.1180	Band 3 - SIS mixer option: Other components	100%		
4.145.1203	Cartridge Body construction Band 3		100%	
4.145.1303	Cartridge test cryostat Band 3		100%	
4.145.1403	SIS Junctions Band 3	100%		
4.160	Band 6 Cartridge Design/ Prototype			N. Am.
4.160.1006	Band 6 Cartridge Design / Development	100%		
4.165	Band 6 Cartridge Production			N. Am.
4.165.1066	Signal and LO Sources Band 6	100%		
4.165.1106	LO Production Band 6	100%		
4.165.3106	LO Production Diode Multipliers Band 6	100%		
4.165.1126	SIS Mixer Production Equipment Band 6	100%		
4.165.1166	Build SIS mixer fabrication equipment Band 6	100%		
4.165.1206	Cartridge Body construction Band 6		100%	
4.165.1240	Band 6 SIS Mixer	100%		
4.165.1260	Production Band 6 Orthomode Transducer (OMT)	100%		

Atacama Large Millimeter Array

ALMA Construction Plan 2002-Mar-12

All Tasks selected

ALMA_Project_2002Mar12r06.mpp
View: Import Gantt View
Construction Plan: Page 3 of 5

WBS	Task	NA %	Eur %	Responsibility
4.165.1280	14 IF amplifier 4-12 GHz (Band 6 only)	100%		
4.165.1306	Cartridge test cryostat Band 6		100%	
4.165.1320	Band 6 Other components	100%		
4.165.1406	SIS Junctions Band 6	100%		
4.170	Band 7 Cartridge Design/ Prototype			Europe
4.170.1007	Band 7 Cartridge Design / Development		100%	
4.175	Band 7 Cartridge Production			Europe
4.175.1107	LO Production Band 7	100%		
4.175.3107	LO Production Diode Multipliers Band 7	100%		
4.175.1207	Cartridge Body construction Band 7		100%	
4.175.1307	Cartridge test cryostat Band 7		100%	
4.175.1340	Band 7 Internal optics, feed & polarizer baseline		100%	
4.175.1360	Band 7 SIS Mixer baseline		100%	
4.175.1407	SIS Junctions Band 7		100%	
4.175.1420	Band 7 Other Components baseline		100%	
4.190	Band 9 Cartridge Design/ Prototype			Europe
4.190.1009	Band 9 Cartridge Design / Development		100%	
4.195	Band 9 Cartridge Production			Europe
4.195.1109	LO Production Band 9	100%		
4.195.3109	LO Production Diode Multipliers Band 9	100%		
4.195.1209	Cartridge Body construction Band 9		100%	
4.195.1309	Cartridge test cryostat Band 9		100%	
4.195.1409	SIS Junctions Band 9		100%	
4.195.1460	Band 9 cartridge parts (excl. mixer)		100%	
4.195.1480	Band 9 fabrication equipment Part 1		100%	
4.195.1500	Band 9 fabrication equipment Part 2		100%	
4.195.1520	Band 9 mixer		100%	
4.210	WVR Radiometer Design/ Prototype			Europe
4.210.1011	WVR Cartridge Design / Development		100%	
4.215	WVR Radiometer Production			Europe
4.215.1560	183GHz WVR Production, Installation & Commissioning		100%	
4.220	Integration Test Facilities Develop/Procure			N. Am.
4.220.1580	Front End Test Station Development	100%		
4.225	Integration Test Facilities Duplicate			Europe
4.225.1600	Front End Test Station Replication		100%	
4.230	Frontend Integration			N. Am.
4.230.1620	Front End Integration Center #1 Setup and Operation	100%		
4.230.1630	Front End Integration Center #2 Setup and Operation		100%	
4.235	Frontend Mechanical Chasis/Mount			N. Am.
4.235.1660	Front End Chassis	50%	50%	
4.240	Front End Service Vehicle			N. Am.
4.240.1680	Front End Service and Exchange Vehicle	100%		
4.245	Photonic LO Development			N. Am.
4.245.1700	Photonic LO Development N. Am.	100%		
4.245.1705	Photonic LO Development Europe		100%	
4.250	LO Driver Development			N. Am.
4.250.1720	LO driver continued development section	100%		

Atacama Large Millimeter Array

ALMA Construction Plan 2002-Mar-12

All Tasks selected

ALMA_Project_2002Mar12r06.mpp
View: Import Gantt View
Construction Plan: Page 4 of 5

WBS	Task	NA %	Eur %	Responsibility
4.250.1740	Cold multiplier continued development section	100%		
4.255	Multiplier/Driver Production			N. Am.
4.255.1760	LO Multiplier Drivers fabrication and test	100%		
4.255.1800	Cold multiplier fabrication and test equipment	100%		
5	**Backend Subsystem**			
5.260	Backend Management Subsystem Engineering			BE IPT
5.260.1880	Backend Mgmt/Subsystem Engineering Phase 2	75%	25%	
5.260.1840	LO Ref Engineering Field Support	100%		
5.260.1860	Photonic Dist Engineering Support	100%		
5.260.1900	Backend Engineering Support	67%	33%	
5.265	Backend Analog Processing Design/Prototype			N. Am.
5.265.1920	Prototype System IF Down-converter	100%		
5.270	Backend Analog Processing Production			N. Am.
5.270.1940	IF Down-converter	100%		
5.270.1960	Power Supply Modules	100%		
5.270.1980	BE Production Test & Lab Equipment	100%		
5.275	Backend Digitizer Design/Prototype			Europe
5.275.2000	Backend Digitizer/Sampler Prototype		100%	
5.280	Backend Digitizer Production			Europe
5.280.2020	Digitizer/Sampler		100%	
5.280.2040	DeMultiplexer for Digitizer/Sampler		100%	
5.285	Backend Data Transmission Design/Prototype			N. Am.
5.285.2060	Prototype System Digital IF Tx & Rx	50%	50%	
5.290	Backend Data Transmission Production			N. Am.
5.290.2080	Sampler Clock		100%	
5.290.2100	Digital IF Transmitters and Receivers	25%	75%	
5.295	LO Frequency Synthesis Design/Prototype			N. Am.
5.295.2120	LO Reference Prototype	100%		
5.295.2140	FO Transmitter, LO Ref - Low Freq	100%		
5.300	LO Frequency Synthesis Production			N. Am.
5.300.2160	FO Receiver, LO Reference	100%		
5.300.2180	Two-Laser generator, RF synthesizer	100%		
5.300.2200	Second LO Synthesizer	70%	30%	
5.300.2220	Fringe Generator	100%		
5.300.2240	Central LO Reference Generator	100%		
5.300.2260	H-maser Frequency Standard		100%	
5.300.2280	Power Supply Modules	100%		
5.300.2300	LO Ref Production supervision & int.	100%		
5.300.2320	LO Ref Production test & lab equipment	100%		
5.300.2335	Photonic Dist Prototype	100%		
5.300.2340	Fabricate Photonic Dist Production System	50%	50%	
5.305	Backend Installation/Integration in Chile			BE IPT
5.305.2360	LO Reference On Site Integration and Test	50%	50%	
5.305.2380	Photonic Dist On Site Integration and Test	50%	50%	
5.305.2400	Backend On Site Integration and Test	50%	50%	
6	**Correlator**			
6.310	Correlator Management/Subsystem Engineering			Corr IPT

Atacama Large Millimeter Array

ALMA Construction Plan 2002-Mar-12

All Tasks selected

ALMA_Project_2002Mar12r06.mpp
View: Import Gantt View
Construction Plan: Page 5 of 5

WBS	Task	NA %	Eur %	Responsibility
6.310.2420	Baseline Correlator Mgmt/Subsystem Engineering Phase 2	100%		
6.310.2440	Baseline Correlator Continued Support	100%		
6.315	Baseline Correlator Design/Prototype			N. Am.
6.315.2460	Prototype Correlator Production	100%		
6.320	Baseline Correlator Production			N. Am.
6.320.2480	First 1/4 correlator	100%		
6.320.2500	Second 1/4 correlator	100%		
6.320.2520	Third 1/4 correlator	100%		
6.320.2540	Fourth 1/4 correlator	100%		
6.325	Second Generation Correlator Design/Prototype			Europe
6.325.2570	Second Generation Correlator Development		100%	
7	Computing Subsystem			
7.340	Computing			Com IPT
7.340.2640	Computer Subsystem Management	63%	38%	
7.340.2660	Computing Hardware	50%	50%	
7.340.2680	Science Software Requirements	44%	56%	
7.340.2700	High Level Analysis & Design	44%	56%	
7.340.2720	Software Engineering	42%	58%	
7.340.2740	Common Software	43%	57%	
7.340.2750	Executive Software		100%	
7.340.2760	Control Software	81%	19%	
7.340.2780	Correlator Software	100%		
7.340.2800	Pipeline Software	65%	35%	
7.340.2820	Archiving	24%	76%	
7.340.2840	Scheduling	100%		
7.340.2860	Observing Preparation & Support		100%	
7.340.2880	Off-line Data Processing/Analysis	70%	30%	
7.340.2890	Data Reduction User Interface		100%	
7.340.2900	Telescope Calibration		100%	
7.340.2920	Integration, Test & Support	53%	47%	
8	System Eng. & Integration			
8.360	System Engineering Management			Sys IPT
8.360.2940	SE&I Management	50%	50%	
8.365	System Engineering Development Support			Sys IPT
8.365.2960	Phase 2 System Engineering	50%	50%	
8.370	Test Interferometer Support			Sys IPT
8.370.2980	ALMA Prototype Antenna Evaluation	50%	50%	
8.370.3000	Prototype ALMA System Integration	50%	50%	
8.375	System Validation, Integration, Acceptance			Sys IPT
8.375.3020	ALMA System Integration	50%	50%	
9	Science			
9.380	Science			Sci IPT
9.380.3040	Phase 2 Science Support	50%	50%	
9.385	Education and Public Outreach			Executives
9.385.3060	North American EPO	100%		
9.385.3080	European EPO		100%	
9.385.3100	Chilean EPO			

Assignment of Deliverables

As stated in Article 2 of ~~this~~the Agreement, NSF and ESO will make equal ~~Value~~value contributions to ALMA with the work equally and equitably shared between them. Therefore,~~using~~ the~~*values* assigned to~~ level-3 tasks, ~~the tasks~~i.e., deliverables, were divided in a manner that (a) led to an equal assignment of value to both sides; (b) led to a division of equal risk to both sides, as measured by contingency~~, to both sides~~; and (c) respected particular institutional experience on both sides. The~~division of values was also informed by the funding schedules planned by both parties over the ten year duration ofthe construction project.~~

~~The resulting division of value~~resulting assignment of deliverables is presented in the WBS for each level-3 task as a percentage division between Europe and North America.~~A Cost Summary sheet, included with the WBS, presents explicitly this same information rolled up to level 1.~~

~~Value: An ALMA Partner executing a particular level-3 task will receive for the successful completion of that task credit for the *value* assigned in the WBS. The Partner has the discretion to carry out the task in the manner the Partner chooses to be in its best interest, but the *value* is not affected by that choice.~~

~~Responsibility:~~ Task responsibility is assigned at WBS level-2. This is noted for each task in the final (right-most) column in the WBS. The level-2 tasks are referred to as work packages that the responsible partner may wish to assign to one of its participating institutions. Each work package is sub~~-~~divided into work elements. These are the level-3 tasks to which value is assigned. Usually the work elements are assigned wholly to one partner or the other. In the case of shared level-3 tasks the division of effort as 100 percent to one side or another is made at a still lower level. This information is given on the individual ALMA Work Element sheets that are not included here.

Schedule of Values

Costs and contingencies were developed for each subtask of the WBS and rolled up as the summed costs of tasks; the task costs were subsequently rolled up as the summed Project cost. The basis for the cost estimates was a bottom-up sum of the costs associated with each subtask of the ~~Project-wide~~project-wide WBS. The European and North American technical leaders, working together, developed estimates for the entire task product tree using a standard~~project-supplied~~ ALMA Cost Data Sheet that asked the technical leaders to provide for each task:

- Task description;
- Task duration (or start and stop dates and predecessor tasks);
- Currency used for materials, supplies and contract expense;
- Basis of the estimate;
- Contingency;
- Staff Effort;
- List of materials and estimated cost of each;
- List of contracts and estimated cost of each;
- Cost parameterization.

Personnel costs are fully burdened costs. That is, the personnel costs include personnel benefits and a percentage of institutional indirect costs. The institutional indirect cost is a uniform percentage derived from the major partner institutions; this is done to make the personnel cost independent of where the work is performed.

Contingency was separately calculated for each subtask. The contingency methodology used was a bottom-up computation of the sum of three separately calculated contingencies. These three contingencies correspond to three different risk factors: the technical risk (how difficult is the task?), the cost risk (what is the uncertainty on the cost?), and the schedule risk (how does this task affect the overall schedule?). Estimators evaluated the technical, cost and schedule risk factors for a particular WBS task and then entered those factors in the ALMA Cost Data Sheets.

The ~~resulting costs and contingencies are shown on the foregoing WBS at level-3. Where the costing estimates were made at a lower level, these were rolled up and displayed at level-3. Three cost columns are shown: the~~value of a level-3 task~~cost, computed as described above, the computed task contingency, and the task *value* which~~ is the sum of the cost and contingency for ~~each task~~
that task. An ALMA partner executing a particular level-3 task will receive for the successful delivery of that task credit for the value assigned in the WBS. The partner has the discretion to carry out the task in the manner the partner chooses to be in its best interest, but the value is not affected by that choice.

~~A summary of project costs by WBS area for the~~A summary of costs (in thousands of FY 2000 dollars), contingencies, and values (in thousands of FY 2002 dollars) by level-1 WBS task for the construction project is given in the following ~~Table. The Table~~table. The table also shows the ~~cost breakdown~~division of values by WBS area ~~for~~between North America and Europe ~~separately~~.

Schedule of Values and Cost Summary for ALMA Phase 2 Construction (Y2000 K$)

	Total Project			North American Tasks			European Tasks		
Level-1 WBS Task	Cost	Contingency	Value	Cost	Contingency	Value	Cost	Contingency	Value
1. Management/Administration	$16,470	5.1%	$17,313	$8,440	5.0%	$8,861	$8,030	5.3%	$8,452
2. Site Development	$61,154	14.6%	$70,049	$23,418	14.4%	$26,787	$37,736	14.6%	$43,262
3. Antenna Subsystem	$198,022	15.0%	$227,739	$96,925	14.8%	$111,299	$101,097	15.2%	$116,440
4. Front End Subsystem	$90,800	20.0%	$108,982	$43,886	21.4%	$53,291	$46,914	18.7%	$55,691
5. Back End Subsystem	$40,777	22.0%	$49,765	$24,004	18.4%	$28,416	$16,773	27.3%	$21,349
6. Correlator	$13,204	12.5%	$14,856	$12,675	12.8%	$14,294	$529	6.2%	$562
7. Computing Subsystem	$29,843	15.5%	$34,468	$15,905	14.4%	$18,199	$13,938	16.7%	$16,269
8. System Eng. & Integration	$18,172	10.8%	$20,125	$9,358	10.4%	$10,335	$8,814	11.1%	$9,790
9. Science	$8,721	5.2%	$9,173	$4,527	5.0%	$4,753	$4,194	5.4%	$4,420
Total	$477,163	15.8%	**$552,470**	$239,138	15.5%	**$276,235**	$238,025	16.1%	**$276,235**