ANNEX A: PROJECT DESCRIPTION

Technical Overview

The Atacama Large Millimeter Array (ALMA) will be built and operated by a bilateral North-American European partnership. It is~~be a~~ a millimeter-submillimeter wave interferometer consisting of 64 12m diameter antennas located on the Chajnantor Altiplano in the Atacama Desert of northern Chile.   ~~To be built by a bilateral North-American European partnership,~~ ALMA will be equipped with dual-polarization receivers covering 4 atmospheric windows: 84 - 116 GHz, 211 - 275 GHz, 275 - 370 GHz~~-~~, and 602 - 720 GHz.

A tabular summary of the instrument's basic characteristics is shown in Table 1. Additional details are as follows:

Site: The site is in a region of the Altiplano in northern Chile known as Zona Chajnantor–Cerro Chascon with approximate coordinates ~~of the ALMA site are~~ 67.75° W, 23.02° S~~. The site~~ at an elevation ~~is slightly more than~~of approximately 5000 m. The site land is administered by the Chilean Ministry of National Assets (*Bienes Nacionales)* and set aside by Presidential decree as a protected region for science. Measurements of the atmospheric transparency and stability made~~,~~ *in situ* continuously since 1995~~,~~ confirm that the site has superior conditions for millimeter-wave~~,~~ and submillimeter-wave astronomy and that it will meet the ~~science~~ requirements ~~for~~ of the ALMA Project.

Antennas and Antenna Configurations: The ~~ALMA~~ antennas are 12 meter-diameter Cassegrain-fed paraboloids, with an aggregate rms surface error < 25μm. Each antenna is fully steerable and designed for rapid position-switching (up to 1.5 degrees in 1.5 seconds); more than 85 percent of the celestial sphere is visible from the Chajnantor site.

The antennas are all movable using -a specially designed antenna transporter among 250 prepared antenna stations. Each station has a concrete foundation to support the antenna and provision for electrical power and data communications. ~~The antennas are moved by a specially designed antenna transporter.~~ Array configurations range from ~150 meters in diameter (for the study of large or low brightness objects) to ~14 km in extent (for the study of small, high brightness objects).

Front End Electronics: Each antenna will be equipped with four receiver cartridges – one for each frequency band – housed in a common 4K cryostat. All detectors are coherent, and rely upon a local oscillator signal phase-locked to an array frequency reference standard. Each receiver cartridge includes two receivers, operating in orthogonal senses of linear polarization. Off-axis from the Cassegrain focus of each antenna, a radiometer tuned to the 183 GHz atmospheric water vapor line will measure the column density of water above the antenna~~; from these data, the phase distortion of astronomical signals passing through the atmosphere to the antenna can be determined a~~ and enable the distorting effects of the water to be removed.

~~The ALMA construction Project will deliver an antenna array capable of meeting the scientific requirements as summarized in Annex B. A summary of the technical description of ALMA as derived from those science requirements is presented in Table 1. A brief description of the key elements is included here.~~

Table 1: ALMA Technical Summary

Array	
Number of Antennas (N)	64
Total Collecting Area ($\pi ND^2/4$)	7238 m^2
Total Collecting Length (ND)	768 m
Angular Resolution	0.2” λ(mm)/baseline (km)
Array Configurations	*{dimension of filled area}*
Compact: Filled	150 m
Continuous Zoom	200-5000 m
Highest Resolution	14.0 km
Total Number of Antenna Stations	250
Antennas[1]	
Diameter (D)	12 m
Surface Accuracy	25 micrometers RMS
Pointing	0.6” RSS in 9 m/s wind
Path Length Error	< 15 µm during sidereal track
Fast Switch	1.5 degrees in 1.5 seconds
Total Power	Instrumented and gain stabilized
Transportable	By vehicle with rubber tires
Front Ends[2]	*{All frequency bands}*
84 - 116 GHz	*-Dual polarization*
211 - 275 GHz	*-Noise performance limited*
275 - 370 GHz	*by atmosphere*
602 - 720 GHz	*-SiS*
Water Vapor Radiometer	183 GHz
Intermediate Frequency (IF)	
Bandwidth	8 GHz, each polarization
IF Transmission	Digital
Correlator	
Correlated baselines	2016 (=64 * 63/2)
Bandwidth	16 GHz per antenna
Spectral Channels	4096 per IF
Data Rate	
Data Transmission from Antennas	120 Gb/s per antenna, continuous
Signal Processing at the Correlator	1.6 x 10^{16} multiply/add per second

[1]The antenna specifications are detailed in Request for Proposals for a Prototype Antenna for the Millimeter Array/Large Southern Array, dated March 30, 1999.

[2]These four frequency bands are those required on the first-light ALMA as specified by the ALMA Science Advisory Committee at the committee meeting of March 11, 2000. Receivers in six additional atmospheric windows are deferred to future development.

Back End Electronics: Signals from each front end receiver will be converted to a common intermediate frequency (IF), amplified, and digitized at the antenna by the backend electronics. In order to process the 8 GHz bandwidth of the IF, the backend electronics will subdivide the IF into four 2 GHz sub-bands for transmission to the correlator.

Correlator: The correlator combines the digitized IF signals from each pair of antennas in the array, and creates astronomical images by Fourier transforming the complex phase and amplitude of the correlated signals. There are up to 2016 possible pairs of antennas in ALMA.

Organization: The system engineering, scientific oversight, and management necessary to coordinate the task activities of the ALMA technical team responsible for production of the ALMA technical system noted above are integral deliverables of the ALMA Project as well. The project safety office is included in the management function and reports directly to the ALMA Director.

Facilities and Infrastructure

ALMA will minimize the number of staff ~~assigned to~~at the 5000m Array Operations Site (AOS), by relying as much as possible upon remote operations. Physical infrastructure at the AOS will ~~therefore~~ consist ~~only~~ of a central electronics and control building, an emergency refuge, and a meteorological building. ~~Only those personnel needed to assure the security of the site, to maintain the backend electronics and correlator at the central electronics building on the array site, those responsible for module exchange (replacing failed instrument modules with spares stored on the AOS), and those whose task it is to transport the antennas for array reconfiguration, will work at altitude. Personnel operating at altitude will be provided oxygen or oxygen-enhanced environments. The array operator and all personnel involved with astronomical observations and maintenance of array instrumentation will be located at ALMA facilities at lower elevation.~~

Other operating staff will be located ~~close to the AOS, but~~ at a lower altitude Operations Support Facility (OSF). Infrastructure at the OSF will consist of the antenna service building, array control building, electronic laboratories, and office, administrative and residential facilities. The OSF will be connected to the AOS by a road constructed to transport the antennas and the operations/maintenance staff, and a communications line of buried optical fibers through which the astronomical data and the instrument monitor data will be carried in real-time~~, and~~ at high bandwidth.