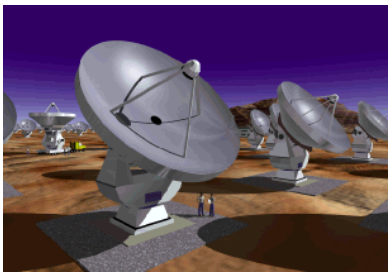

Atacama
Large
Millimeter
Array

ANNEX 1

PROJECT DESCRIPTION

Preliminary Inquiry for the

Design, Manufacture, Transport and Integration on Site

in Chile of the

ALMA ANTENNAS

Issued by: European Southern Observatory, Garching, Germany

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1 INTRODUCTION

The Atacama Large Millimeter Array (ALMA) is an international astronomy facility. ALMA is an equal partnership between Europe and North America, in cooperation with the Republic of Chile, and is funded by the U.S. National Science Foundation (NSF), the National Research Council of Canada (NRC), the European Southern Observatory (ESO), and the Ministries of Science and Technology and of Public Works of Spain. ALMA construction and operations are led on behalf of Europe by ESO, and on behalf of North America by the National Radio Astronomy Observatory (NRAO), which is managed by Associated Universities, Inc. (AUI).

The Array Operation Site (AOS) will be located at an elevation of 5000 meters above sea level on the Chajnantor plateau. The array will be a synthesis radio telescope of 64 antennas of 12m diameter, operating in interferometric mode at millimeter and sub-millimeter wavelengths (0.3 to 10 millimeters). The antennas will be relocated by means of a dedicated transporter between more than 200 stations spread over an area of approximately 20 Km diameter. An assembly and maintenance facility, the Operating Support Facility (OSF) will be constructed near to San Pedro de Atacama.

A Joint ALMA Office (JAO), under a Director, has been established to coordinate and manage the construction and operation of ALMA, which is being carried out jointly by ESO and AUI.

In the first phase of the project ESO and AUI entrusted one industrial group each with the design and the manufacturing of one antenna prototype, based on nearly identical Technical Specifications with the purpose of proving the feasibility and the technologies of the ALMA antennas.

These two prototypes, one designed and manufactured by VertexRSI, and one by the ALCATEL/EIE Consortium are undergoing commissioning and testing at a dedicated facility at the site of the Very Large Array in New Mexico, USA.

ESO and AUI intend to issue two parallel Call for Tenders for the production of the 64 ALMA antennas, whereby 32 antennas will be contracted through AUI and 32 antennas will be contracted through ESO. The antennas may be contracted to a single vendor or to two separate vendors. For scientific purposes and operational reasons it is strongly desirable to have the antenna manufactured according to a single design, even if produced by more than one vendor. The Technical Specifications and the Statements of Work will be identical for both contracts. Contractual terms and conditions will be different given the different rules of ESO / AUI.

The ALMA antennas, here referred to as “antennas” (to distinguish them from the “prototype antennas”), are expected to be based on the design of one of the two prototype antennas currently being tested in New Mexico.

2 CONTENT OF THE CALL FOR TENDER`

The ESO Call for Tender will contain:

- A Statement of Work,
- A Technical Specification for the antennas,
- Requirements for Bidders,
- Technical documentation of the two manufactured prototype antennas.

2.1 TECHNICAL SPECIFICATION

The Technical Specification on which the Contract(s) for the ALMA antennas will be based will be a **functional specification** and not a manufacturing specification based on the blueprint design of one of the two antenna prototypes. It will contain all the functional and performance requirements of the antennas, irrespective of any specific design. It will also include all the requirements related to the interfaces with other ALMA subsystems (receivers, site, etc.).

The Technical Specification is derived from the ones used for the design and manufacturing of the two prototypes. Various modifications were introduced to specific requirements based on the experience gained with the two prototypes. Changes were also introduced at the level of the Interface Control Documents and standards.

A summary of the Technical Specification is given later in the present document.

2.2 STATEMENT OF WORK

The Statement of Work on which the Contract(s) for the ALMA antennas will be based describes the tasks and the deliverables which are expected from the Contractor. It clearly indicates that the Contractor will design the antennas on the basis of a functional performance Technical Specification.

An initial design phase is foreseen in which the Contractor will bring the design proposed in the bid phase to the final design stage. This design phase will terminate with a design review. The first serial antenna is expected to undergo more tests than the following ones, including a more complete acceptance testing. Delivery of the antennas will at the Operation Support Facility (OSF) in Chile, where ALMA will provide a number of dedicated antenna stations. These antenna stations will be used by the Contractor(s) for assembly and testing of the antennas.

More details regarding the Statement of Work are given later in this document.

2.3 TECHNICAL DOCUMENTATION OF THE TWO ANTENNA PROTOTYPES

The detail design of the prototype antennas will be provided in the Call for Tenders in order to allow a potential bidder to choose the basic concept from which the final antenna design will be generated as well as the relevant technologies proposed. (The two prototypes are based on different technologies in a number of key areas).

The general layout design of the prototype antennas is included in appendix to this document.

The design information provided is not sufficient to produce the ALMA antennas and considerable bidder know-how is needed to guarantee conformity to the ALMA antenna Technical Specification. In addition, as mentioned above, significant changes have to be introduced into the prototypes design to make it compliant with the new Technical Specification, ICDs, and Standards.

ESO does not make any statement about the ability of the two antenna prototype design to meet entirely or in part the requirements of the Technical Specification

2.4 REQUIREMENT FOR BIDDERS

A bidder must examine the two antenna prototype designs and critically review their characteristics in order to evaluate their ability to meet the demanded performance, the risk associated with them and the implications on the manufacturing process.

The bidder may select one of the two concepts and further elaborate its design in order to make it fully respondent to the Technical Specification and the associated ICDs. The deviations proposed with respect to the design of the prototype antennas shall be clearly listed and analysed for their technical as well as programmatic (schedule, cost impact, manufacturing risk) implication.

The guideline for the changes proposed by a bidder is that they shall not demand a new campaign of antenna evaluation by the ALMA project. These design modifications will be first reviewed in the technical evaluation of the tenders, and later during the execution of the Contract by means of the engineering review process foreseen by the Statement of Work. The overall antenna design will be verified by the Contractor in order to ensure his ability to meet the specification and by means of the acceptance testing phase of the first antenna to be delivered.

In addition to all supportive technical discussions of the proposed design changes, the bidder will be required to provide in their bid package a number of other documents of technical and programmatic nature (Analyses Tree, Risk register, Manufacturing plan etc…). The list of the documents to be provided will be part of the Call for Tenders.

3 SUMMARY OF TECHNICAL SPECIFICATION

The most relevant requirements are given here, as preliminary information. The requirements of the Technical Specification will likely be organized in two main sections: the System Requirements, namely the requirements which have a direct impact on the scientific performance of the antennas, and the Subsystem Requirements, which are linked to all aspects of performance, including electromagnetic compatibility requirements, reliability, maintainability etc. Standards and guidelines for safety are also imposed in the specification.

A summary of the major System Requirements is detailed in the following sections. The final requirements will be part of the Technical Specification of the CFT.

3.1 MAJOR SYSTEM REQUIREMENTS

3.1.1 Optical configuration

D	Primary Aperture	12.0 m
f_p	Focal Length of Primary	4.80 m
	f_p / D of Primary	0.40
D	Secondary Aperture	0.75 m
	Final f / D	8.00
	Magnification Factor	20.0
θ_p	Primary Angle of Illumination	128.02°
θ_s	Secondary Angle of Illumination	7.16°
2c	Distance between Primary and Secondary Focus	6.177 m
H	Depth of Primary	1.875 m
A	Distance from Elevation Axis to Focus	0.803 m
V	Primary Vertex Hole Clear Aperture	0.75 m

3.1.2 Antenna Mount Requirements

The antennas shall be equipped with an Alt-Azimuth mount:

- Azimuth axis range -270 to +270 degrees from North
- Elevation axis range 0 to 125 degrees
- Maximum keyhole at zenith (blind spot) 0.2 degrees
- Azimuth angular speed and acceleration: $\geq$ 6 deg/s, $\geq$ 24 deg/ s^2
- Elevation angular speed and acceleration $\geq$ 3 deg/s, $\geq$ 12 deg/ s^2
- Alignment error between AZ and EL axes <2 mm, < 1 arcmin

- Redundant drive system, able to operate and stow the antenna up to 20 m/sec wind speed and icing, conditions.
- Antenna to survive earthquakes and other accidental conditions
- Dedicated Interfaces for Antenna Transporter
- Fast motion capability (fast switching, sky mapping etc..)

3.1.3 Surface Accuracy Requirements

A total equivalent antenna surface accuracy of < 25 micrometers root-sum-squared (RSS) during all Primary Operating Conditions (wind up to 9.5 m/sec, during nighttime and daytime and solar irradiation) is required. The error budget will include contributions from both primary reflector and the sub-reflector, and include contribution like panel setting accuracy, ageing, manufacturing accuracy of panels, and atmospheric effects, amongst other.
Prior to delivery the primary reflector surface will have to be set by the Contractor to a reduced level of precision, typically within 100 micrometer RMS.

3.1.4 Antenna Pointing Requirements

The pointing error is defined as the difference between the commanded position of the antenna and the actual position of the main beam of the antenna. Pointing errors are classified as repeatable and non-repeatable.

The repeatable pointing error for the antenna shall not exceed 2 arc minutes.

Non-repeatable pointing error is specified for two different kinds of pointing, “offset” and “absolute” pointing. The “offset” pointing error over a solid angle of 2 degrees radius about the desired position, and within 15 minutes shall not exceed 0.6 arc seconds root sum square (RSS) when tracking an astronomical source at sidereal rate. The non-repeatable pointing error under Primary Operating Conditions for “absolute” pointing shall not exceed 2.0 arc seconds RSS when tracking any astronomical source at sidereal rate.
The non-repeatable pointing error will include the contribution of wind, weighted according to its impingement direction on the antenna.

3.1.5 Path Length Error

Path length errors must be considered since the antennas will be part of an interferometer. Path length or “delay errors” are influenced by the deformation of the antenna under wind, gravity and temperature changes. Delay errors have a repeatable and a non-repeatable component.
The repeatable residual delay is caused by the difference in gravity deformation between the antenna and the nominal antenna (alignment errors, bearing run-out, etc….) which repeat as a function of antenna position and can be corrected using a computer delay model. The repeatable residual delay is limited to 20 micrometers when the antenna moves between any two points 2 degrees apart in the sky.

The non-repeatable delay varies with time and it is not function of the antenna position. It is caused by atmospheric effects, hysteresis, friction etc. The non-repeatable residual delay is limited to 15 micrometers RSS when tracking an astronomical source at sidereal rate.

3.1.6 Solar Observations

Continuous, direct observations of the sun shall be possible while meeting all performance specifications. The primary reflector surface will have a suitable surface treatment to prevent solar heating damage to any part of the antenna. The specification sets also a limit to the maximum power absorbed by a black body anywhere in the secondary focal region in case of sun observation (<0.3 W/cm$^{2)}$.

3.1.7 Transportability

The antennas shall be specifically designed to be transportable by a dedicated transporter which is used both for the transport from the Operation Support Facility to the Array Operation Site, and for the periodical array reconfiguration. Specific interface and functional requirements will be provided in an ICD.

4 SUMMARY OF THE STATEMENT OF WORK

4.1 TASKS OVERVIEW

The tasks associated with the design and development, manufacturing, transport, testing, and delivery of the contracted number of antennas to the ALMA OSF site in Chile have been globally distributed into phases. (Unit #n refers to the nth unit to be delivered). A preliminary summary of the task organization is given here.

For Unit #1:

Phase A: To elaborate and develop the antenna design proposed during the bid phase in order to make it fully compliant with the Technical Specification. This phase will terminate with a Design Review (Pre-Production Review) in which the overall design will be reviewed by the ALMA Project Office.

Phase B: In this phase the Contractor will manufacture the first antenna according to the reviewed design. The Contractor will perform system and subsystem tests as he deems necessary to guarantee the compliance of the final performance of the antennas to the Technical Specification.

Phase C Transport of the Unit #1 to the OSF site in Chile an incoming inspection shall be performed upon arrival on site of the major antenna parts.

Phase D: During this phase the antenna is assembled, aligned and tested at the OSF. This phase ends with an assembly & inspection point in Chile, which allows the Provisional Acceptance testing to start.

Phase E: During this phase all the testing activities related to the Provisional Acceptance of the first antenna (Unit #1) are performed at the OSF in Chile.

Phase F: This is the period from Provisional Acceptance until the guarantee period expires and Final Acceptance is granted.

For the following units:

It is expected that the amount of testing performed for Units #2 to #N will be reduced compared to Unit #1. Individual subsystems will have nevertheless to be inspected, tested, and accepted by the Contractor in order to guarantee that possible non conformities of equipment are detected to the extent possible prior to shipment to the OSF in Chile.

The following phases are defined in conjunction with Units #2 to Unit #N:

Phase Bn: Manufacturing the Unit #n

Phase Cn: Transport to the OSF of Unit #n

Phase Dn: Assembly at the OSF site. Each phase Dn ends with an assembly & inspection point, allowing Provisional Acceptance testing to take place.

Phase En: This phase is constituted by the testing activities related to the Provisional Acceptance of Unit #n. A simplified Acceptance Testing program is foreseen compared to that of Unit #1.

Phase Fn: This phase is the guarantee period for Unit #n.

4.2 TECHNICAL MILESTONES

The following technical milestones are foreseen at the present time:

T0	Start of Contract (or kick-off meeting)
PPR	Pre-Production Design Review
AIPC1	Assembly and Inspection Point in Chile Unit #1
PACC1	Provisional Acceptance Unit #1
FACC1	Final Acceptance of Unit #n

4.3 PLANNING AND SCHEDULE REQUIREMENTS

The information about the schedule available at the time being is the following (baseline 64 antennas):

- It is expected that the first antenna shall be delivered at the OSF approximately 18 months after start of the Contract.
- The second antenna is planned approx. 4 months after the delivery of the first antenna.
- The following antennas (3 to 64) are expected to be delivered at the rate of approximately one per month.
- The final antenna (n=64) is expected to be delivered at the OSF during the first quarter of 2011.

5 ATTACHMENTS

- Photograph of the Prototype antennas at the VLA site in New Mexico
- ALCATEL/EIE Antenna Layout
- VertexRSI Antenna Layout