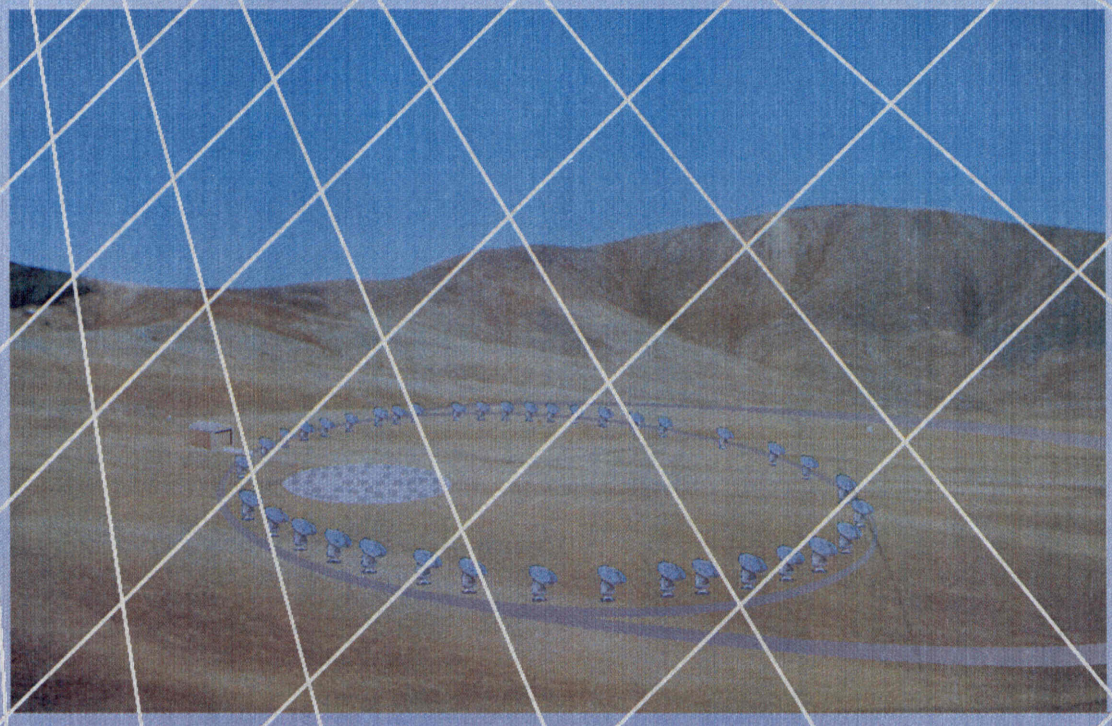
ATACAMA LARGE MILLIMETER ARRAY

U.S. Prototype Antenna Purchase Order

2000-February-18



NATIONAL RADIO ASTRONOMY OBSERVATORY
A facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

ATACAMA LARGE MILLIMETER ARRAY

U.S. PROTOTYPE ANTENNA PURCHASE ORDER

2000-FEBRUARY-18

NATIONAL RADIO ASTRONOMY OBSERVATORY

The National Radio Astronomy Observatory is a Facility of the National Science Foundation Operated Under Cooperative Agreement by Associated Universities, Inc.

PURCHASE ORDER

PAGE NO.	1
DATE	2/18/00
ORDER NO.	**204186**
DEPT. NO.	

VENDOR

VERTEX ANTENNA SYSTEMS, LLC
2211 LAWSON LANE
SANTA CLARA CA 95054

SHIP TO

ASSOCIATED UNIVERSITIES, INC.
NATIONAL RADIO ASTRONOMY OBSV
VERY LARGE ARRAY SITE
50 MILES WEST OF SOCORRO, NM
SOCORRO NM 87801-0387

DATE ORDERED	02/22/00	REFERENCE	
DATE REQUESTED	10/20/01	TAKEN BY	W.PORTER
SHIP VIA	FOB - ORIGIN		

SEND INVOICES TO

ASSOCIATED UNIVERSITIES INC.
NATIONAL RADIO ASTRONOMY OBSERVATORY
520 EDGEMONT ROAD
CHAROTTESVILLE, VA 22903-2475

(804) 296-0313 Voice
(304) 456-2271 Fax-Accounts Payable
(804) 296-0226 Fax-Purchasing

STOCK NO.	DESCRIPTION	QUANTITY	U/M	UNIT PRICE	EXTENDED PRICE
	***** FIXED PRICE AGREEMENT *****				
	ALMA U.S.PROTOTYPE ANTENNA	1	EA	6,061,447.0000 EA	6,061,447.00
	DESIGN, FABRICATION, SHIPPING, ERECTION, ALIGNMENT, AND ACCEPTANCE TESTING OF THE ALMA U.S. PROTOTYPE ANTENNA.				
	LASER METROLOGY DESIGN	1	EA	96,000.0000 EA	96,000.00

* THE FOLLOWING ATTACHMENTS ARE PART HEREOF:
* ATTACHMENT A - SPECIFICATIONS AND STATEMENT OF WORK
* ATTACHMENT B - TERMS AND CONDITIONS
* ATTACHMENT C - RELEASE OF CLAIMS
* ATTACHMENT D - GLOSSARY

DIRECT ALL CORRESPONDENCE TO:
ALMA U.S. Business Manager
Associated Universities, Inc.
National Radio Astronomy Observatory
520 Edgemont Road
Charlottesville, VA 22903-2475

** TERMS:PROGRESS PAYMENTS,10% RETAINAGE,& BALANCE 30 DAYS

Acknowledged and Accepted by Vertex Antenna Systems, LLC:

Louis E Bleeker
Signature

President — 2/22/00
Title — Date

204186

12003.3030.03

TERMS	AUTHORIZED SIGNATURE	DATE	TOTAL AMOUNT OF ORDER
Progress Payments		2-21-00	6,157,447.00

TABLE OF CONTENTS

ATTACHMENT A

ATTACHMENT A

SPECIFICATIONS AND STATEMENT OF WORK

[This Attachment A is numbered consistently with Section 3 of the "Request for Proposals for a Prototype Antenna for the Millimeter Array/Large Southern Array (MMA/LSA)" dated 1999 March 30.]

3.1 STATEMENT OF WORK

3.1.1 GENERAL STATEMENT OF WORK AND SCHEDULE

The work described herein shall consist of the furnishing of labor, materials, services, drawings, data, detailed specifications, test documents, and other items required for the detailed design, manufacture, assembly on site, alignment, and testing for a prototype antenna for the Atacama Large Millimeter Array (ALMA) radiotelescope, in accordance with the following specification and Vertex Antenna Systems (VAS) Proposal No. SYS859, Rev. B, dated December 23, 1999 incorporated herein by reference.

The incorporation of the Contractor's Proposal into this contract is for the purpose of establishing the Contractor's general approach, management organization, and understanding of the National Radio Astronomy Observatory (NRAO) specification referenced above.

The incorporation of the Contractor's documents into this contract shall not be interpreted to mean or imply approval by Associated Universities, Inc., (AUI) of any design, engineering, manufacturing, or testing techniques, methods, or materials described in those documents.

The Contractor accepts total responsibility for the design and performance of the total antenna system. Any data furnished by AUI on its design concept does not affect the specified requirements nor can any AUI-supplied information be construed to form a basis for present or future Contractor's cost claims. The Contractor understands and agrees that any AUI design concept data was presented as information only and any use by the Contractor of any AUI-specified information is at the Contractor's risk.

The prototype antenna shall be delivered twenty (20) months following contract authorization to proceed in general agreement with the Vertex schedule proposal, which will be refined and presented to AUI within 15 business days following contract award.

3.1.2 OBJECTIVES OF THE PROGRAM

The ALMA radiotelescope is currently intended to consist of a goal of 64 identical 12 m diameter antennas to be built on a remote, high-altitude site in Northern Chile. A prototype of this 12 m antenna will be extensively tested by AUI and European Southern Observatory (ESO) at a test

site in the United States of America (USA) to ensure that it meets all requirements before the production phase of the project is initiated. The six primary objectives of this program concern the design, technology testing, fabrication, assembly, acceptance testing, and production planning of this prototype 12 m diameter antenna, including both primary and secondary reflectors as follows:

1. Design

The important features of the prototype antenna design include the following:

(a) A design that meets the operating parameters and requirements set forth in this specification. The key performance parameters are reflector surface accuracy, pointing accuracy, path length stability and fast motion performance. With respect to fast motion performance, the design should take into account ways of reducing the electrical power required to accelerate the antenna at its maximum acceleration rate so as to minimize the demand on the site power system when all antennas accelerate together.

(b) A design that satisfies the requirement that the antenna be transportable between foundations. The Contractor will perform a mass optimization of the antenna structure to minimize the total mass of the antenna as much as is reasonable while still meeting all performance specifications.

(c) A design that is optimized for production of a quantity goal of 64 units, taking advantage of economies that may be realized by maximum duplication and standardization of parts, use of tooling to minimize labor, and simplification of assembly effort. Since assembly of the future planned production run of antennas will take place at a remote location in Northern Chile, the antenna will be designed for manufacture and shipping in such modules as will minimize shipping and assembly costs to the extent possible.

(d) A design that takes into consideration ease of maintenance and the reliability of components to minimize maintenance and for which the major components of the antenna such as the mount structure, the azimuth and elevation bearings, the drive systems, the reflector backup structure and the reflector surface have a lifetime of 30 years in the environmental conditions expected to prevail at the Chilean site.

2. Technology testing

The Contractor may elect to use technology on the 12 m diameter antenna that has not been previously demonstrated in a similar application. Prototype specimens of any critical technology which is used in the antenna and which has not been previously demonstrated in a similar application shall be fabricated and tested prior to building the technology into the prototype antenna. For example, such technology could include, but would not be limited to, high precision reflector panels, novel methods for joining carbon fiber reinforced plastic (CFRP) elements of the reflector backup structure, metrology for measuring mount deformations or high-accuracy angle encoders. The Contractor shall perform testing of a single pie section of the CFRP backup structure (BUS), and the fully assembled BUS, with gravity and thermal loading to verify that the section performs as predicted by the finite element analysis (FEA) modeling of that section.

3. Prototype antenna fabrication

A prototype antenna will be fabricated according to the Contractor's Design. Since AUI plans to thoroughly test this prototype to verify that it meets all performance requirements before initiating the production phase of the project, it is important that the performance of this prototype antenna be the same as production antennas built to the same design.

4. Antenna assembly and alignment

The prototype antenna will be assembled and aligned at the ALMA test site in New Mexico, according to the specifications and procedures set forth during the design stage.

5. Acceptance testing

The Contractor will perform acceptance tests according to the acceptance documents prepared in the design stage to establish that the antenna meets the specified performance requirements. Some aspects of the antenna performance will be accepted based on the results of calculations (see Section 3.9.4.3).

6. Production planning

The Contractor shall deliver a Manufacturing Plan and On-Site Erection Plan for the production antennas and an updated production cost estimate. The production plans and cost estimate will be revised, and updated versions of the plans and cost estimate submitted, based on the experience gained in performing the prototype manufacturing and erection. The Contractor, after delivering the prototype antenna, will present a binding firm fixed price for the production antennas in response to a formal request for quote (RFQ) for production antennas to be issued by AUI. AUI reserves the right to seek pricing from other antenna suppliers, and to award the production contract to a firm other than the prototype contractor. Any pricing submitted by the Contractor shall be kept confidential from other potential contractors until the final selection is made.

3.1.3 Summary List of Contractor Deliverables

Item	Schedule	Reference
Initial Project Schedule	15 business days after contract award	SC5
Project Manpower Schedule	15 business days after contract award	SC6
Project Breakdown for Scheduling and Payment	15 business days after contract award	SC11
Submit Drafting Standards for Approval	15 business days after contract award	3.9.1
Current FEA Model	1 month after contract award, updated monthly	3.9.2

Item	Schedule	Reference
Updated Project Schedule	5th day of each month	SC7
Status Report	5th day of each month	SC10
Preliminary Design Review (PDR) Information Package	2 weeks prior to PDR	3.1.4
PDR	Project schedule	3.1.4
Critical Design Review (CDR) Information Package	2 weeks prior to CDR	3.1.5
CDR	Project schedule	3.1.5
Gravitational Deformation Calculations	CDR	3.9.2
Eigenfrequency and Eigenmode Calculations	CDR	3.9.2
Structural Calculations for Wind Loading	CDR	3.9.2
Structural Calculations for Thermal Loading	CDR	3.9.2
Pointing Error Budget	CDR	3.9.2
Reflector Surface Error Budget	CDR	3.9.2
Path Length Error Calculations	CDR	3.9.2
Servo Analysis	CDR	3.9.2
Dynamic Analysis of Fast Switching	CDR	3.9.2
Dynamic Analysis of Application of Brakes at Full Velocity	CDR	3.9.2
Structural Fatigue Analysis	CDR	3.9.2
Metrology Analysis	CDR	3.9.2
HVAC System Calculations	CDR	3.9.2
CFRP Properties Definition Document	CDR	3.7.2
CFRP Process Control Definition Document	CDR	3.7.2
BUS Connection Joint Analysis	CDR	3.9.2
Antenna Stress Analysis	CDR	3.9.2

Item	Schedule	Reference
Foundation Design Analysis and Three Foundation Designs	CDR	3.5.3
Grounding Counterpoise Design and Analysis With Impedance Calculations for All Grounding Wires	CDR	3.9.2
Seismic Survival and Transporter Analysis	CDR	3.3.2.5
High Altitude Cooling Analysis of All Electrical Components	CDR	3.9.2
Compliance Analysis for All AUI Interfaces	CDR	3.6
Antenna Disassembly Plan	CDR	3.5.10
Antenna Assembly Plan	CDR	3.9.4.1
Antenna Alignment Plan	CDR	3.9.4.1
Acceptance Test Procedures	CDR	3.9.4.3
Corrosion Resistance Plan, Specification for Solar Reflecting Paint and Results of Accelerated Tests	CDR	3.7.4
Results of Technology Testing	CDR	3.1.2
List of Supplier's MTBF and Lifetime Specifications	CDR	3.5.9
RFI/EMI Plan	CDR	3.5.7
Complete Design Documentation (CDD)	Project schedule	3.1.6
Operations and Maintenance Manuals	CDD	3.9.6
Quality Assurance Plan	CDD	3.9.5
Spare Parts List	CDD	3.9.7
Initial Updated Production Cost Estimate	CDD	3.1.2
Final Design Approval	Project schedule	3.1.6
Antenna Fabrication	Project schedule	3.1.2
Antenna Assembly and Alignment	Project schedule	3.1.2

Item	Schedule	Reference
Acceptance Testing	Project schedule	3.1.2
Control Hardware and Software Documentation Including Complete Source and Object Code to Control/Monitor Antenna	At time of antenna delivery	3.5.6.5
Updated Plan for Production Phase	1 month after antenna delivery	3.1.2
Firm Fixed Price for Production Antenna	1 month after antenna delivery	3.1.2
As-Built Drawings and Updates of Documentation	1 month after antenna delivery	3.9.1

3.1.4 PRELIMINARY DESIGN REVIEW (PDR)

Contractor should anticipate receiving direction from AUI at the PDR that will require Contractor to perform additional design work at no additional cost to either further demonstrate proof of concept, or to redesign areas that AUI does not approve as indicated in (a) below. Material to be reviewed at the PDR shall include:

(a) Control and software: General design of control and software including full hardware architecture, electronics interfaces, and hardware/software standards. Areas requiring feasibility work shall be identified. Software analysis shall be done at the level corresponding to functional specifications, showing compliance with the corresponding ICD. This should also include analysis of startup/shutdown procedures and explain how maintenance/repairs can be assisted by software procedures. A preliminary list of error/alarm conditions should exist, in particular conditions leading to shutdown or stow conditions shall be analyzed. Control algorithms shall be available. Definition of local user interfaces. The expected documentation shall cover as a minimum the areas of software architectural design, and functional specifications and control design.

(b) General Proof of Concept: The design shall be developed to the level that the feasibility, performance, manufacturability, reliability and maintainability of all structural, mechanical, electrical and control design of the antenna are proven.

(c) Proof of Performance: Contractor shall present data and design information to demonstrate that all of the Contract performance specifications will be achieved with the design presented.

(d) Survivability: Contractor shall present data and design information to demonstrate that the design presented will survive the survival conditions presented in Section 3.3.2.5.

(e) Design Performance: Contractor shall develop a system level FEA model to allow the static, dynamic, and thermal design performance to be determined. The model shall include all components that influence the structural performance of the design, including the compliance of bearing, drives, non-intersecting structural joint members, stress stiffening, foundations and soil properties. Contractor shall clearly indicate the basis for selection of the stiffness values used to model mechanical components of the design such as bearings, drives, etc. The model shall be used to verify the performance of the antenna under the operating conditions defined in Section 3.3.2.2. Contractor shall clearly identify all structural components that are designed to operate with stresses that exceed the infinite lifetime fatigue limit during normal operating conditions. Contractor shall present error budgets for reflector surface accuracy, pointing performance and path length errors and shall present results of analysis to demonstrate that the error budgets are achievable. Special attention will be given to any metrology provided to allow active correction of reflector surface, pointing or path length errors. Contractor shall present results of analysis of the control and drive system to demonstrate that fast motion performance requirements are achievable.

(f) Design Layout: Contractor shall provide a full assembly drawing and drawings of all sub assemblies to clearly indicate the design configuration of the design. The drawings shall include details of all structural connections necessary to meet the transportability requirements of the Contract. Contractor shall provide mass estimates accurate to 10 percent for all antenna components. Contractor shall provide preliminary wiring diagrams. Contractor shall provide performance data and engineering calculations for all selected components. Contractor shall provide catalog information for all selected major mechanical components (metrology, drive motors, brakes, encoders, bearings, HVAC, etc.).

(g) Material Selection: Contractor shall fully specify material properties for all major structural components. Contractor shall supply specifications of materials and processes required for the fabrication of any CFRP component. Contractor shall construct and test a representative full size connection of the backup structure (BUS) and test structural integrity of the connection. Results of these tests are to be presented at the PDR.

(h) Interface Definition. Contractor shall demonstrate that all of the interfaces defined in the specifications have been incorporated, or can readily be incorporated, into the design.

(i) Maintainability: Contractor shall present procedures for preventative and corrective maintenance for all major mechanical components, including, but not limited to, bearings, drive motors, encoders, and brakes, to demonstrate that provisions have been incorporated into the design to allow these procedures to be performed efficiently and safely.

(j) Risk Management: Contractor shall identify and list all aspects of the design that represent a risk to achieving completion of the design, manufacture, and site assembly of the antenna, on schedule, and to budget, and at the same time, meeting all Performance Requirements.

(k) Manufacturability: Contractor shall demonstrate that all aspects of the design can be manufactured.

(l) Code Compliance: Contractor shall demonstrate that the design will meet all applicable codes.

(m) Production Run: Contractor shall present aspects of the design that are well suited, or may present problems, to achieving economic quality production of 64 antennas over 8 years. Contractor shall present any special requirements that will be required to achieve product assurance during the production run.

(n) Within 2 weeks of the completion of the PDR, AUI will provide Contractor with a list of aspects of the design that:

(a) require additional engineering to clearly demonstrate Proof of Concept, or

(b) require redesign because the rejected aspects of the design will not meet the requirements of the specification. For any work that AUI requires redesigning, AUI will provide detailed written explanations of why the rejected aspects of the design will not meet the specified requirements

Contractor will incorporate all of the comments made by AUI into the PDR documentation and present the modified PDR documents to AUI for approval before starting work for the CDR

3.1.5 CRITICAL DESIGN REVIEW (CDR)

The material to be reviewed at the CDR will include, but will not be limited to:

1. The final antenna design.
2. Final versions of all material presented in preliminary form at PDR.
3. Final versions of all of the analysis, error budgets and plans and procedures listed in Table 3.1.3 for delivery at the CDR.
4. Final results of any technology testing.
5. Final antenna foundation design analysis and drawings in sufficient detail to allow AUI's foundation subcontractor to construct the foundation at the US test site.
6. Control and software deliverables. Computer architecture and control electronics updated from PDR and finalized. Software details design, including exact list of commands and syntax. Completion of feasibility studies foreseen at PDR. Exact definition of control algorithms (possibly updated from PDR). Minimum documentation shall include: preliminary user manual, and final ICD version (subject to agreement with AUI), detailed design documentation, modular/integration test plans and procedures, acceptance tests.

Within 2 weeks of the completion of the CDR, AUI will provide Contractor with a list of aspects of the design that require redesign. For any work that AUI requires to be redesigned, AUI

will provide detailed written explanations of why the rejected aspects of the design will not meet the specified requirements. This work will be provided at no additional cost to AUI.

Contractor will incorporate all of the comments made by AUI into the CDR documentation and present the modified CDR documents to AUI for approval before starting work for the Complete Design Documentation package.

3.1.6 Complete Design Documentation (CDD)

The Complete Design Documentation package is the final deliverable product of the Design Phase of the antenna. It will contain sufficient drawings (including shop fabrication drawings), specifications, plans, procedures and manuals to allow the antenna to be fabricated, assembled, tested and maintained, including full information of all interfaces to AUI equipment and computers.

Within 2 weeks of the completion and delivery of the CDD, AUI will provide Contractor with a list of aspects of the package that require additional information. For any area that AUI requires additional work, AUI will provide detailed written explanations of why additional information is needed.

Contractor will incorporate all of the additional information required by AUI into the CDD and present the modified CDD documents to AUI for approval before starting work on the fabrication of the antenna, except for specific long-lead items which may be approved by AUI. This work will be provided at no additional cost to AUI.

3.2 Applicable Documents

The following documents (current version as of issue date of Contract) are to be used as a guide in the preparation of the design. The development of the required additional configuration and detailed design drawings and specifications supplementing and extending these documents are a part of the effort required in the design stage. In the event of a conflict between this specification and any of the documents listed, this specification shall govern:

1. Electronic Industries Association TIA/EIA-222-F- Structural Standards for Steel Antenna Towers and Antenna Supporting Structures

2. American Institute of Steel Construction - Manual of Steel Construction

3. National Fire Protection Association, National Electrical Code

4. MIL-STD-461A. - Electromagnetic Interference

5. "Analysis Concepts for Large Telescope Structures under Earthquake Load," by F. Kock, in Proc. SPIE 2871, 117-126 (1997).

6. Occupational Safety and Health Administration - Workplace Safety Regulations & Index, 29CFR1926 and 29CFR1910.

7. ANSI Y14.5M-1994 "Dimensioning and Tolerancing."

8. MMA Antenna VLA Site, New Mexico, Geotechnical Engineering Services, Job No. 1-90402, May 13, 1999.

9. "Geotechnical Feasibility Report (Rev. B), MMA Project, National Radio Astronomy Observatory," Geo Consultores Grupo G.A., September, 1999.

10. ANSI Z136.1-1993, "American National Standard for Safe Use of Lasers."

11. ALMA ICD No. 1 "Antenna/Receiver Interface, Version A."

12. ALMA ICD No. 2 "Antenna/Apex Interface, Version A."

13. ALMA ICD No. 3 "Antenna/Site Electrical Power Interface, Version B."

14. ALMA ICD No. 4 "Antenna/Site Foundation Interface, Version A."

15. ALMA ICD No. 5 "Antenna/Transporter Interface, Version A."

16. ALMA ICD No. 6 "Antenna/Cable Wrap Interface, Version A."

17. ALMA ICD No. 7 "Antenna/Helium Compressor Interface, Version A."

18. ALMA ICD No. 8 "Antenna/Optical Pointing Telescope Interface, Version A."

19. ALMA ICD No. 9 "Antenna/Monitor and Control Interface, Version A."

20. ALMA ICD No. 10 "Antenna/Receiver Cabin Equipment Rack Interface, Version A."

21. ALMA ICD No. 11 "Basic Antenna Definitions, Version A."

3.3 Design Parameters

3.3.1 Configuration

The operating frequency range of the antenna will be 30 GHz to 950 GHz. The antenna will be a symmetric paraboloidal reflector, of diameter 12 m, mounted on an elevation over azimuth mount. The overall optical layout of the antenna will be a Cassegrain geometry, as shown in Appendix A. The subreflector support legs will be a quadripod configuration.

The primary reflector surface will consist of machined aluminum panels. The reflector surface will not be painted but must have a suitable surface finish to enable the solar observing requirement (see Section 3.4.7) to be met. The reflector surface will be mounted on a carbon fiber reinforced plastic (CFRP) reflector backup structure (BUS). The BUS may be built completely of CFRP or may consist of CFRP struts connected by metal nodes.

There is no requirement that the elevation and azimuth axes of the mount intersect, although there is a requirement regarding how closely the axis offsets must match among antennas built using the design (Section 3.4.1).

The antenna will be bolted to a reinforced concrete foundation buried in the ground. The Contractor shall design the foundation (see Section 3.5.3 below) and the interface between the foundation and the antenna. AUI will be responsible for the construction of the foundation.

The antenna shall be designed for a lifetime of 30 years in the environment expected to prevail on the Chilean site. During its lifetime the antenna will execute not less than 270,000 complete cycles of elevation motion, where a complete cycle of elevation motion is here defined to be movement of the reflector from its lower elevation limit up to its upper elevation limit and back down to its lower elevation limit. During its lifetime the antenna will execute not less than 200,000,000 degrees of total motion about each axis.

All drawings shall have metric units in general as the primary units with non-metric units, if they are required, being provided as secondary units. All fasteners will be metric; however, allowances may be made for fasteners that are on off-the-shelf units. The use of standard metric cross-sections for construction materials is preferred but will not be required if such use results in increased cost.

The antenna will be designed to operate on supply voltages of 230 VAC single phase, 400 VAC three phase. The Chilean supply frequency is 50 Hz but AUI plans to test the prototype antenna in the U.S. using a supply frequency of 60 Hz. All electrical equipment on the antenna shall be designed to operate correctly using both 50 Hz and 60 Hz supply frequencies. AUI will provide the transformer required at the U.S. test site to convert from U.S. to Chilean voltages.

3.3.2 Operating Parameters and Conditions

3.3.2.1 General Operating Conditions and Parameters

The antennas will operate on a high altitude (5000 m) volcanic plateau in Northern Chile (latitude -23d 01m S, longitude 67d 45m W). The average barometric pressure at this altitude is 55 percent of its sea level value. The site ground surface is principally volcanic soil and gravel with no vegetation of any kind to stabilize the surface, so the antenna must be designed to withstand windblown dust and grit. The annual 50th, 75th and 95th percentile winds on the site are respectively 6.5 m/s, 10.4 m/s and 17 m/s. The annual median temperature is -2.5 C.

Annual precipitation on the site is in the range 100 mm to 300 mm. Most of this falls as snow but thunderstorms do occur. The antenna must be designed to withstand brief periods of heavy rain and hail. The monthly average humidity in the summer (January) is 53 percent and in the winter (June) it is 31 percent. The annual average humidity is 39 percent. The monthly average water vapor pressure in the summer (January) is 4.0 hPa (4 g/cm^2) and in the winter (July) it is 1.2 hPa. The annual average water vapor pressure is 2.3 hPa.

The site location on the southern tropic, the high altitude and low water vapor result in insolation rates among the highest in the world. The median midday solar flux in the wavelength range 0.3-60 micrometers for the months of December and June are 1290 w/m^2 and 840 w/m^2 respectively. Ultraviolet radiation will be approximately 70 percent higher than at sea level.

3.3.2.2 PRIMARY OPERATING CONDITIONS

For the purpose of computing the performance of the antenna (see specifications below) the Contractor shall assume the following conditions:

Gravity: Elevation angle range 2 deg to 90 deg.

Temperature: ambient temperature -20 C to +20 C.

Wind and thermal:

Daytime: 6 m/s average wind, spectral content to be obtained by scaling the Simiu spectrum, S(u), shown in Figure 3.3.2.2-1. Equivalent wind speed, including the effect of wind gusts, to be used for quasi-static calculations, shall be 6.4 m/s. For dynamic calculations, two cases are to be analyzed: 6 m/s average wind with variable component S(u); 6 m/s average wind with variable component 4*S(u).
full solar heating from any direction (assume no reduction in structure temperature gradients due to wind)
change in ambient air temperature in 10 minutes 0.6 C
change in ambient air temperature in 30 minutes.1.8 C

Nighttime: 9 m/s average wind, spectral content is the Simiu spectrum, S(u), shown in Figure 3.3.2.2-1. Equivalent wind speed, including the effect of wind gusts, to be used for quasi-static calculations, shall be 9.5 m/s. For dynamic calculations, two cases are to be analyzed: 9 m/s average wind with variable component S(u); 7 m/s average wind with variable component 4*S(u). Assume that all parts of the antenna are at the same constant temperature.

Precipitation: no precipitation

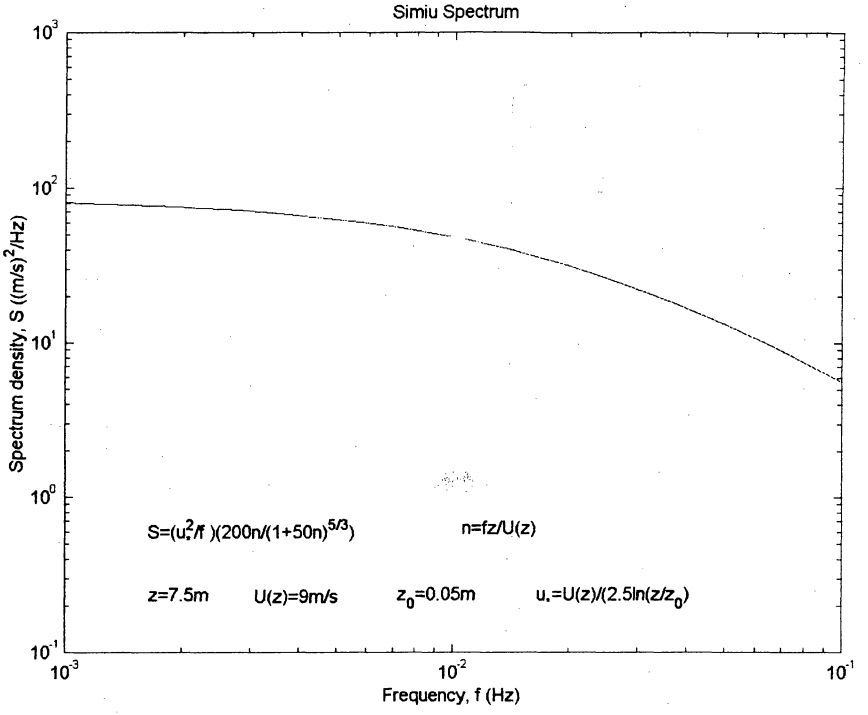


Figure 3.3.2.2-1. Wind Spectrum for MMA Site, 9 m/s average wind speed.

3.3.2.3 SECONDARY OPERATING CONDITIONS

Observations with the antenna will continue to be possible under the following conditions. It is understood that performance will be degraded.

Gravity: Elevation angle range 2 deg to 125 deg
Temperature: ambient temperature -20 deg C to +40 deg C
Wind: wind up to 20 m/s
Precipitation: no precipitation

3.3.2.4 STOW CONDITIONS

The antenna will be stowed under the following conditions:

Temperature: temperature below -20 C. It shall be possible to drive the antenna to stow when the ambient temperature is in the range -25 deg C to +40 deg C.

Wind: wind greater than 20 m/s. It shall be possible to drive the antenna to stow when the wind is in the range 0 to 30 m/s with a single drive motor operating on either axis.

Precipitation: the antenna will be stowed if it is raining, snowing or if ice accumulation is occurring. It shall be possible to drive the antenna to stow in a rainfall rate of 2 cm/hr, with a snow accumulation of 50 kg/m^2 in the reflector or with an ice load of 1 cm radial ice on all exposed surfaces.

3.3.2.5 SURVIVAL CONDITIONS

The antenna must survive without damage, and continue to meet all performance specifications after experiencing, the following conditions:

Earthquake: 0.3G horizontal or 0.3G vertical acceleration, antenna in any position. For analysis purposes the Contractor will use the Acceleration Response Spectrum for the Maximum Likely Earthquake shown in Figure 3.3.2.5-1. The definition of this spectrum is provided in Document (5) of Section 3.2. The Contractor will use the analysis method of Document (5), or an equivalent method, to analyze the seismic performance of the telescope.

Transporter Handling (antenna is in zenith position): accident during set-down on the foundation, 4-G vertical impact on the antenna base of short duration; accident during transport on transporter, 2-G horizontal impact on the antenna base of short duration. Antenna to survive three of each impact loading events during the 30 year life.

Braking: activation of the azimuth or elevation brakes when the antenna is moving at its maximum velocity (3 deg/s elevation velocity, 6 deg/s azimuth velocity—see Section 3.4.4), antenna in any position.

Wind: 65 m/s with the antenna in the stow position with elevation and azimuth stow pins in, wind from any azimuth.

Temperature: -30 C, antenna in stow position.

Precipitation: maximum rate of rainfall 50 mm/hr, hailstones 2 cm diameter with velocity 25 m/s, radial ice on all exposed surfaces 1 cm, all with the antenna in any orientation. Snow load 100 kg/m^2 on reflector surface, with antenna at zenith. Reflector surface heating to prevent snow and ice buildup not required. The ice loading and survival wind conditions are to be survived simultaneously.

Lightning: direct lightning strike, lightning protection required as qualified in Table 8.1 of the Vertex proposal. Antenna in any orientation.

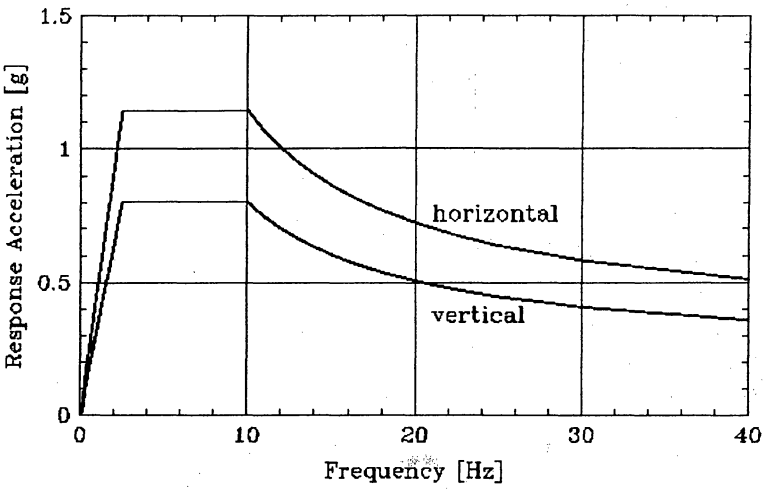


Figure 3.3.2.5-1. Acceleration Response Spectrum for Maximum Likely Earthquake.

3.4 ANTENNA PERFORMANCE

3.4.1 MOUNT REQUIREMENTS

The allowable observing range of motion of the antenna in azimuth will be 270 degrees on either side of due north and in elevation it will be 2 degrees to 125 degrees. The keyhole at the zenith in which tracking at sidereal rate is not possible will have a radius of less than 0.2 degrees. Prelimits and final limits will be beyond this range. As well as hardware prelimits and final limits a software prelimit will be provided. Positions of the prelimits and final limits will be chosen so as to stop the antenna before the final limit if it enters the prelimit moving at its maximum velocity. Passive elevation and azimuth energy absorbing hard stops will be provided to protect all parts of the antenna from damage beyond the elevation and azimuth final limits. Stow position for Survival Conditions will be 15 degrees elevation, 90 degrees azimuth. Maintenance stow position will be 90 degrees elevation, 90 degrees azimuth. Computer commanded stow pins for both azimuth and elevation shall be provided for both survival and maintenance stow positions.

The height of the antenna pedestal shall be such that the edge of the primary reflector in no case will be closer than 1 meter to ground or to the level of the upper surface of the foundation.

The azimuth and elevation axes do not need to intersect but the offset between the axes must be very nearly the same for all antennas built using the design, so the offset between the axes shall be set to the nominal design value to within +/- 3 millimeters. The azimuth and elevation axes shall be orthogonal to within 1 arcminute. The axis of symmetry of the primary reflector shall intersect the elevation axis to within +/-3 millimeters and shall be orthogonal to the elevation axis to within

1 arcminute. The azimuth axis of the antenna shall be parallel to local gravity. The plane of the bolt circle on the base of the antenna that interfaces to the antenna foundation shall be orthogonal to the azimuth axis to within 25 arcseconds.

3.4.2 Reflector Surface Accuracy

A total equivalent antenna surface accuracy of < 20 micrometers root-sum-squared (RSS) during Primary Operating Conditions is required. The total error budget includes contributions from both primary reflector and the subreflector. Factors contributing to the error budget are shown in the example error budget shown in Table 3.4.2-1. AUI will take responsibility for the final precision setting of the primary reflector surface using holography. In the Contractor's error budget the Contractor will allocate 10 micrometers rms for the holographic setting accuracy and 2 micrometers rms for the panel setting accuracy perpendicular to the plane of the reflector surface, as shown in Table 3.4.2-1. The Contractor may vary all other contributions in the error budget in any way he/she wishes, provided that the RSS total is less than 20 micrometers.

The errors for panels shall be calculated by taking root mean square (RMS) of the component along the boresight axis of the normal-to-surface deviations between the theoretical paraboloid and the deformed panel surface without fitting. (This does not exclude fitting measured data to eliminate measurement reference errors when determining the panel manufacturing error.) In measuring the manufacturing accuracy of each panel a grid of points shall be chosen such that each measured point represents approximately 10 cm^2 of surface area. The RMS error of the panel measurement method shall not exceed 25 percent of the panel RMS manufacturing accuracy.

Backup structure (BUS) gravity errors shall be calculated by taking the RMS of the component along the boresight axis of the normal-to-surface deviations between the deformed surface and the best fit paraboloid. For calculating gravity errors, the Contractor may select the surface tuning which provides the best overall performance. When calculating BUS thermally induced and other slowly varying errors the Contractor may assume that the antenna is refocused every 30 minutes.

The errors of the subreflector shall be calculated by taking the RMS of the component along the boresight axis of the normal-to-surface deviation between the deformed, non-ideal surface and the best-fit hyperboloid. The subreflector errors shall be taken at points that are equivalent to the points in which the surface of the panels is defined, i.e., at the locations where the nominal rays from the main reflector through the panel definition points intercept the subreflector.

The final, precision measurement of the surface will be done using holography and AUI will be responsible for this adjustment after the Contractor has released the antenna to AUI. Prior to releasing the antenna to AUI the Contractor will be responsible for adjusting the surface to an RMS setting accuracy of 100 micrometers (see Section 3.9.4.4).

The panel adjusters will be calibrated so that an adjustment point can be moved with a resolution of 5 micrometers. A full surface adjustment should require no more than 16 person-hours of work. Panel gaps shall not exceed 0.45 percent of the total area of the reflector.

The specifications for reflector surface accuracy shall be met with re-alignment of the reflector panels no more often than every five years. Allowance for aging (creeping, etc.) shall be made in the error budget of Table 3.4.2-1 under the item "Backing Structure."

3.4.3 POINTING ACCURACY

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 nonrepeatable.

Repeatable pointing errors are caused by gravity deformation, axis alignment errors, encoder offsets, bearing runout, bearing alignment, and similar errors, which can be corrected using a computer pointing model. The repeatable pointing error for the antenna shall not exceed 2 arcminutes.

Nonrepeatable pointing errors are pointing errors that vary with time or are not repeatable as a function of antenna position. Such pointing errors are due to wind, effects of temperature differences and temperature changes, acceleration forces, encoder resolution, encoder errors, servo and drive errors, position update rate, bearing nonrepeatability and other sources of nonrepeatable errors. The Contractor may include metrology equipment in the antenna design to provide active correction for some of these error sources and the contribution to the pointing error budget for such corrected error sources may be reduced accordingly. Nonrepeatable pointing errors which are "systematic" in the sense that the pointing error is likely to be the same for all antennas and approximately constant in time are much more damaging to the performance of the array than pointing errors which are random amongst antennas and time variable. In the pointing error budget the Contractor will give preference to minimizing "systematic" pointing errors in preference to sources of error which are likely to be random amongst antennas and variable in time. The pointing error is specified for two different kinds of pointing, "offset" and "absolute" pointing. For "offset" pointing the contribution to the error budget for slowly varying causes of pointing error, but not for wind induced errors, may be limited to the differential error over a solid angle of 2 degrees radius about the desired position, and then only the change in that differential error over a 15 minute period when tracking at sidereal rate. For "absolute" pointing no such limitation of slowly varying errors will be made to contributions in the error budget. The nonrepeatable pointing error under Primary Operating Conditions (3.3.2.2) for "offset" pointing shall not exceed 0.6 arcseconds root sum square (RSS) when tracking an astronomical source at sidereal rate. The nonrepeatable pointing error under Primary Operating Conditions for "absolute" pointing shall not exceed 2.0 arcseconds RSS when tracking any astronomical source at sidereal rate.

The nonrepeatable pointing error will be computed in the following way:

Table 3.4.2-1 Example Surface Accuracy Budget

Error Source	RMS Error
Panels	
Manufacturing *(Including measurement errors)*	8.5 μm
Aging	2.0 μm
Gravity	4.0 μm
Wind	4.0 μm
Absolute Temperature	4.0 μm
Temperature Gradients	4.0 μm
Total Panel (RSS)	**11.8 μm**
Backing Structure	
Gravity (Ideal)	5.5μm
Gravity (Departure From Ideal)*	3.0 μm
Wind	2.0 μm
Absolute Temperature	2.0 μm
Temperature Gradients	2.3 μm
Aging	2.0 μm
Total Backing Structure	**7.5 μm**
Panel Mounting	
Absolute Temperature	2.0 μm
Temperature Gradients	2.0 μm
Panel Location in Plane	2.0 μm
Panel Adjustment Perpendicular to Plane***	2.0 μm
Gravity	3.0 μm
Wind	2.0 μm
Total Panel Mounting (RSS)	**5.4 μm**
Secondary Mirror	
Manufacturing	5.0 μm
Gravity	2.0 μm
Wind	2.0 μm
Absolute Temperature	2.0 μm
Temperature Gradients	4.0 μm
Aging	3.0 μm
Alignment	3.0 μm
Total Secondary Mirror (RSS)	**8.4 μm**
Holography**	
Measurement	10.0 μm
Total Holography (RSS)	**10.0 μm**
Other Errors not Included Above	**2.0 μm**
TOTAL (RSS)	**20.0 μm**

* *Departures from ideal such as member true size, manufacturing, modeling accuracy, etc*

** *AUI is responsible for the precision adjustment of the primary surface.*

*** *AUI is responsible for the panel adjustment perpendicular to plane of the primary surface (fixed at 2.0 μm).*

(1) For nighttime Primary Operating Conditions (9 m/s wind, see Section 3.3.2.2) calculate the pointing error for each of the sources of nonrepeatable pointing error and RSS these contributions together to obtain the RSS pointing error. Calculate this RSS pointing error for each of the eleven wind directions shown in Table 3.4.3-1. The RSS pointing error for any of the eleven wind pointing directions individually shall not exceed 1.0 arcsecond. The nighttime nonrepeatable pointing error is defined to be the weighted RMS of these eleven RSS pointing errors, where the weighting is shown in Table 3.4.3-1 and accounts for the fraction of observing time anticipated for each wind direction.

(2) For daytime Primary Operating Conditions the Contractor will use a computer thermal model of the antenna to determine the worst case nonrepeatable pointing error due to temperature differences and temperature changes in the structure. The structural temperature differences calculated using the computer thermal model must be consistent with the structural temperature differences actually measured on radiotelescopes. The daytime thermal pointing error is defined to be 75 percent of this worst case error. Compute the daytime wind pointing error using the definition in (1) above with a wind velocity of 6 m/s. The daytime nonrepeatable pointing error is defined to be the RSS of the daytime thermal pointing error and the daytime wind pointing error.

Table 3.4.3-1 Antenna Orientations for Wind Pointing and Path Length Error Calculations

Azimuth Angle (deg)	Elevation Angle (deg)	Weighting Factor
0	0	.031
60	0	.062
120	0	.062
180	0	.031
45	45	.188
135	45	.188
0	60	.094
90	60	.188
180	60	.094
90	90	.031
0	90	.031

*Assume that the wind is blowing in direction 180 deg. Thus the case azimuth 0, elevation 0 corresponds to the reflector being face into the wind.

An example of possible daytime and nighttime pointing error budgets is shown in Table 3.4.3-2. Wind and temperature effects may be partially corrected by incorporating information from an antenna metrology system (see Section 3.5.1).

Table 3.4.3-2 Example pointing error budget

Nonrepeatable Pointing Error (Arcsec)	Day	Night
wind, steady component	.2	.45
wind, gusty component	.1	.1
structure temperature gradients	.35	0.0
ambient temperature changes	.2	0.0
inertial forces	.15	.15
encoder errors	.2	.2
servo error	.1	.1
bearing errors	.2	.2
other errors	.19	.19
Total RSS error	.60	.60

3.4.4 Fast Motion Capability

The antenna will be used to track astronomical sources across the sky at sidereal rate. Three observing modes require the ALMA antenna to have special fast motions superimposed on the slow sidereal tracking rate. These fast motion modes are fast switching phase calibration, on-the-fly total power mapping and on-the-fly interferometric mosaicking.

Fast switching phase calibration requires the antenna to move from the target source to a calibration source 1.5 degrees away on the sky and settle to within 3 arcseconds peak pointing error, all in 1.5 seconds of time. A few seconds later the antenna will switch back to the target source with the same requirements on switching time and settling accuracy. A typical time for a full cycle of target-calibrator-target observation is 10 to 20 seconds and the antenna may spend many hours cycling in this way. The antenna must be designed to survive 50 million of these cycles during a 30 year lifetime.

In the on-the-fly total power mapping mode the antenna will scan at a rate of up to 0.5 deg/s on the sky across a large target source, several or many beamwidths in size, and then turn around as rapidly as possible and scan back across the source in the opposite direction. As the antenna scans

across the source, it is not necessary for the position at any time to be precisely a pre-commanded position. It is sufficient to simply know where the antenna is actually pointing.

In on-the-fly interferometric mosaicking, the antenna will scan at a rate of up to 0.05 deg/s on the sky across a large target source, several or many beamwidths in size, and then turn around and scan back across the source in the opposite direction. As the antenna scans across the source it must follow the commanded path to within 1 arcsecond RSS pointing accuracy under primary operating conditions in offset pointing mode.

These fast motion modes place the following requirements on antenna velocity, acceleration and settling time:

3.4.4.1 VELOCITY AND ACCELERATION

Maximum angular velocity:	>3 deg/s in elevation
	>6 deg/s in azimuth
Maximum angular acceleration:	>12 deg/s^2 in elevation
	>24 deg/s^2 in azimuth

where both these axes must be able to achieve these rates simultaneously. Since all antennas in the array must move at the same time, the demand on the array electrical power system will be large and consideration will be given in the antenna design to reducing the power requirements during maximum acceleration.

3.4.4.2 SETTLING TIME

If a step change in position is commanded, the direction of the boresight axis shall settle to within 3 arcseconds of the new position within a time interval of

t_{max} = 1.5 s for a step of 1.5 deg or less
1.5 s + x/(3deg/s) for a step of x > 1.5 deg

This applies to the motion on the sky and in any direction, except that the azimuth component of the motion need only meet this requirement if the elevation is less than 60 deg.

3.4.5 PATH LENGTH ERRORS

Path length errors must be considered since the antenna will be used in an array. Path length (also called delay) errors are defined as follows. Consider a plane wave arriving at the antenna from the direction of the boresight. Define the "excess delay" of the antenna to be the difference between the arrival time of that wave at the secondary focus (via the main reflector and subreflector) and its arrival time at an arbitrary reference point fixed with respect to the ground as if the antenna were not present. (It is convenient to choose the reference point along the azimuth axis. If the boresight axis,

elevation axis and azimuth axis all intersect, then choosing that intersection as the reference results in an excess delay that is nearly constant.) The Contractor shall calculate the excess delay (expressed as a pathlength) for the nominal antenna in the absence of environmental perturbations, as a function of boresight direction over the full range of azimuth and elevation, and he/she shall provide this data to AUI as the "nominal excess delay function." Now define the "residual delay" as the difference between the actual excess delay of a particular antenna under existing conditions and the nominal excess delay. The residual delay is limited by the specifications of this section. The residual delay has a repeatable and a nonrepeatable component.

The repeatable residual delay is caused by the difference in gravity deformation between an antenna and the nominal antenna (for example, this could be caused by differences in the material properties of an antenna compared to the nominal material properties), axis alignment errors, bearing runout, bearing alignment, and similar errors, which repeat as a function of antenna position and can be corrected using a computer delay model. The repeatable residual delay for an antenna shall not change by more than 20 micrometers when the antenna moves between any two points 2 degrees apart in the sky.

The nonrepeatable residual delay is the delay component that varies with time or is not repeatable as a function of antenna position. It is caused by wind, effects of temperature differences and temperature changes, acceleration forces, bearing nonrepeatability and other sources of nonrepeatable errors. The Contractor may include metrology equipment in the antenna design that can be used to estimate the residual delay in real time. In that case, both the measured values and the results of a calculation estimating the residual delay shall be provided to AUI via the digital interface (see Section 3.5.6.3). If this is done, then the estimate shall be subtracted from the actual residual delay for the purpose of meeting the specifications of this section. Further, for slowly varying sources of residual delay, but not for wind induced residual delay, the contribution to the residual delay budget may be limited to the differential residual delay over a solid angle of 2 degrees radius on the sky and then only the change in that differential delay over a 3 minute period when tracking at the sidereal rate. The nonrepeatable residual delay under Primary Operating Conditions (3.3.2.2) must be less than 15 micrometers RSS when tracking an astronomical source at sidereal rate.

The nonrepeatable residual delay will be computed in the following way:

(1) For nighttime Primary Operating Conditions (9 m/s wind, see section 3.3.2.2) calculate the residual delay for each of the sources of nonrepeatable residual delay and RSS these contributions together to obtain the RSS residual delay. Calculate this RSS residual delay for each of the eleven wind directions shown in Table 3.4.3-1. The nighttime nonrepeatable residual delay is defined to be the weighted RMS of these eleven RSS residual delays, where the weighting is shown in Table 3.4.3.1 and accounts for the fraction of observing time anticipated for each elevation angle.

(2) For daytime Primary Operating Conditions the Contractor will use a computer thermal model of the antenna to determine the worst case nonrepeatable residual delay due to temperature differences and temperature changes in the structure. The structural temperature differences

calculated using the computer thermal model must be consistent with the structural temperature differences actually measured on radiotelescopes. The daytime thermal residual delay is defined to be 75 percent of this worst case residual delay. Compute the daytime wind induced residual delay using definition (1) above with a wind velocity of 6 m/s. The daytime nonrepeatable residual delay is defined to be the RSS of the daytime thermal residual delay and the daytime wind residual delay.

3.4.6 CLOSE PACKING

It shall be possible to locate two antennas with their azimuth axes within 15 meters of each other without any possibility of the antennas colliding with each other, no matter what the relative orientation of the two antennas.

3.4.7 SOLAR OBSERVATIONS

Direct observations of the sun will be allowed and all specifications will be met during solar observations. The primary surface will be unpainted but will have a suitable surface treatment to prevent solar heating damage to the subreflector support legs or subreflector during solar observing or when the sun is close to boresight. When the antenna is pointed directly at the center of the Sun, the power absorbed by a black body anywhere in the secondary focal region shall not exceed 0.3 W/cm^2.

3.4.8 LOW NOISE

Contributions to system noise from the antenna, due to resistive loss of the primary reflector surface and scattering of ground noise into the feed, will be minimized as much as possible without compromising the surface accuracy and pointing requirements. Design features will include supporting the subreflector support legs close to the edge of the reflector and shaping the underside of the support legs to reduce ground pickup. The total geometric blockage shall not exceed three (3) percent. Contributions to geometric blockage shall include: subreflector, vertex hole in primary, subreflector support legs, panel gaps, front side panel adjustors, optical pointing telescope, and any other items in the design that will contribute to the geometric blockage. It shall be required that the support structure behind the subreflector be of a smaller diameter in size than the subreflector. The undersides of the subreflector support legs will have removable shields with a wedge shaped profile to minimize ground noise pickup. This profile will be specified by AUI, in negotiation with the Contractor, after the Contractor has designed the overall subreflector support leg geometry.

The primary reflector surface and the secondary mirror shall each have a surface resistive loss of less than 1.0 percent over the operating frequency range (Section 3.3.1) of the antenna.

3.5 OTHER REQUIREMENTS

3.5.1 METROLOGY

The Contractor shall provide a stable support structure, independent of the load-bearing yoke arms of the antenna mount, for the elevation encoder, or an equivalent method of achieving the pointing specification.

For the purpose of achieving the pointing specification (Section 3.4.3) and the path length error specification (Section 3.5.1) the contractor shall provide not less than 3 electronic tiltmeters for measuring tilts of the antenna pedestal with respect to gravity during antenna operation and not less than 20 temperature probes to measure antenna structural temperature during antenna operation. The contractor shall provide the required real-time correction software in a dedicated metrology computer.

In addition to the equipment listed above in this section, the Contractor, under the "Metrology Design" option, will design into the antenna a laser metrology system for the purpose of measuring the position of the ends of the elevation axis and the position of the subreflector during antenna operation. The number of degrees of freedom to be measured and the measurement accuracy to be provided by the metrology system will be as specified in Section 4.2.8.4 of the Vertex Proposal. The contractor shall also design the real-time software required to convert the measured position data into pointing and path length error corrections in a dedicated metrology computer. The actual provision of this laser metrology system and its associated software is not part of this contract but may be requested by AUI's acceptance of an option in the future. Any real-time corrections provided by this laser metrology system cannot be used by the contractor for the purposes of achieving the pointing and path length error specifications.

All data provided by all of the metrology equipment mentioned above in this section will be provided as digital monitor data from the dedicated metrology computer to the AUI Antenna Computer. All metrology equipment will be monitored and controlled by the Contractor's equipment.

3.5.1.1 OPTICAL TELESCOPE FOR POINTING TEST

An optical telescope will be mounted on the antenna for pointing tests that will be used to characterize the mount of the telescope. This telescope will be mounted in a representative position on the antenna BUS and protrude through the reflector surface. AUI will provide the optical telescope and install the unit. The Contractor will provide a stable mount on the BUS for the optical telescope and a cut-out through the reflector surface for the telescope to protrude. The mounting plate on the antenna for the optical pointing telescope shall be stable with respect to the mount axis of the antenna with a nonrepeatable error of less than 0.2 arcseconds rms over a two hour period. The drawings and specifications of the optical telescope are in ALMA ICD No. 8.

3.5.2 TRANSPORTABILITY

The antenna will be designed to be transportable. The antenna will be transported on a transporter vehicle, which will be designed and provided by AUI. The Contractor will provide an interface above the azimuth bearing that will enable the antenna transporter to pick up the antenna and move it between antenna foundations. This interface shall be several points on the antenna that will enable secure and stable attachment to transporter while being transported. For the prototype antenna, there will be interface flanges on the antenna between the attachment devices of the transporter and the antenna. This interface is defined in ICD No. 5 "Antenna/Transporter Interface." AUI will resolve the details of this interface with the Contractor when the Contractor has defined the overall layout of the antenna. This interface in general compliance with ICD No. 5 will be provided at no additional cost. The pickup points are located above the azimuth bearing so that the azimuth bearing and drive can be used to rotate the base of the antenna for bolt hole alignment as the transporter places the antenna on the foundation. The antenna base must be able to be rotated +/- 30 degrees in azimuth while on the transporter. The maximum diameter of the antenna base must be less than 7.0 meters to a height of 3.0 meters above ground level.

The antenna must be designed to minimize the amount of time that it takes to make and break the connections between the antenna and the foundation and the antenna and the transporter. All connections and interfaces to the transporter and foundation must be removable in less than 15 minutes and installable in less than 15 minutes. This shall include all setting and calibrating of metrology instruments, and removal and installation of platforms or ladders that may be in the way for the attachment of the transporter.

3.5.3 FOUNDATION

The Contractor is responsible for the design of the antenna foundation to ensure that it provides the support and stiffness necessary to achieve the deformation allowed by the Contractor's error budgets for the various antenna performance specifications. The construction and installation of the foundation will be the responsibility of AUI. The Contractor will design a foundation suitable for the installation of the antenna at the ALMA U.S. test site in New Mexico. Since the soil conditions on the ALMA site in Chile are quite variable over the 10 km extent of the array, the Contractor will design two additional foundations, one representative of the best soil conditions on the ALMA Chilean site and the other representative of the worst soil conditions. These two Chilean foundations will be used by AUI as a proof of design existence and for planning and costing purposes. The design of the actual foundations to be built on the Chilean site is not part of this contract. Note the impact loading survival requirement in Section 3.3.2.5 Survival Conditions, Transporter Handling.

The Contractor must ensure that the design of the foundation provides the performance required by his/her error budget. The design will include all connections between the foundation and antenna. The design shall be optimized to minimize the cost of the foundation, because the ALMA will require foundations in five different locations for each antenna. The compliance of the combined soil and foundation shall be included in the dynamic analysis of the antenna. Foundation connections to

the antenna must provide azimuth axis repeatability of +/- 2 millimeters for translation and +/-25 arcseconds for angular repeatability for multiple installations of the antenna on the foundation. The azimuth axis of the antenna shall be parallel to local gravity.

The foundation design will include a center vault with a french drain that is large enough for a person to work on cables in the vault. This vault will include a sealed cover plate. Conduits must be provided through the foundation for cables of various kinds. The foundation design must also accommodate a loaded antenna transporter crossing over the foundation. The top of the antenna foundation may project vertically no more than 100 mm above ground level.

3.5.4 RECEIVER CABIN

A receiver cabin with dimensions, approximately as shown in Appendix A, will be provided at the Cassegrain focus. The minimum receiver cabin door size shall be 1 meter wide by 1.6 meters in height in order to move receiver equipment in and out. Cabin service access will be with the antenna positioned at the zenith. The receiver cabin floor must be flush with the external access platform to prevent a tripping hazard and to facilitate loading of equipment into the Receiver Cabin. An allowance shall be made for a water seal that shall be approved by AUI. A covered subfloor cable tray will be provided from the side of the receiver cabin to the base of the receiver with a cross section size of 8 cm by 4 cm. The cover to this tray shall be removable and flush with the receiver cabin floor. The mass of AUI installed equipment in the cabin will not be greater than 1,600 kg. Adequate work lighting shall be provided in the receiver cabin. A total of 12 electrical receptacles shall be located in the receiver cabin with locations approved by AUI.

Temperature in the cabin shall be maintained by an antenna mounted HVAC system at a temperature which can be selected in the range of 16-22 C. Air temperature will be regulated to an accuracy of +/- 1C in the output plenum of the HVAC system. This system shall be capacity modulated with proportional control. The air distribution system shall utilize continuous air flow through the receiver cabin to avoid sudden changes in temperature. The air distribution system shall take into account the fact that the receiver cabin is continuously changing position relative to gravity. The system shall use high-grade air filters. The outputs of the plenum will be to 2 equipment racks, 2 room vents and 3 auxiliary use vents. Each plenum output shall have an adjustable damper. AUI will furnish and install equipment in the receiver cabin with electrical power consumption of not greater than 10 kW. The receiver cabin walls, floor and ceiling shall be insulated. All refrigeration piping shall be insulated. All exposed insulation shall be mechanically protected with a metal cover and weatherproof in exterior applications.

A built-in mechanism shall be provided so that a receiver can be lifted from the ground, through the cabin door and into its observing location, all without significant man-handling of the receiver. The maximum weight of the receiver is 550 kg. The equipment interface is an important issue for the antenna structure. Two racks of equipment will be required in the cabin along with access to these racks and receiver package. AUI will negotiate the detailed mounting interface for the

equipment and receiver in the cabin with the Contractor during cabin design. Any Contractor-supplied equipment located in the receiver cabin shall be specifically approved by AUI.

The cabin will be watertight and a thin RF-transparent membrane will cover the aperture through which the RF beam enters the cabin at the vertex hole. AUI will provide the material for this membrane. The Contractor shall provide a computer actuated shutter which will be deployable to protect the membrane under survival condition (3.3.2.5) when necessary. The shutter shall be automatically deployed by the Contractor's equipment when the antenna is commanded to the survival stow position. The shutter shall be capable of being controlled and monitored by the AUI Antenna Computer. This system shall have status sensors with a manual override and will perform about 400 cycles per year.

AUI may wish to add oxygen to the air in the receiver cabin when workers are inside on the high altitude site. For this reason, the cabin must not have any large air leaks and a flange will be provided on an HVAC air duct external to the cabin into which the oxygen can be injected. Any such oxygen enhancement equipment will be provided by AUI.

Antenna mounted ladder and/or platforms will allow access to the receiver cabin while in maintenance stow position.

3.5.5 APEX EQUIPMENT

The Contractor shall design and provide a subreflector with three translation stages at the apex of the antenna. Two stages will be orthogonal to the optical axis with automated translation stages having 20 millimeters of travel with a positional repeatability and accuracy required by pointing specification. All three stages shall travel at a speed of 2 mm/sec with a closed loop servo, limit switches, readouts and shall be monitored. The third stage is parallel to the optical axis and will be automated with +/- 15 millimeters of travel from secondary focus with a positional repeatability of +/-10 micrometers. These systems will be integrated into the Contractor's antenna servo and control system, and be available for monitor and control from AUI's Antenna Computer.

The subreflector support legs shall also be designed to support a cable weight of 2 kg/m that can be divided among the subreflector support legs and meet all specifications herein. The apex structure shall be designed so that specifications regarding clearance, mounting and mass as shown in"ALMA ICD No. 2 Antenna/Apex Interface" are met. The spacer block and mounting flange will provide for an AUI supplied reactionless nutator and subreflector in the future if necessary. The configuration shall be such that a clear opening of approximately 375 millimeter diameter exists on the centerline of symmetry. The support structure behind the subreflector shall be of a smaller diameter in size than the subreflector and not protrude outside the subreflector diameter in any translation position.

3.5.6 SERVO AND CONTROLS

3.5.6.1 GENERAL DESCRIPTION

The Contractor shall provide an antenna control system that includes a closed-loop servo for driving the antenna to follow a commanded trajectory. It shall also include reasonable protection equipment and circuitry, such as limit switches. Additional details of the requirements are given in this section.

The control system shall provide all the necessary controls for the azimuth and elevation axis drives and shall monitor the angular position of the antenna in both axes. Cabling to interconnect all components of the system shall be supplied and installed by the Contractor. No components of this system may be located in the receiver cabin except perhaps some low-power sensors, and then only with AUI's approval. A cable run from any component of this system to the receiver cabin will not be longer than 15 meters in length.

3.5.6.2 LOCAL CONTROL AND MONITORING

A centralized monitor and control panel shall be provided at each antenna. It shall include at least (1) an Emergency Stop switch (see also 3.5.6.7), (2) selection of Remote or Local access (see 3.5.6.3), (3) mode selection (see 3.5.6.3) and (3) rate loop driving of the antenna. It shall display at least the following information:

1. Binary encoder position
2. Binary commanded position
3. Motor status (each)
4. Field status (each)
5. Motor over temperature (each)
6. Emergency Stop
7. Stow Pins
8. Limit Switch Status (each)
9. Computer Mode Status (each)
10. Each Motor Current
11. Each Tachometer (Pin Jacks)
12. Circuit Breakers (each)
13. Contractor Metrology System Status

A portable control unit shall also be provided for the use of maintenance personnel who may be servicing the antenna. This shall provide at least rate loop driving of the antenna in both azimuth and elevation, effective only during Local Access. This portable control unit shall also provide emergency stop control. Provisions shall be made so that the portable control unit can be connected to the antenna base, servo cabinet, and receiver cabin with a removable cable. These cable

connections will be waterproof and protected from the weather. The cable shall be made available in both 10 meter and 30 meter lengths.

3.5.6.3 MODES OF OPERATION

At any time, the controller may be in one and only one of several operating modes, as listed in Table 3.5.6.3-1. Simultaneously, it may be in either of two access modes, Local or Remote. When Remote access is selected, the controller responds to a defined set of commands via the digital interface (3.5.6.4). When Local access is selected, commands received from the digital interface are ignored (but status requests are still accepted and processed) and the antenna may be driven using the controls described in 3.5.6.2. Switching between Local and Remote access may be done only from the ACU front panel. Upon changing access mode and at power-up, the controller automatically enters the Shutdown operating mode. Not all operating modes may be entered from either access mode; see Table 3.5.6.3-1. In addition, Stow mode or Shutdown mode may be entered automatically when the controller detects certain fault conditions, regardless of the selected access mode.

The following rules govern changes of mode: From Shutdown mode, the only change permitted is to Standby mode, and then only if no fault conditions are true. An Active mode may only be entered from Standby mode. From Stow mode, Standby mode is automatically entered upon reaching the stow position. This is reflected in the Auto column of Table 3.5.6.3-1.

Table 3.5.6.3-1 Modes of Operation

Operating Mode	Local	Remote	Auto	Description
Shutdown	Yes	Yes	Yes	Brakes set, no power to motors
Standby	Yes	Yes	No	Ready to drive
Active:				Brakes off, servo loop closed
Velocity	Yes	No	No	
Position				
Encoder	Yes	Yes	No	Drive so encoders equal commanded position.
Auto..omous	No	Yes	No	Drive so boresight equals commanded position.
Stow	Yes	Yes	Yes	Drive to stow position.

3.5.6.4 MONITOR AND CONTROL DIGITAL INTERFACES

3.5.6.4.1 GENERAL

The antenna shall be controlled via commands from an AUI-supplied computer and shall provide status information to the same computer. The connection will be via an ISO11898 CAN BUS whose details will be specified at the PDR (3.5.6.4.2). The bus may be shared with other devices mounted in the antenna. There are strict timing requirements with respect to the execution of some commands and the sampling of some status data (3.5.6.4.3).

The primary commands consist of the azimuth and elevation to which the antenna shall be pointed. Other commands may be generally described as changing the mode of operation of the antenna. The detailed design of the command set will be negotiated between AUI and the Contractor during the design phase.

The primary status information consists of the actual azimuth and elevation to which the antenna was pointed at an accurately known time. Additional status information for monitoring the health and safety of the antenna is also required, such as motor currents, temperatures at critical locations, and any detected fault conditions.

3.5.6.4.2 PHYSICAL LAYER AND LOW-LEVEL PROTOCOL

The serial data bus is the method by which the Contractor's equipment will communicate with AUI's computer via an ISO11898 CAN BUS version 2.0B. Status information will be solicited by polling, and the Contractor's equipment will not send any messages nor generate any interrupts autonomously.

3.5.6.4.3 TIMING

In addition to a connection to the serial bus, the antenna controller will receive a precise timing reference signal. This will be a periodic pulse, supplied by differential signaling conforming to RS485. The pulse period shall be 50 ms. The pulse duration will be no less than 1 microsecond. The leading edge of each pulse marks a timing event.

For certain commands, in particular the antenna position command, the antenna controller shall consider the effective time of the command to be that of the second timing event after the command is received. The controller must then ensure that the condition specified by the command becomes true within 10 microseconds of the effective time whenever this is not prevented by a mechanical or structural limit. For other commands, such as mode changes, there is no requirement for precise timing.

The controller shall also measure the actual position of the antenna twice per timing event, with one measurement made within 10 microseconds of a timing event and the other within 1 ms of the

midpoint between timing events. Each such measurement shall include the readings of all appropriate sensors (although sensors whose values are known to change slowly may have their readings interpolated from measurements made less frequently). The controller shall store these measurements in a circular buffer sufficient to hold data from at least the last 10 seconds. Status request codes shall be included to solicit (a) the most recent measurement at the last timing event; (b) a subset of the measurements in the buffer (and size shall be negotiated); and (c) all measurements in the buffer. There may be other status request codes that require delivery of a measurement made at the last timing event.

The number of commands and status requests that might be transmitted in a given time interval is limited only by the speed of the bus and its low-level protocol. However, the total number of commands and status requests requiring precise timing will be limited to a maximum of 4 per timing event. The controller shall be capable of processing all of these. Other commands and status requests shall be buffered and executed at lower priority in the order that they were received. The buffer should be capable of storing at least 256 commands and status requests.

3.5.6.4.4 HIGH LEVEL COMMAND PROTOCOL

Each antenna position command will have 4 parameters, consisting of elevation, azimuth, elevation rate, and azimuth rate. The elevation and azimuth will be 32 bit numbers, interpreted as signed, twos-complement, fixed-point binary numbers representing angles from -1 turn through +[1-2^{-31}] turn (i.e., the binary point comes just after the sign bit). The elevation rate and azimuth rate will be in the same fixed-point format in units of turns per second.

For the elevation parameter, zero represents the horizon and the valid range is from the lower mechanical limit (2 degrees) to the upper mechanical limit (125 degrees (see 3.4.1)). For the azimuth parameter, a value of zero represents the center of the range of rotation (3.4.1) and the valid range is from one mechanical limit to the other (540 degrees). If out-of-range commands are received, the antenna should be driven to the nearest mechanical limit and an error status bit should be set.

The commanded position and rate apply at the second timing event after the command is received. The AUI computer will guarantee that the command is available no later than 10 ms in advance of the next timing event. If no position command is received between two timing events, the position and rate applicable at the next timing event shall be derived by constant-velocity extrapolation of the most recently received command. In this way, there is a commanded position and rate that applies at each timing event. At any time between timing events, the commanded trajectory shall be determined by a fixed interpolation rule chosen by the Contractor to produce smooth motion, taking into account the response of the servo. The position and velocity command is the primary control interface.

The servo shall attempt to make the actual trajectory of the antenna follow the commanded trajectory. If the latter contains first or second derivatives exceeding the maximum angular velocity

or acceleration (see 3.4.4), the servo shall drive the antenna so as to converge to the commanded trajectory as quickly as possible while meeting the settling time requirements (3.4.4).

The antenna may have several sub-modes of active operation determined by the Contractor, but at least the following two modes shall be included.

Autonomous pointing mode: In this mode, position commands are interpreted to mean the actual orientation of the axis of symmetry of the main reflector (boresight axis) with respect to established local coordinates (zenith direction and nominal azimuth zero). The controller shall determine this automatically by using all available sensors and, if necessary, calibration information specific to this antenna that has been previously determined and stored. Accuracy specifications given earlier in (3.4.3) are expected to be met.

Encoder positioning mode: In this mode, position commands are interpreted to mean the readings of the azimuth and elevation shaft rotation sensors (encoders). The readings of other sensors shall be ignored in executing the position command, but they shall still be measured and recorded for reporting in response to status requests.

3.5.6.5 COMPUTING AND SOFTWARE

It is assumed that the control unit will contain one or more embedded microprocessors. The source code for programming all such processors shall be delivered to AUI.

It is required that (a) all application programming for processors in the control unit be written in C or C++; (b) executable code be stored in non-volatile electronic memory, avoiding mechanically driven peripherals such as disk drives; and (c) if a general-purpose computer requires an operating system, the operating system shall be VxWorks. All embedded microprocessor systems except for the ACU shall be based on PowerPC processors and VME backplanes. All VxWorks microprocessor systems shall have ethernet interfaces for debugging and testing.

3.5.6.6 LIMIT SWITCHES

There shall be two limit switches near each extreme of motion of each axis, at slightly different positions. The two switches of each pair shall use independent wiring and independent circuit components as much as possible; the likelihood of a component failure affecting both circuits shall be minimized.

3.5.6.6.1 FIRST LIMIT (PRELIMIT)

When the first limit switch of a pair is actuated, the controller shall inhibit driving further in the same direction (into the limit), but should permit driving in the opposite direction (out of the limit) in all modes. Receipt of a second command (Remote or Local) that would cause motion into the limit shall cause the controller to enter Shutdown Mode, and thus to remove motor power and engage

the brakes. An override switch shall be provided to disable these features of the first limit. This switch shall be accessible only locally (not via remote control), and it shall not be on the control unit's front panel.

3.5.6.6.2 SECOND LIMIT (FINAL LIMIT)

When the second limit switch of a pair is actuated, all motion of the antenna shall be stopped by causing the controller to enter Shutdown Mode immediately. In addition, each second limit switch shall include a set of normally closed contacts through which current to at least one brake of its axis must flow. There shall be no provision in the ACU for overriding the second limits. The Contractor shall make provisions for manual override of brakes and axis drives.

3.5.6.7 EMERGENCY STOPS AND FAULT DETECTION

The Contractor shall supply, wire and install emergency stop switches that can be padlocked in stop position for Lock-out/Tag-out. The setting of an emergency stop switch shall completely remove power from the motor drive circuits and cause the brakes to be engaged. It shall cause the control system to enter the Shutdown mode, but the removal of motor power and engaging of brakes shall be independent of any other control circuits; it shall be effective even if the main electronics chassis is powered down. These switches are to be located in at least the following locations:

1. In the receiver cabin
2. Two on the antenna base
3. One on each set of elevation drive motors
4. One on each azimuth drive motor
5. At the local control front panel
6. On the Portable Control Unit (PCU)

The control system shall continuously monitor fault conditions that may affect the safety of equipment or personnel, and shall automatically enter Shutdown mode if a sufficiently serious fault is detected. Serious faults include, but are not limited to:

1. Excessive motor current
2. Motor overheating
3. Servo oscillation
4. Limit switch actuated (but see 3.5.6.6)
5. Critical sensor fault (especially an encoder) or power failure
6. Overspeed of the azimuth or elevation axis.

The overspeed monitoring system shall be separate from the drive system and independent of the main axes encoders. Any error condition that may cause overspeed shall not have the potential of also leading to a malfunction of the overspeed monitoring system.

3.5.6.8 AUTOMATIC SURVIVAL STOW CONDITIONS

The antenna will automatically enter survival stow mode under the following conditions:

1. ACU Commanded
2. No commands received for one minute when in remote access with this time parameter being adjustable over the range of 1 to 60 minutes.

3.5.6.9 PRIME POWER

The drive system prime power shall be 400 VAC +/-10%, 3 phase, 5 wire, 50 Hz or 60 Hz (see Section 3.3.1), connected to a 3 phase circuit breaker located on the antenna pedestal. The connections from this circuit breaker to the motor amplifiers shall be by wire and conduit.

Electronic components of the system shall be connected to 230 VAC, 1 phase 50 Hz or 60 Hz (see Section 3.3.1) and have varistor surge protection. The encoder prime power shall be connected to the same source and have varistor surge protection. This prime power shall be connected to a disconnecting device (supplied under this contract) that will allow resetting all servo and encoder power supplies, motor faults and other faults. The disconnecting device will be actuated by an AUI remote 28 Volt DC signal.

3.5.7 RFI AND EMI (RADIO FREQUENCY INTERFERENCE/ELECTROMAGNETIC INTERFERENCE)

The control circuit, drive motors amplifiers, and switching devices shall be designed and constructed in accordance with Mil-STD-461A, paragraphs 4.2.1.2., 4.2.1.4., and 4.2.1.5. concerning radiated and conducted electromagnetic energy. In particular, all motor leads, power and control should be filtered. The motor leads may be shielded instead of filtered provided the shielding provides suppression equal to or better than the filters. All relay contacts and actuators should be properly bypassed, shielded and/or filtered. All amplifiers and oscillators shall be mounted in shielded enclosures that will provide effective shielding of radio frequency energy. Silicon-controlled rectifiers switching devices shall not be used unless phase controlled and zero current crossing switching techniques are used. No gaseous discharge devices, except noise sources for test shall be employed. Means shall be employed to reduce static electricity and the consequent R.F. noise generated in any rotating machinery. All displays (LCD, plasma, LED, CRT) shall have a transparent RFI shield in front of the display to avoid radiated RFI. In addition, all digital equipment, whether a simple logic circuit, embedded CPU, or rack mounted PC shall be shielded and have its AC power line and modem/LAN line(s) filtered at the chassis.

The frequency range of interest for RFI suppression extends from 50 MHz to 12 GHz. No verification measurements by the Contractor will be required. All wires and cables provided by the Contractor that enter the receiver cabin shall have RFI suppression. The receiver cabin will be an effective continuous metal surface for shielding and will require RFI shielding on the cabin door. AUI will be responsible for shielding of the receiver cabin vertex hole.

The contractor will provide, for AUI's approval, an RFI/EMI plan which describes the design feature implemented in response to the requirements of this section (3.5.7) of the specification. This plan is to be delivered at the time of the CDR.

3.5.8 ELECTRICAL

3.5.8.1 POWER DISTRIBUTION

The Contractor shall supply a 75 kVA electrical service entrance at the base of the antenna for connection to supply power from two sources that are switchable. This switch shall be a simple manually operated switch that shall be located on the antenna at the base, shall have the two power inputs from removable connectors, and shall be provided by the Contractor . The purpose of this switch is to keep power to the helium compressor during transportation and to supply power for the azimuth servo during placement of an antenna on a foundation. The supply voltages of 230 VAC single phase, 400 VAC three phase at a frequency of 50 Hz or 60 Hz will be provided. The Contractor shall be responsible for all his/her antenna electrical wiring from this point. All connector and receptacle types shall be approved by AUI. All cabling and wiring shall be in metal conduit unless specifically approved by AUI.

The antenna Contractor shall supply a three bus system. One bus is the "Critical Electronics Bus" for receiver cabin electronics, encoding systems, ACU and safety systems with a sub-panel in the receiver cabin. The power for this bus shall be supplied by a 20 kVA (at elevation 5000 meters) UPS system. This UPS system shall not be located in the receiver cabin, but at a location on the antenna (to be transported with the antenna) chosen by the Contractor. The second bus is the "Critical Cryogenic Bus" that powers the helium compressor, and cryogenic refrigerator. The other bus is the "Non-Critical Bus" for lighting, HVAC, with sub-panels in the receiver cabin and base of telescope. The bus system is also listed in the Table 3.5.8.1-1. Size and type of the circuit breakers are to be determined later by AUI. Fuses shall not be used for equipment protection unless specifically authorized by AUI. All three buses shall have single phase and reverse phase protection interlocked with smoke detectors specified in Additional Electrical Requirements (3.5.8.4).

Table 3.5.8.1-1 Bus Power Distribution

Bus	Systems on Bus	UPS
(1) Critical Electronics Bus	Receiver cabin electronics, encoding systems, ACU, safety systems	UPS System (20 kVA)for a minimum of 10 minutes, 230 VAC, single phase
(2) Critical Cryogenic Bus	Helium compressor & cryogenic refrigerator	No UPS
(3) Non-Critical Bus	All other system, including prime drives & HVAC systems	No UPS

3.5.8.2 JUNCTION BOXES

Junction boxes shall be provided to accommodate all electrical connections to be supplied by the Contractor. Separation in junction boxes shall be provided for power and signal wiring; junction boxes shall meet National Electrical Code specifications for NEMA Type IV.

3.5.8.3 GROUNDING

The antenna requires safety and equipment grounds. A station ground shall be provided for the antenna structure. The Contractor will design the grounding counterpoise as part of the antenna foundation design (Section 3.5.3) in accordance with National Electric Code Specifications. Soil resistivity data for this design will be included with the soils report prior to award of contract. AUI will provide the counterpoise as part of the foundation construction. The apex, elevation bearings and azimuth bearing shall have a by-pass grounding connection. The antenna grounding system shall be specifically designed to prevent or minimize ground loops.

Lightning rods shall be provided as required to protect all parts of the antenna.

The antenna grounding system shall be specifically designed to prevent or minimize ground loops.

The antenna shall be provided with a lightning protection system designed according to: NFPA 780 "Standard for the Installation of Lightning Protection Systems" (as of this writing, 1997 Edition) or according to IEC 61024 Protection of structures against lightning:

- Part 1: General principles;
- Part 1-2: General principles - Guide B - Design, installation, maintenance and inspection of lightning protection systems.

To determine the zone of protection (zone not subject to direct lightning strokes - LPZ 0B) the rolling sphere model shall be adopted which is described by both the above-mentioned standards.

The lightning protection system shall be designed to achieve Protection Level I as defined by IEC 61024-1.

The earth termination system (ground terminal) shall comprise a ring earth electrode (bonded to or constituted by a foundation earth electrode in form of a loop).

Members of the external lightning protection system (air-terminations, down-conductors, earth-termination system) shall be chosen by adopting, as far as practicable, "natural" components (that is, components that perform a lightning protection function but that are not installed specifically for that purpose).

Equipment installed onto the antenna as well as cables, wiring and any lines interconnecting them (thereby including any metallic pipes) shall be provided with protection against overvoltages and against lightning electromagnetic pulse (LEMP). Reference may be made to principles and methods described by IEC 61312-1 and IEC TS 61312-2. To this purpose the Contractor shall assess which are the lightning protection zones - LPZs - around and within the antenna structure. LPZs are defined as follows:

- LPZ 0A: zone where items are subject to direct lightning strokes and therefore may have to carry up to the full lightning current. The unattenuated electromagnetic field occurs here.
- LPZ 0B: zone where items are not subject to direct lightning strokes but the unattenuated electromagnetic field occurs.
- LPZ 1: zone where items are not subject to direct lightning strokes and where currents on all conductive parts within this zone are further reduced compared with zones 0B. In this zone the electromagnetic field may also be attenuated depending on the shielding measures.
- LPZ 2 and higher: zone where a further reduction of conducted currents and/or electromagnetic field is required.

Structural bonding shall be adopted in order to obtain from "natural" components - as far as possible - the shielding measures required by the lightning protection zones 0B and higher.

For each piece of equipment to be installed and for each conductive part to be laid (thereby including cables of any types and for any applications, metallic pipes, etc.), the Contractor shall choose which is the appropriate lightning protection zone. Upon need, the Contractor shall conveniently design or re-design dimensions, form and borders of the lightning protection zone of the requested level.

As far as possible, conductive parts (i.e., cables of any types and for any applications, metallic pipes, etc.) laid within a given lightning protection zone (e.g., LPZ 0B) shall enter into an inner lightning protection zone (e.g., LPZ 1) at a single point of entry. At this point the conductive parts shall be bonded to the boundary (shield) between the outer and the inner LPZ. Conductive parts not carrying operating currents/voltages - and, therefore, including protective conductors (equipment grounding conductors), metal conduit, armours, sheaths, shields, etc. - shall be bonded directly to the boundary (shield) by means of bonding conductors (clamps). Cross-sectional areas of these bonding conductors shall be those requested by NFPA 780 or by IEC 61024-1.

Live conductors of any circuits (power, data, signal, communication, control, etc., thereby including the neutral conductor N of power circuits) shall be bonded to the boundary by means of surge protection devices (surge arresters).

Live conductors liable to carry a substantial part of lightning current (i.e., those entering the boundary between LPZ 0A and LPZ 1) shall be bonded to the boundary by means of surge protection devices with the following minimal characteristics (the so-called lightning arresters):

- lightning test currents (10/350 μs) $i_B \geq 100$ kA

• specific energy $\int j^2 \geq 2.5$ MJ/Ω (MA^2s)

Live conductors liable to carry no substantial part of lightning current (i.e., those entering any boundary between LPZ 0B and LPZ 1) shall be bonded to the boundary by means of surge protection devices with the following minimal characteristics (the so-called overvoltage arresters):

• nominal discharge currents (8/20 μs) $i_{sn} = 5$ kA

Live conductors to be connected to equipment particularly susceptible to overvoltages shall be bonded to the boundary by means of a chain of surge protection devices (e.g., a gas discharge tube, a varistor and a Zener diode with inductors as separating impedances).

3.5.8.4 ADDITIONAL ELECTRICAL REQUIREMENTS

Smoke detectors are required in any equipment compartment in the base of the antenna and in the receiver cabin and shall be interlocked to shunt trip all electrical power in the antenna. When smoke is detected the detector will immediately close a contact which will be used by AUI for a remote fire alarm and will energize a local audible alarm. The shunt trip of all power will occur 5 seconds after smoke detection. Emergency power for the smoke detectors and local alarm shall utilize "Gel-cells" with a minimal reserve of 6 hours.

Single phase and reverse phase protection is required and will be interlocked to remove all electrical power on the antenna. When a single phase or reverse phase problem is detected the detector will immediately close a contact which will be used by AUI for a remote alarm. The shunt trip of all power will occur 5 seconds after detection of the problem. This shunt trip shall automatically reset after proper conditions are restored. Emergency power for the single phase and reverse phase detectors shall utilize "Gel-cells" with a minimal reserve of 6 hours. All electrical and electronic wires shall be in metal conduits unless specifically approved by AUI.

3.5.9 MAINTENANCE AND RELIABILITY

The antennas shall be designed so that, with normal preventive maintenance, they will operate for 30 years, with 24 hours per day of continuous operation, without requiring the replacement of the elevation bearings, azimuth bearing, reflector surface, antenna structure, or drive surfaces. In order to deal with the possibility of a premature failure a straightforward elevation and azimuth bearing replacement procedure must be included in the antenna design. For all purchased mechanical and electrical components the Contractor shall provide the supplier's lifetime and MTBF specifications for the component.

To the maximum extent feasible, all equipment shall be designed to be repaired by replacement of spare plug-in modules or assemblies so as to minimize any need to repair a failed component in place. Design features shall be incorporated in the antennas to permit the removal, repair, and replacement of components subject to wear or contamination. Bearings (excluding the azimuth and elevation bearings), drive motors, gearboxes, HVAC equipment, etc., that are subject to wear and

contamination shall be easily accessible with minimal removal of other components. All mechanical and electrical components (excluding the azimuth and elevation bearings) that are integral parts of the antenna structure shall be designed to be removed and replaced by a two-person crew in a period of no more than 4 hours. All parts shall be interchangeable with like parts with minimal adjustment.

3.5.10 Disassembly

The prototype antenna will be tested initially at the VLA site and later disassembled and shipped to the ALMA site in Chile. The ability to disassemble the antenna into pieces for economic overseas shipping is required. AUI will be responsible for this future disassembly, shipping and reassembly of the antenna. The Contractor will deliver this disassembly/reassembly procedure at the end of the design phase of the contract. Disassembly of the antenna shall be sufficient to allow the pieces to fit in an industry standard overseas freight container, the dimensions of which are approximately 12 meters in length, 2.3 meters in width, and 2.6 meters in height. There may be exceptions made to this requirement if the Contractor can show that this requirement will significantly increase the cost of the antenna compared to the cost of shipping an oversize piece. The disassembly/reassembly procedure must be approved by AUI.

It is likely that the production antennas will be assembled, outfitted and tested at a low (2400 m) altitude site 50 km from the high altitude ALMA site. The antenna would then be split into two pieces, the mount and the reflector, for transport to the high altitude site. For this purpose the antenna shall be designed for ease of disassembly and reassembly at the elevation axis. The Contractor will provide connectors on all cables to allow them to be disconnected at the elevation axis. Pickup points will be provided on both the mount and reflector so that they can be lifted as entire units.

3.5.11 Safety

The antenna shall meet all applicable requirements of National Electrical Code, Occupational Safety and Health Administration Standards, Underwriters Laboratory Requirements 1950 and the contract. This is particularly important when designing for preventive maintenance during antenna operation.

All machinery shall be covered or protected in such a way that working personnel are not subject to hazards. All axis drives will have Castell lockout systems or equivalent system approved by AUI. All brake system shall be of a fail-safe type.

3.6 Summary of AUI and Contractor Interfaces

3.6.1 Monitor and Control Digital Interfaces

AUI will provide specifications and guidelines for the Monitor and Control Digital Interface in Section 3.5.6 and the ALMA ICD No. 9 "Antenna/Monitor and Control Interface, Version A."

Contractor will provide a monitor and control interface that will meet AUI's requirements.

3.6.2 Interface to Cable Wraps

A cable wrap or loop shall be provided in azimuth and elevation which will accommodate all Contractor-provided cables and AUI cables and be of the bending type only. The ALMA ICD No. 6 "Antenna/Cable Wrap Interface, Version A" lists all the AUI cables and hoses for elevation and azimuth wraps. The cable wrap shall permit full angular rotation of the antenna as specified in 3.4.1. The cable wrap arrangements shall be such that cables are neither excessively stressed by twisting or bending, nor damaged by pulling over edges of fixed structure.

AUI will provide and install all its own cables and hoses.

The Contractor shall provide cable wraps. Contractor shall provide pass throughs for all cables from the entrance at the base of the telescope to the inside of the receiver cabin. Two cable/hose feed-through plates will be provided by the Contractor of size 30 cm x 60 cm. The base plate will bolt to the base of the antenna from inside. The second plate is at the receiver cabin and will bolt to the outside of the receiver cabin.

3.6.3 Interface to On-axis Cable Wraps

Provisions will be made for a separate, special, stable fiber optic cable wrap that will pass through the two axes of the telescope. These on-axis cable wraps will hold a fiber optic cable fixed between axes. AUI will be responsible for providing this cable wrap.

The Contractor shall provide accesses in the azimuth and one in the elevation axis for this on-axis special cable wrap. A minimum diameter hole of 28 millimeters through the center of each axis will be required. This shall include a hole of this size through the azimuth encoder. The details required in the on-axis cable wrap are specified in ALMA ICD No. 6 "Antenna / Monitor and Control Interface, Version A."

3.6.4 Receiver Package Interface

AUI provides receiver specifications in ALMA ICD No. 1 "Antenna/Receiver Interface, Version A."

Contractor will design and provide a receiver mount that meets all antenna specifications.

3.6.5 Receiver Cabin Equipment Rack Interface

AUI provides receiver cabin equipment rack specifications in ALMA ICD No. 10 "Antenna/Receiver Cabin Equipment Rack Interface, Version A" and will provide the receiver cabin equipment racks and installation of the unit.

Contractor will design and provide a receiver cabin equipment rack mounting that meets all antenna specifications and provides cooling for the equipment racks (see Section 3.5.4).

3.6.6 Receiver Package Installation Interface

AUI provides receiver package specifications in ALMA ICD No. 1 "Antenna/Receiver Interface, Version A" and installation guidelines in Section 3.5.4.

Contractor designs and installs the receiver package installation system.

3.6.7 Helium Compressor Interface

AUI provides the helium compressor specifications in ALMA ICD No. 7 "Antenna/Helium Compressor Interface, Version A" and will install helium compressor, including hoses and cables.

Contractor designs location for helium compressor and provides power receptacle, ventilation, hose, and cable pass-throughs. This design will include a simple method for installing and removing the compressor from the antenna structure. The Helium compressor shall be located on the antenna above the azimuth bearing and shall not tip with the elevation structure in order to keep helium lines (high pressure gas lines) relatively short and minimize the flexing of these lines. The Contractor shall provide a suitable compressor platform at a location of his/her choosing with AUI's approval.

3.6.8 Transporter Interface

AUI shall provide guidelines for transporter interface in Section 3.5.2 and in the ALMA ICD No. 5 "Antenna/Transporter Interface, Version A." AUI shall approve Contractor's design of the antenna transporter interface.

Contractor designs antenna transporter interface that is approved by AUI.

3.6.9 Foundation Interface

AUI provides site soil report and provides foundation as specified and described in ALMA ICD No. 4 "Antenna/Site Foundation Interface, Version A."

Contractor designs and documents three foundations based on soils report. Contractor provides all interface mechanical and electrical connection hardware for one foundation.

3.6.10 Optical Telescope Interface

AUI provides specification in the ALMA ICD No. 8 "Antenna/Optical Pointing Telescope Interface, Version A" for the optical telescope.

Contractor designs, documents, and provides the interface between the optical telescope and the antenna system. AUI provides and installs the optical telescope.

3.6.11 Molecular Sieve Interface

AUI provides manufacturer's specifications for a molecular sieve for oxygen enrichment of the receiver cabin (see Appendix B). AUI will purchase this item and install it on the antenna.

Contractor will design a mounting location on the antenna for the molecular sieve that is in accordance with the manufacturer's specifications.

3.6.12 Electrical Power Interface

AUI provides electrical power specification in Section 3.5.8.1 and in ALMA ICD No. 3 "Antenna/Site Electrical Power Interface, Version B."

Contractor shall design antenna to meet entrance power specification.

3.6.13 RF- Transparent Membrane Interface

AUI provides material for membrane and location (3.5.4).

Contractor shall design and install membrane at vertex hole.

3.6.14 Computer Actuated Shutter Interface

AUI provides specification in (3.5.4).

Contractor shall design and provide the computer actuated shutter to specifications.

3.7 Materials and Fabrication

3.7.1 General

Materials shall be in agreement with the general requirements as set down in these specifications. It shall be the responsibility of the Contractor to prepare specific material specifications for the various components of the antenna. These specifications may be either on the drawings or in a separate document and shall be subject to AUI review and approval. Fabrication shall be in accordance with best shop practices and shall be fabricated to proper size and tolerance as shown on the approved drawings.

3.7.2 MATERIALS

The elevation-over-azimuth mount is to be of carbon or low alloy steel using the most economical shapes available from both a weight and fabrication cost standpoint. The type of steel selected for the mount structure shall be such that the low temperature embrittlement characteristics shall be acceptable. The nil-ductility transition temperature of the selected material shall not exceed -45 C. Nil-ductility transition temperature is defined as a temperature below which a specimen will exhibit cleavage fracture with very little or no evidence of notch ductility. It is the intent of these specifications to secure a metal which at the lowest operating temperature will not be brittle enough for flaws or defects in joints or welds to be subject to brittle propagation.

All components which are designed for welded connections shall be weldable grade material. Bull gears and pinions, if used, shall be of a material having a minimum hardness of 255 BHN and shall be surface hardened as required by life of the system (Section 3.1.2 #1).

The Contractor shall consider annealing steel structures to removed locked in stresses and long term creep, important for reducing nonrepeatable structural deformations and achieving pointing specifications.

For those parts of the antenna fabricated from CFRP the Contractor will provide AUI, for approval, specifications for all materials and processes required for the fabrication. For the bonding methods selected for CFRP to CFRP joints or for CFRP to metal joints the Contractor will perform tests on sample joints to verify that the required strength and lifetime are achieved. Special attention will be given to the problem of degradation of CFRP by solar radiation. All CFRP structure will be protected from solar radiation either by a sun shade or by a suitable coating. The Contractor shall make considerations for the Chile site being of low humidity in the selection and design of items made out of CFRP.

3.7.3 MANUFACTURE

All structural components shall be manufactured to proper size and tolerance and in the manner shown on the approved drawings. Methods of manufacture shall be of the best shop practice. Mis-manufactured members shall be discarded and not repaired unless prior written approval is obtained from AUI. Shop connections for metal structure may be either welding or bolting (as stated in the design drawings), but components to be field assembled shall be high strength bolted. All holes shall be drilled or sub-punched and reamed according to good practice so that connection clearances may be held to a minimum. Manufacture and assembly of all components will be such that uniform dimensions of the components and sub-assemblies of the antenna may be maintained and maximum commonality of both components and antennas built using the design may be maintained.

3.7.4 PROTECTIVE COATINGS

The reflector surface of the antenna will be unpainted but will have a suitable surface treatment to enable direct observations of the sun without causing heat damage to structure and components in the vicinity of the antenna apex (see Section 3.4.7).

To limit the effect of solar heating and associated differential expansion of structural members and to protect the structure against atmospheric corrosion, the antenna structure, with exception of the reflector surface, shall be painted with white solar reflecting paint. The paint will be chosen to last at least 10 years before repainting is necessary. Special attention will be given to the severe solar radiation environment on the high-altitude site. The Contractor will provide a specification for material, preparation, application and quality control testing for the paint system for approval by AUI. Prior to submitting the paint specification for approval, the Contractor will provide AUI with the results of accelerated testing of samples which demonstrates the adequacy of the paint system.

3.8 FIELD ASSEMBLY

3.8.1 GENERAL

The Contractor will assemble and test this prototype antenna at the site of the ALMA Test Interferometer which will be located at the Very Large Array (VLA) Radio telescope site. The VLA is located 80 km west of Socorro, New Mexico on U.S. Rt 60 at an elevation of 2100 m. At the VLA the following facilities can be made available to the Contractor at no cost provided that an agreement concerning the liability assignment, scheduling and operation of the facilities is negotiated between the Contractor and AUI.

VLA facilities:

(1) Mobile cranes: 30 tons (short), 30 tons (short), 5 tons (short).
(2) Man lifts and fork lifts.
(3) Fully equipped machine shop for making field modifications.
(4) Sleeping, bathroom and cooking accommodations.

The antenna will be assembled and tested on an antenna foundation designed by the Contractor and provided by AUI (Section 3.5.3). The foundation is approximately 800 m from the AAB. An ALMA antenna transporter will NOT be available at the time of the assembly of the antenna.

The Contractor shall furnish all materials, plant and equipment, tools (except such materials, plant and equipment, and tools as may be furnished by AUI as provided elsewhere in this document) and all labor, services and supervision necessary to complete the assembly, alignment and testing of the antennas.

3.8.2 WORK AT THE SITE

Special and other conditions applying to work at the site are contained in Attachment B.

3.9 DRAWINGS, SPECIFICATIONS AND OTHER DATA

3.9.1 DESIGN AND MANUFACTURING DRAWINGS

Design and manufacturing drawings shall be produced on standard size drawing forms whose size and format have been approved by AUI. Drawings shall conform to good commercial practice and use symbols, conventions, and notations endorsed by manufacturing and standards associations such as the Drawing Requirements Manual by Jerome H. Lieblich (ISBN 1-57053-034-3), DIN or ISO codes . At the start of the design phase, the Contractor shall submit a copy of his/her drafting standards to AUI for its review and approval. The electronic format of documentation shall be in the following formats: AutoCAD Release 14, Microsoft Word 97, Microsoft PowerPoint 97 and Adobe PDF Version 4 or the latest version available. Three printed copies and one editable electronic version of all design and manufacturing drawings shall be submitted to AUI for its review and approval at the time of completion of the drawings. On board reviews may be substituted. One reproducible and three printed copies shall be furnished to AUI after approval of drawings. One reproducible copy and an editable electronic copy of all drawings generated by the Contractor or any sub-contractor will be supplied as part of this contract. The final drawing sets will be the as-built fabrication drawings, schematics, assembly drawings, alignment procedures, procurement specifications, and parts list required to duplicate the antenna system. As-built drawings shall be final and reproducible. "Red-lined" drawings are not considered as final. Lower tier Contractors will furnish sufficient drawings so that their equipment can be fabricated, operated and maintained by AUI. All documentation (drawings, specifications, data and calculations) shall be written in the English language. The coordinate system for design, drawings and FEA modeling shall conform to ALMA ICD No. 11.

3.9.2 DESIGN CALCULATIONS AND DATA

Three printed copies and one editable electronic copy of all design calculations, design data, studies, or other information prepared or utilized by the Contractor in the performance of the work shall be delivered to AUI. One copy of all computer programs, calculation runs, and printouts shall be furnished for AUI's review. When a computer program is not owned by the Contractor, input and output data will be provided along with the identification of the computer program. All structural input data will be provided on CD-ROMs. Calculations and data to be provided will include, but will not be limited to:

1. Gravitational Deformation Calculations
2. Eigenfrequencies and Eigenmodes
3. Wind Loading Conditions
4. Wind Pointing Calculations

5. Thermal Loading Conditions
6. Thermal Pointing Calculations
7. Survival Wind Calculations
8. Path Length Error Calculations
9. Servo Analysis
10. Dynamic Analysis of Fast Switching
11. Dynamic Analysis of Application of Brakes at Full Velocity
12. Surface Error Budget
13. Pointing Error Budget
14. Path Length Error Budget
15. Metrology Analysis
16. HVAC System Calculations
17. CFRP Properties
18. CFRP Processes
19. BUS Connection Joint Analysis
20. Antenna Stress Analysis
21. Foundation Design Analysis
22. Dynamic Seismic Analysis
23. Structural Fatigue Analysis
24. Grounding Counterpoise Design and Analysis with Impedance Calculation for all Grounding Wires
25. High Altitude Cooling Analysis of all Electrical Components
26. Dynamic Seismic Analysis and Antenna Transporter Shock Analysis
27. Documentation on Suppliers' MTBF and Lifetime specifications for all Electrical and Mechanical Components
28. Mass optimization study to minimize the mass of the antenna.

Current FEA models shall be provided to AUI on a monthly basis with the first FEA model due one month after the contract is awarded. These models shall include descriptions of changes made since the previous version. Contractor shall state accuracy of the FEA models describing all relevant assumptions and loadings. All documentation (drawings, specifications, data and calculations) shall be written in the English language. The antenna coordinate system used for FEA models and drawings shall conform to the coordinate systems defined in ALMA ICD 11 Basic Antenna Definitions.

3.9.3 Manufacturing and Procurement Specifications

Three (3) printed copies and one (1) editable electronic copy of all manufacturing and procurement specifications, referenced on any drawing or prepared for procurement of purchased items, are to be submitted for AUI approval.

3.9.4 TESTS, ASSEMBLY, ALIGNMENTS, AND ACCEPTANCE

3.9.4.1 ASSEMBLY AND ALIGNMENT PLANS

The Contractor shall, at the completion of the detailed design, prepare and submit to AUI for its approval the following items:

(a) An assembly plan which shall specify each step in the assembly, equipment to be used, the facilities to be used, and a schedule for the completion of the work.

(b) An alignment plan which shall demonstrate to AUI the methods to be used to ensure that the alignment tolerances specified in this document and specified in the antenna Contractor's design effort shall be accomplished. Performance parameters and error budgets set forth in the specifications shall be satisfied.

(c) A plan for the disassembly of the antenna, shipping to Chile and reassembly. Execution of this plan is not part of this contract.

3.9.4.2 TESTS AND INSTRUMENTATION

The Contractor shall provide all special instrumentation and equipment required to align and test the antenna structure accurately. The term special instrumentation and equipment is defined to be equipment which is specially designed for alignment or testing of the antennas. Procedures and reference points, required for the initial alignment of the antennas and periodic checking thereafter, shall be furnished by the Contractor. Consideration shall be given to preserving the reference marks made on the antennas in the process of initial alignment and adjustment for operational use. The alignment tolerance shall be consistent with and reflected in the system accuracy analyses required in this document.

3.9.4.3 TESTING AND ACCEPTANCE

The Contractor shall prepare a test plan to be approved by AUI that will qualify the mechanical, electrical, safety, and electronic equipment performance in accordance with this specification after assembly and alignment are completed.

Because of the precision required and the range of environmental conditions specified, AUI does not consider it feasible for the Contractor to demonstrate by test full compliance with the reflector surface accuracy (3.4.2), pointing accuracy (3.4.3) and path length error (3.4.5) specifications. The full performance of the antenna with respect to these specifications will be determined by AUI using extended radioastronomical tests after AUI has accepted the antenna from the Contractor. For these specifications AUI will accept the gravity, wind and thermal performance of the antenna on the basis of the Contractor's calculations, approved by AUI, that demonstrate that the allocations for gravity, wind and thermally induced errors in the specification error budget have been achieved. The

acceptance of the antenna on the basis of these calculations shall not be deemed a waiver of the Contractor's responsibility to meet the specification. The Contractor will provide tests to demonstrate that other entries in the specification error budget have been achieved. If the Contractor provides any metrology equipment, tests will be provided to demonstrate the correct operation of this equipment. For the pointing specification the Contractor will provide tests which use the optical telescope supplied by AUI (see Section 3.6.10) to confirm the correct operation of the antenna drive system and the pointing performance of the antenna mount. The Contractor should assume that the optical telescope will provide pointing information accurate to 0.2 arcsecond in 1 second of time. Further details concerning acceptance of the surface accuracy specification are given in Section 3.9.4.4 below.

Three (3) printed copies and one (1) editable electronic copy of the test plan shall be submitted to AUI for its approval prior to commencement of acceptance testing of the antenna. Approval of a test plan shall not preclude AUI from requiring additional testing. In addition, it shall not be deemed a waiver of the requirement to demonstrate the performance of the antenna in accordance with any or all of the performance specifications. The tests and alignments shall be conducted by Contractor personnel in the presence of an AUI representative unless written authority is obtained to do otherwise. During this testing program, the Contractor shall demonstrate to AUI that the performance specifications set forth in this document have been met.

3.9.4.4 REFLECTOR SURFACE ACCURACY TESTS

Since the final precision adjustment of the primary reflector surface panels is the responsibility of AUI (see Section 3.4.2), it will not be possible for the Contractor to demonstrate that the specified primary reflector surface accuracy has been achieved prior to handing the antenna to AUI. Instead the Contractor will prepare and execute a plan that demonstrates, either by calculation or test, that all components of the primary reflector surface accuracy error budget under Primary Operating Conditions, except reflector panel setting, have been achieved.

The Contractor shall conduct a survey of the primary reflector surface after adjustment using his/her instrumentation and personnel to demonstrate that the reflector as installed meets the coarse adjustment setting accuracy of 100 micrometers rms with the antenna positioned at the zenith. The Contractor will propose a measurement method of suitable accuracy to achieve this coarse setting. AUI shall approve the Contractor's instrumentation and method of survey before this survey is conducted. Surveys shall be conducted at times of minimum wind and thermal loading (i.e., on windless nights) with the reflector positioned at the zenith. Measurements shall be made to reference points on reflector panels and adjacent to the panel adjustment points. These measurements shall then be reduced to a RMS error from a best-fit paraboloid. The acceptance of the paraboloid will be based on the acceptable results of these surveys.

3.9.5 QUALITY ASSURANCE INSPECTION PROCEDURES

The Contractor shall submit three (3) printed copies and one (1) editable electronic copy each of quality assurance and inspection procedures to AUI for review and approval prior to the start of procurement and manufacturing.

Quality assurance tests will be performed on materials, components, and assemblies as specified in the quality assurance procedure. AUI will be notified prior to these tests and may be a witness to such tests. All quality assurance test results recorded by either the Contractor or its Contractors shall be signed and submitted to AUI in an approved documented form. AUI may perform such inspections or tests it considers necessary on any component or assembly during or after fabrication at the site of fabrication or the site of assembly. Copies of test results normally performed by suppliers, such as certificates of conformance for steel, bearings, etc., shall be supplied in duplicate to AUI.

3.9.6 OPERATION AND MAINTENANCE MANUALS

The Contractor shall deliver at the start of assembling the antenna three (3) printed copies and one (1) editable electronic copy of an Operation and Maintenance Manual. This Operation and Maintenance Manual shall contain the following information:

(a) Manufacturers' drawings, exploded view assembly drawings, parts list and recommended lubrication procedures for all mechanical components. Manufacturers' drawings, parts lists, specifications, wiring diagrams, and testing procedures for all electronic components. A lubrication schedule showing lubrication points, types of lubrication, recommended lubricant, and frequency of lubrication.

(b) A maintenance section that describes the method for removal of mechanical components, methods and control to be used to reassemble and realign components that might be reasonably expected to be replaced because of wear characteristics. Assembly and subassembly drawings, which include mechanical setting dimensions such as bearing preload, gear runouts, gear backlash settings, torque bias settings, drive train alignment requirements, and the weight of components.

(c) An operations section, which describes the function of the various mechanical and electrical components of the antennas. A narrative section shall be provided which describes the various controls and modes of operation which also includes illustrations of the control circuitry.

(d) A safety section, which details the required safety means and methods necessary to provide access and safe work platforms/areas for routine maintenance and operation activities.

3.9.7 SPARE PARTS

Within sixty days of the approval of the detailed design, the Contractor shall submit a recommended spare parts list. Three (3) printed copies and one (1) editable electronic copy of the list shall be furnished to AUI. Each item listed shall be detailed as to the identity, OEM part number, drawing reference, original manufacturer, model number, etc.

AUI shall have the right by change order to its contract to order such spare parts as it has selected and/or such parts, whether so selected or not, which were originally manufactured by the Contractor. The Contractor agrees to negotiate in good faith to arrive at a firm fixed price for such spare parts.

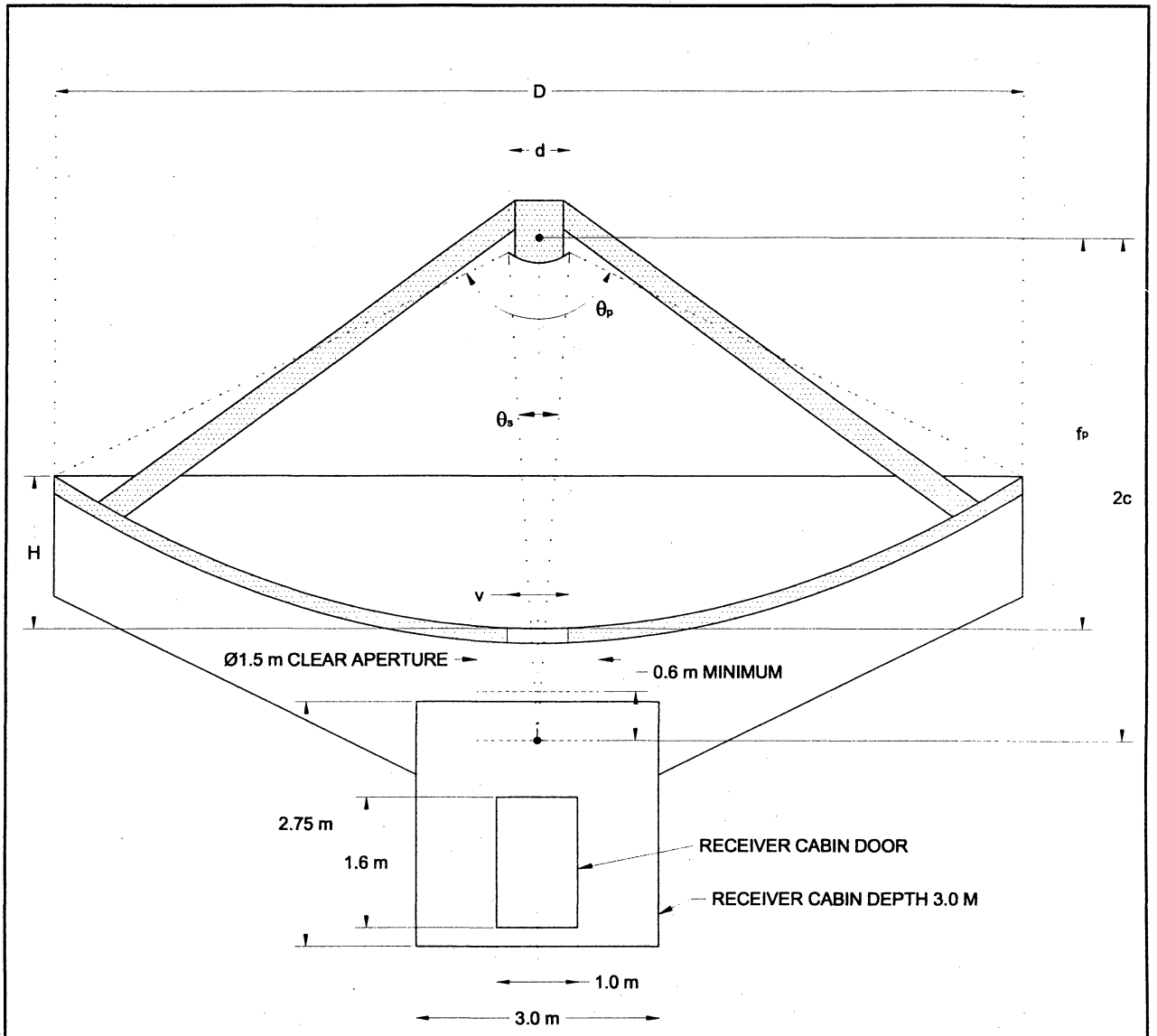
The Contractor shall maintain the capability to furnish AUI the agreed spare parts for a period of ten years from the acceptance of the final antenna.

AUI may purchase such spare parts from any supplier or have such parts manufactured by others as it appears in its best interest to do so, without limitation or liability to the Contractor and/or its lower tier Subcontractor(s).

APPENDIX A

ANTENNA OPTICAL CONFIGURATION

ALMA
OPTICAL CONFIGURATION



OPTICAL CONFIGURATION			
D	Primary Aperture	12.0 m	472 in
f_p	Focal Length of Primary	4.8 m	189 in
	fp / D of Primary	0.40	0.40
d	Secondary Aperture	0.75 m	29.5 in
	Final f / D	8.00	8.00
	Magnification Factor	20.0	20.0
θ_p	Primary Angle of Illumination	128.02°	128.02°
θ_s	Secondary Angle of Illumination	7.16°	7.16°
2c	Distance Between Primary and Secondary Foci	6.177 m	243.2 in
H	Depth of Primary	1.875 m	73.8 in
v	Primary Vertex Hole Clear Aperture	0.75 m	29.5 in

VERSION 2 (1999 MAY 21)

APPENDIX B

MOLECULAR SIEVE INTERFACE

For additional information call
Toll-Free U.S./Canada:
800-874-0202

AS-12
Specifications

AirSep Corporation
290 Creekside Drive
Buffalo, NY 14228-2070 USA
Tel: (716) 691-0202 24 Hr. Fax: (716) 691-0707
TELEX: 6102500585 AIRSEP

Dewpoint:	–100° F (–73° C)
Feed Air Requirements:	None if equipped with compressor. 150.0 SCF/hr @ 30 psig 3.9 Nm³/hr @ 207 kPa
Sound Level:	55 dba @ 1 meter, open field conditions (with enclosure)
Dimensions:	17.25 x 10 x 26.75 inch (WxDxH) 44 x 25.5 x 68 cm (WxDxH)
Weight:	55 lb. (25 kg.) 46 lb. (21 kg.) less enclosure 25 lb. (11.5 kg.) less compressor
Power Requirements:	120 VAC, 60 hz, Single Phase, 4.0 ampere (with compressor) 220 VAC, 50 hz, Single Phase, 2.0 ampere (with compressor) Other voltages available.
Power Consumption:	350 watts (with compressor) 25 watts (less compressor)
Oxygen Outlet:	'B' size oxygen adaptor

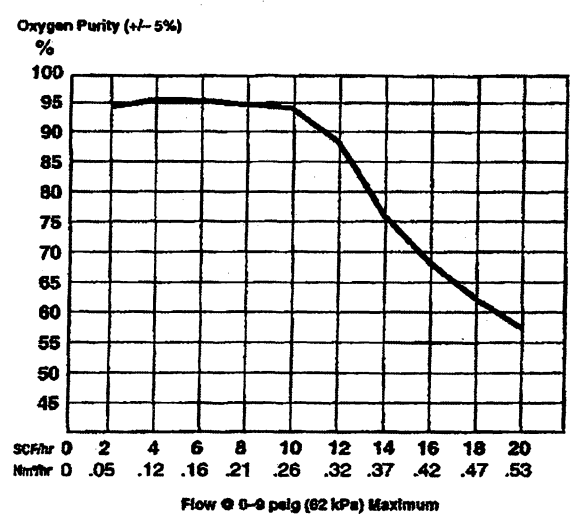
Operating Conditions:

The generator must be located in a well ventilated area which remains above 40° F/5° C and below 100° F/38° C. Operating the generator in an area below 40° F/5° C, or above 100° F/38° C will cause damage not covered under the manufacturer's warranty. AirSep Oxygen Generators are sold for use in industrial applications only. The generator must not be used for any "respiratory" medical application.

Standard Accessory Kit Included With Unit Contains:

1 ea. Instruction Manual
1 ea. Cross Particle Filter
1 ea. Barbed Hose Connector

Generator Output



Flow @ 0–9 psig (62 kPa) Maximum

Note: Contact Factory for operation at higher pressures and/or flows.

Ordering Information:

Description	Part Number
~~AS-12 Oxygen Generator (120 VAC)~~	~~AS-00-012~~
~~AS-12 Oxygen Generator (220 VAC)~~	~~AS-00-012E~~
Options:	
Description	**Part Number**
~~Deduct Enclosure~~	~~SB-IN-002~~
Deduct Compressor Assembly	~~SB-IN-000~~

ATTACHMENT B

TERMS AND CONDITIONS

SPECIAL CONDITIONS OF THE CONTRACT

SC1. ORDER OF PRECEDENCE

Any inconsistency in this contract shall be resolved by giving precedence in the following order: (a) Special Conditions of the Contract, Attachment B; (b) General Conditions of the Contract, Attachment B; (c) Specifications and Statement of Work, Attachment A, and drawings, excluding the Contractor's proposal; (d) Interface Control Documents (ICD); (e) other provisions, documents, exhibits, and attachments, including the Contractor's proposal.

SC2. CHANGE ORDER AUTHORITY

No change in contract performance, specifications, terms and conditions or other matters affecting the work or contract price shall be authorized unless in writing signed by the Director of NRAO or his/her authorized representative designated in writing and acting within the scope of his/her authority. Any changes made or work performed outside of the scope of the contract prior to the receipt of a written Change Order shall be solely at the Contractor's risk and expense.

SC3. SUPERVISION OF THE WORK

Technical direction and supervision of the work in accordance with the terms of this contract will be under the direction of the ALMA U.S. Project Manager. Unless otherwise designated, the authorized representative for contractual matters shall be the ALMA Business Manager.

Under this contract, all rights and privileges, claimed by and accorded to Associated Universities, Inc., (AUI) shall be extended to any ALMA Project managing entity which shall be organized and implemented, and of which the Contractor has been notified in writing.

SC4. LIAISON DURING DESIGN AND FABRICATION PROGRAM

Periodic technical and progress review meetings are to be held between the Contractor and AUI during the design program. The place and time of such meetings will be determined by the ALMA U.S. Project Manager appointed by AUI. At least two of these meetings will be formal review meetings, a preliminary design review (PDR) and a critical design review (CDR). These meetings will be held at the Contractor's facilities. In addition to these face-to-face meetings a weekly teleconference will be held between Contractor and AUI personnel to discuss progress and problems.

It is expected that AUI technical representatives will spend considerable time, up to and including full time, at the Contractor's home plant or at plants of any Subcontractor during design

and fabrication. The Contractor shall provide, at no cost to AUI, acceptable office space for the AUI representative, with private telephone connection, and shall ensure that its subcontractors, at any level, also provide the same.

SC5. SCHEDULE

The Contractor shall, within fifteen (15) working days after notice of award of the contract, prepare and submit to the ALMA U.S. Project Manager for approval three (3) copies of a practicable detailed schedule, both in hard-copy and electronic (digital) form, showing the Work Breakdown Structure (WBS) of the project, the working order in which the Contractor proposes to carry on the work, the date on which he/she will start each phase, subdivision, and task (including the procurement of materials, plant, and equipment). The work breakdown shall be of adequate scale so that all information required can be entered legibly. Dates for the PDR and CDR, delivery of Complete Design Documentation Package, approval of Complete Design, fabrication, shipment, erection, and test of the telescope shall be shown. The project critical path shall be clearly shown.

Fabrication of the antenna shall not begin until the Complete Design Documentation Package has been approved by AUI, except for specific long-lead items approved by AUI.

SC6. MANPOWER SCHEDULE

The Contractor shall furnish a curve or graph depicting the anticipated design, fabrication, and assembly manpower requirements of the contract.

SC7. UPDATING SCHEDULES

The Contractor shall enter on the approved schedule the actual progress at the end of each month and deliver to the Project Manager three (3) copies by the fifth working day of the month following.

The Contractor shall keep the approved progress schedule and manpower chart in accord with the job conditions, making internal changes as necessary and incorporating any AUI-required changes to the schedule. The Contractor shall not, however, make changes of any kind that will affect price or the completion date of the project without a written change order to the contract. If extensions of time are granted by AUI, the Contractor shall within five (5) working days revise the schedule and manpower chart accordingly and submit three (3) copies of each.

SC8. WORK PROGRESS

The Contractor shall furnish sufficient forces, construction plant and equipment, and shall work such hours including night shifts, overtime operations, and holiday work as may be necessary to ensure the prosecution of the work in accordance with the approved progress schedule. When, in the opinion of the ALMA U.S. Project Manager, it appears the Contractor is falling behind on the approved schedule, the Business Manager will so notify the Contractor in writing. The Contractor

shall confirm the schedule slippage and submit for approval the necessary plan to accomplish a schedule recovery and shall initiate such plan within five (5) working days. The plan may include a manpower increase, increase in number of shifts worked, additional days of work, overtime operations, and/or increase in construction plant; all without additional costs to AUI.

SC9. OTHER DATA

In addition to the requirement set forth in this section, if the Contractor uses other techniques to schedule and manage the work, three (3) copies of all such documents will be submitted for information to the ALMA U.S. Project Manager.

SC10. STATUS REPORT

In conjunction with the updated schedule required in paragraph SC7, the Contractor shall submit a monthly status report setting forth the status of the work under the contract. The report shall contain, but not be limited, to the following:

- Work completed during the month
- Progress to date
- Problems encountered and solutions
- Explanation and detail for any schedule delays and recovery schedule plans or schedule advances
- Planned activity for ensuing month
- Number of assigned employees by classification, and manhours spent, during the previous month
- Planned personnel and manhour loading for ensuing month

Reports will be signed by the Contractor's authorized representative and transmitted to the ALMA U.S. Project Manager by the fifth day of the following month.

SC11. PROJECT BREAKDOWN FOR SCHEDULING AND PAYMENT

The Contractor shall within fifteen (15) working days after award of the contract, and prior to any progress payment request, prepare and submit to the ALMA U.S. Project Manager for approval a comprehensive price breakdown of the project for use in scheduling the work and for payment. This breakdown shall be in a form adequate for control of progress payments by AUI. Sub-items shall total to the price breakdown submitted in the proposal or as negotiated prior to the award of the contract.

SC12. PROGRESS PAYMENTS

Progress payments shall be made to the Contractor based on the percentage of acceptable work completed. The Contractor shall permit AUI personnel to physically identify materials delivered.

The Contractor shall file a monthly statement with its invoice detailing the percentage of completion in accordance with the project breakdown provided under paragraph SC5. above.

No monthly progress payment shall be made until the progress schedule has been updated and submitted.

Payments shall be in accordance with the terms of the Progress Payments clause. All request for payment shall be made in United States dollars. All payments will be made in United States dollars.

SC13. RELEASE OF CLAIMS

The Contractor shall submit to AUI a Release of Claims in the form set forth in Attachment C hereof, as a condition precedent to final payment by AUI. Any balance due to the Contractor under the progress payments provisions of this contract as a result of final acceptance of the antenna will be held by AUI until a Release of Claims has been received by AUI.

SC14. U.S. GOVERNMENT PROPERTY

No materials, property, or facilities will be furnished by AUI or the U.S. Government unless otherwise provided herein or agreed to in writing during the course of the project.

SC15. TOOLING AND TEST EQUIPMENT

Any permanent tooling, special tooling, or special test equipment which has been fabricated, purchased, or otherwise procured, such as assembly fixtures, measuring devices, jigs, etc., that are used to fabricate or assemble any components, to locate, measure, or adjust any components or assemblies, or to perform any special operation during the scope of the work shall become the property of the U.S. Government. All permanent tooling, special tooling, and special test equipment shall be delivered to AUI or disposed of at AUI's direction. Optical tools, inclinometers, levels, theodolites, and similar tooling which are not purchased specifically for this job and whose purchase price is not included in the cost of the work herein are excepted from this requirement.

The design and accuracy of all tooling is the responsibility of the Contractor.

SC16. CONTROL OF THE ERECTION SITE

The ALMA U.S. Project Manager, or his/her designee, will have authority to control the erection site. His/her authority shall include but not be limited to the following:

- Assignment of work areas
- Assignment of storage space
- Access and other roads

- Utilities
- Vehicle traffic and parking
- Conduct of personnel
- Safety and fire protection
- Security

SC17. On-Site Work Areas

The ALMA U.S. Project Manager will assign to the Contractor an adequate assembly, storage, and test area for the execution of its on-site work. The Contractor's equipment will have direct access to the installation site. Provision of all-weather access within the construction area is the Contractor's responsibility.

SC18. Shipment, Unloading, and Protection

All components shall be properly prepared, packaged, and marked for shipment. Gear boxes, open gears, bearings, couplings, and other mechanical components shall be given a rust preventive coating and shall be packaged such that outside storage or exposure to the elements would not damage the component. Shipment, and protection during shipment, shall be the responsibility of the Contractor.

All unloading, receiving, storing, and protecting the Contractor's material and equipment shall be the Contractor's responsibility.

SC19. Electric Service

The Very Large Array (VLA) site electricity is supplied by a 25kV line administered by the Socorro Electric Cooperative (SEC). AUI will run electric services to the prototype antenna construction site as a part of the foundation construction project. The Contractor's foundation design shall designate clearly the power design, point of service pickup, and the required type of interface.

Electricity in quantities sufficient for the Contractor's normal requirements for performing the work and for warehousing and office use will be furnished by AUI without charge. AUI is not responsible for interruptions in commercial power.

SC20. Water and Sanitary Facilities

Potable (chlorinated) water will be available at a hydrant on the site within one (1) mile of the prototype antenna construction site. The Contractor may use the water, in reasonable quantities, free of charge. The Contractor must provide his/her own hauling and storage facilities. Water use shall be coordinated with the ALMA U.S. Project Manager, or his/her designee.

The Contractor shall furnish all his/her own necessary sanitary facilities. Water will not be provided for these.

SC21. TELEPHONE AND MAIL

AUI will supply necessary telephone (voice and data) lines to the construction site for the Contractor's use. There is no charge for line installation; however the Contractor will be billed for usage. The Contractor must supply his/her own telephone equipment.

The Contractor shall be responsible for handling his/her own mail and shipping/receiving needs.

SC22. HEALTH AND FIRST AID

The Contractor shall provide his/her own health and first aid facilities.

SC23. SECURITY

The Contractor shall provide his/her own security for materials, supplies, and equipment on site. The Contractor shall take such measures as he/she deems necessary to protect his/her material, plant, and equipment and be solely liable for any losses. The Contractor shall comply with all physical security rules and regulations set forth by the ALMA U.S. Project Manager.

SC24. FIRES

The Contractor shall keep adequate fire fighting equipment on site to quickly extinguish accidental fires. Open fires will not be allowed.

SC25. TRAFFIC CONTROL

Construction site access will be through the main VLA entrance and near the VLA Visitor Center. The Contractor's vehicular traffic shall be controlled and scheduled so as not to interfere with VLA operations or present a hazard to AUI employees or visitors. Flagmen shall be provided by the Contractor as necessary during busy periods, and when required by the ALMA U.S. Project Manager, or his/her designee.

Site access by the Contractor's employees is limited to the construction site and public areas. The Contractor's employees are required to stay clear of all operations areas, shops, assembly areas, etc., not part of the ALMA U.S. prototype construction project, unless invited and accompanied by an authorized AUI representative.

SC26. Erosion and Sediment Control

AUI shall provide and install all necessary erosion and sediment control devices required by Federal, State, and/or local ordinance.

SC27. Disposal of Debris

The construction site shall be kept free of litter at all times and litter shall not be allowed on adjacent areas. The Contractor may dispose of reasonable amounts of construction debris in the VLA construction waste dump. Such disposal shall be coordinated with the ALMA U.S. Project Manager, or his/her designee. If in the judgment of AUI, the waste stream is excessive, the Contractor shall haul excess litter and debris off-site to an approved, licensed disposal site at no additional cost to AUI.

In no case may the Contractor dump material in the VLA disposal area which may harm the water quality of the underlying aquifer. No disposal of any toxic or hazardous waste is allowed on site.

No burning is allowed.

SC28. Sensitivity to Radio Frequency Interference

The prototype construction site is located in an area sensitive to radio frequency interference (RFI). The Contractor is encouraged to make maximum use of diesel and RFI-protected equipment (gasoline motor driven equipment, mobile telephones, CB radios, computers, etc., are significant sources of RFI which are detrimental to radio astronomy observations at certain frequencies).

The Contractor on occasions may be required to limit or cease his/her RFI-producing operations for limited periods. Any shutdowns to eliminate RFI will be coordinated with the Contractor by the ALMA U.S. Project Manager, or his/her designee.

SC29. Bonds

(a) Performance and payment bonds, satisfactory to AUI, must be provided by the Contractor. AUI shall pay the bond premium(s) upon presentation by the Contractor of a premium invoice from the surety.

(b) A performance bond is required in an amount equal to 100 percent of the price of the construction work planned to be accomplished at the site of the telescope. The performance bond must be provided prior to initiation of work on the construction site.

A payment bond is required in the amount of $2,500,000. The payment bond must be provided prior to the commencement of work under this contract.

(c) If any surety upon any bond furnished in connection with this contract becomes unacceptable to AUI, or if any such surety fails to furnish reports as to its financial condition as requested by AUI, the Contractor shall promptly furnish such additional security as may be required to protect the interest of AUI and a person supplying labor or materials in the prosecution of the work contemplated by this contract.

SC30. CONTRACT DATA RIGHTS

(a) AUI recognizes that the Contractor may have a legitimate proprietary interest (e.g., a property right or other valid economic interest) in data resulting from private investment. Protection of such data from unauthorized use and disclosure is necessary in order to prevent the compromise of such property right or economic interest, avoid jeopardizing the Contractor's commercial position, and preclude impairment of AUI's ability to obtain access to or use of such data. The protection of such data by AUI is also necessary to encourage the Contractor to apply innovative concepts to the program. In light of the above considerations, in applying these policies, AUI will strike a balance between AUI's need and the Contractor's legitimate proprietary interest.

(b) Notwithstanding the foregoing, the data rights clauses found at FAR 52.227-14 (Rights in Data–General) and 52.227-16 (Additional Data Requirements) are hereby incorporated by reference, substituting "AUI" for "the Government" throughout.

GENERAL TERMS AND CONDITIONS

GC1. INDEPENDENT CONTRACTOR/INDEMNIFICATION

(a) In the conduct of the work hereunder the Contractor is acting in the capacity of an independent Contractor and is not an agent or employee of AUI in the performance of the work. AUI, however, shall have general direction of the work and the right to control the final result sought to be obtained.

(b) Notwithstanding anything in this Agreement to the contrary, Contractor shall be responsible for and shall defend, indemnify and hold harmless Associated Universities, Inc., NRAO, its parent company, affiliates and subsidiaries and their respective trustees, officers, agents and employees, from and against any and all claims, actions, lawsuits, demands, judgments, liabilities, assessments, damages, losses, fines, penalties (whether civil or criminal) and expenses whatsoever (including reasonable attorney's fees, costs of investigations and other expenses incident thereto but excluding fees for attorneys employed directly by AUI and NRAO) in any manner or to any extent caused by or resulting from the breach or default, misrepresentation, misconduct, negligence or other act or omission of Contractor or any of its officers, directors, agents or employees, subcontractors, vendors and suppliers, in connection with the Agreement, including but not limited to claims, actions, etc., for or arising from injury to or death of persons or damage to or destruction of property. Both parties' rights and responsibilities under this paragraph shall survive any expiration or termination of this Agreement.

GC2. NOTICES AND APPROVALS

(a) All communications shall be in writing and mailed or delivered to ALMA U.S. Business Manager, National Radio Astronomy Observatory, 520 Edgemont Road, Charlottesville, Virginia 22903-2475, and to the Contractor at the address set forth on his/her proposal letterhead, or to such other place or places as AUI or the Contractor, as the case may be, shall designate in writing.

(b) In order to be effective, acceptance and approval of Contractor submittals by AUI must be in writing. Neither AUI nor the U.S. Government will be bound by oral approvals.

GC3. PERMITS AND RESPONSIBILITY FOR WORK

The Contractor shall, without additional expense to AUI, obtain all necessary licenses and permits required for completion of the work. He/she shall assure that activities carried on outside the United States are coordinated as necessary with AUI and U.S. Government authorities and that appropriate licenses, permits, and approvals are obtained prior to undertaking proposed activities. Neither AUI nor NSF assume responsibility for Contractor compliance with the laws and regulations of the country in which the work is to be conducted. He/she shall be responsible for all damages to persons or property that occur as a result of his/her fault or negligence in connection with the prosecution of the work. He/she shall also be responsible for all materials delivered and work performed until completion and final acceptance, except for any completed unit thereof which theretofore may have been finally accepted. He/she shall take proper safety and health precautions to protect the work, the workers, the public, and the property of others.

GC4. COMPLIANCE WITH LAWS AND REGULATIONS

(a) The Contractor agrees to comply with the latest revision or modification of all applicable Federal, State, and local laws, codes, and regulations in connection with the prosecution of the work, including those applicable by reason of the fact that this contract is issued under a cooperative agreement with the U.S. Government.

(b) The Contractor shall ensure that activities under this award carried on outside the United States are coordinated as necessary with appropriate Government authorities and that appropriate licenses, permits or approvals are obtained prior to undertaking proposed activities. AUI and the NSF do not assume responsibility for Contractor compliance with the laws and regulations of the country in which the work is to be conducted.

GC5. DESIGN—REVIEW AND OWNERSHIP

All drawings, sketches, designs, design data, specifications, notebooks, technical and scientific information, and all photographs, negatives, reports, findings, recommendations and memoranda of every description, as well as all copies of the foregoing, relating to, originating under, incorporated in or used in the antenna work or any part thereof, shall be subject to review by AUI, the ALMA

Project managing entity, and the NSF at all reasonable times. All such material (whether or not specifically identified above) originated in the course of the work shall be the property of AUI and the ALMA Project managing entity and may be used by them for any purpose whatsoever, without any claim on the part of the Contractor for additional compensation. Such material shall be delivered to AUI or the ALMA Project managing entity, or otherwise disposed of by the Contractor as AUI or the ALMA Project managing entity may direct during the progress of the work, or in any event as AUI or the ALMA Project managing entity shall direct upon completion or termination of this contract. The Contractor and his/her subcontractors shall afford AUI, the ALMA Project managing entity, and the NSF proper facilities for any inspection pursuant to this article.

GC6. CHANGES

(a) AUI may, at any time, without notice to the sureties, by written order designated or indicated to be a change order, make any change in the work within the general scope of the contract, including but not limited to changes: (i) in the specifications (including drawings and designs); (ii) in the method or manner of performance of the work, or place of delivery; (iii) in the AUI-furnished or U.S. Government-furnished facilities, equipment, materials, services, or site; (iv) time of performance of the work, or delivery schedule; or (v) plans and specifications and instructions incorporated in the contract.

(b) Any other written order, including direction, instruction, interpretation, or determination which is regarded as a change by the Contractor will be considered, provided AUI receives written notice within thirty (30) days stating the date, circumstances, and source of the order and that the Contractor regards the order as a change order.

(c) Except as herein provided, no order, statement, or conduct of AUI or its representatives shall be treated as a change under this article or entitle the Contractor to an equitable adjustment hereunder.

(d) If any change under this article causes an increase or decrease in the Contractor's cost of, or the time required for, the performance of any part of the work under this contract, whether or not changed by an order, an equitable adjustment will be made and the contract modified in writing accordingly. Except for claims based on defective specifications, no claim for any change under (b) above shall be allowed for any costs incurred more than 20 days before the Contractor gives written notice as therein required. Furthermore, in the case of defective specifications for which AUI is responsible, the equitable adjustment shall include any increased cost reasonably incurred by the Contractor in attempting to comply with such defective specifications.

(e) If the Contractor intends to assert a claim for an equitable adjustment under this article, he/she must, within 30 days after receipt of a written change order under (a) above, submit to AUI a written statement setting forth the general nature and monetary extent of such claim, unless this period is extended by AUI. The statement of claim hereunder may be included in the notice under (b) above. Failure to agree to any adjustment shall be a dispute concerning a question of fact within

the meaning of the "Disputes" article of this contract; however, nothing in this article shall excuse the Contractor from proceeding with the contract as changed.

(f) No claim by the Contractor for an equitable adjustment hereunder shall be allowed if asserted after final payment under this contract.

GC7. INSPECTION AND INSPECTION SYSTEM

(a) Except as otherwise provided in this contract, all material and workmanship shall be subject to inspection, examination and test by AUI at any and all times during the manufacture and/or construction and at any and all places where such manufacture and/or construction are carried on. AUI shall have the right to reject defective material and workmanship or require their correction. Rejected workmanship shall be satisfactorily corrected, and rejected material shall be replaced with proper material without charge therefor and the Contractor shall promptly segregate and remove the rejected material from the premises. If the Contractor fails to proceed at once with the replacement of the rejected material and/or the correction of defective workmanship, AUI may, by contract or otherwise, replace such material and/or correct such workmanship and charge the cost thereof to the Contractor, or may terminate the right of the Contractor to proceed as provided in the Termination for Default article.

(b) The Contractor shall furnish promptly, without additional charge, all reasonable facilities, labor, and materials necessary for the safe and convenient inspection and tests that may be required by AUI. All inspection and tests by AUI shall be performed in such manner as not unnecessarily to delay the work. The Contractor may be charged with any additional cost of inspection when material and workmanship are not ready at the scheduled time of inspection as agreed between the Contractor and AUI.

(c) Should it be considered necessary or advisable by AUI at any time before final acceptance of the entire work to reexamine work already completed, the Contractor, on request, shall promptly furnish all necessary facilities, labor and materials. If such work is found to be defective or nonconforming in any material respect, due to fault of the Contractor or its subcontractors, it shall defray all the expenses of such examination and of satisfactory reconstruction. If, however, such work is found to meet the requirements of this contract, an equitable adjustment shall be made in the amount due under this contract to compensate the Contractor for the additional services rendered in such examination and reconstruction. If completion of the work has been delayed, the Contractor shall be granted a suitable extension of time on account of the additional work involved.

(d) Inspection of material and finished articles to be incorporated in the work at the site shall be made at the place of production, manufacture or shipment, whenever the quantity justifies it, unless otherwise agreed in writing between the Contractor and AUI. Such inspection and acceptance shall be final, except as to latent defects, departures from specific requirements of this contract and the Specifications and drawings made a part thereof, damage or loss in transit, fraud, or such gross mistakes as amount to fraud. Subject to the requirements contained in the preceding sentence, the

inspection of material and workmanship for final acceptance as a whole or in part shall be made at the site. Nothing contained in this article shall in any way restrict AUI's right under any warranty or guarantee.

(e) The Contractor shall (1) maintain an adequate inspection system and perform such inspections as will ensure that the work performed under the contract conforms to the contract requirements, and; (2) maintain and make available to AUI adequate records of such inspections.

GC8. MATERIALS AND WORKMANSHIP WARRANTY

(a) All equipment, material, and articles incorporated into the work covered by this contract shall be new and of the most suitable grade for the purpose intended, unless otherwise specifically provided in this contract. References in the specifications to equipment, material, articles, or patented processes by trade name, make, or catalog number, shall be regarded as establishing a standard of quality and shall not be construed as limiting competition. The Contractor may, at its option, use any equipment, material, article, or process that, in the judgment of AUI, is equal to that named in the specifications, unless otherwise specifically provided in this contract.

(b) The Contractor shall obtain AUI's approval of the machinery and mechanical and other equipment to be incorporated into the work. When requesting approval, the Contractor shall furnish to AUI the name of the manufacturer, the model number, and other information concerning the performance, capacity, nature, and rating of the machinery and mechanical and other equipment. When required by this contact or by AUI, the Contractor shall also obtain AUI's approval of the material or articles which the Contractor contemplates incorporating into the work. When requesting approval, the Contractor shall provide full information concerning the material or articles. When directed to do so, the Contractor shall submit samples for approval at the Contractor's expense, with all shipping charges prepaid. Machinery, equipment, material, and articles that do not have the required approval shall be installed or used at the risk of subsequent rejection.

(c) All work under this contract shall be performed in a skillful and workmanlike manner. AUI may require, in writing, that the Contractor remove from the work any employee AUI deems incompetent, careless, or otherwise objectionable.

GC9. WARRANTY

Unless otherwise expressly provided herein, the Contractor warrants to AUI that the goods to be delivered hereunder shall be free from defects in design, material, workmanship, and title, shall fully conform to the specifications and shall meet all the requirements of this contract. If it appears at any time or times within one (1) year from the date of final acceptance by AUI that the goods delivered hereunder do not meet the warranty specified above, and AUI notifies the Contractor promptly to this effect, the Contractor shall thereupon correct any defect, including non-conformity with the specifications, at its own expense, in a manner satisfactory to AUI, or, at the option of and at no cost to AUI, replace the goods F.O.B. AUI's premises with goods conforming to the

requirements. If installation and/or final testing is required as a condition of this Contract, the Contractor warrants that the material, equipment, and apparatus, after such installation and/or final testing, shall give proper and continuous service under all conditions and services required and specified, or which may be reasonably inferred from the specification. This warranty shall be applicable to any and all corrected or replaced parts, material, or workmanship until one (1) year after the delivery, or, as the case may be, the installation, final testing and acceptance of the same. The rights and remedies specified in this Article shall be without prejudices to any other rights or remedies that AUI may have for breach of warranty.

GC10. PREFERENCE FOR UNITED STATES-FLAG AIR CARRIERS

(a) "International air transportation," as used in this article, means transportation by air between a place in the United States and a place outside the United States, or between two places both of which are outside the United States.

"United States," as used in this article, means the 50 States, the District of Columbia, the Commonwealth of Puerto Rico, and possessions of the United States.

"United States-flag air carrier," as used in this article, means an air carrier holding a certificate under Section 401 of the Federal Aviation Act of 1958 (49 USC 1371).

(b) Section 5 of the International Air Transportation Fair Competitive Practices Act of 1974 (49 USC 1517 (Fly America Act)) requires that all Federal agencies and U.S. Government Contractors and subcontractors use U.S. flag air carriers for U.S. Government financed international air transportation of personnel (and their personal effects) or property, to the extent that service by those carriers is available. It requires the Comptroller General of the United States, in the absence of satisfactory proof of the necessity for foreign-flag air transportation, to disallow expenditures from funds, appropriated or otherwise established for the account of the United States, for international air transportation secured aboard a foreign-flag air carrier if a U.S.-flag air carrier is available to provide such services.

(c) The Contractor agrees, in performing work under this contract, to use U.S.-flag air carriers for international air transportation of personnel (and their personal effects) or property to the extent that service by those carriers is available.

(d) In the event that the Contractor selects a carrier other than a U.S.-flag air carrier for international air transportation, the Contractor shall include a certification on vouchers involving such transportation essentially as follows:

CERTIFICATION OF UNAVAILABILITY OF U.S.-FLAG AIR CARRIERS

I hereby certify that international air transportation of persons (and their personal effects) or property by U.S.-flag air carrier was not available or it was necessary to use foreign-flag air carrier service for the following reasons (see Section 47.403 of the Federal Acquisition Regulation). [STATE REASONS]:

_____

_____

(end of certification)

(e) The Contractor shall include the substance of this article, including paragraph d., in each subaward or purchase under this agreement that may involve international air transportation.

GC11. ASSIGNMENT

Neither this contract nor any interest therein, or claim thereunder, shall be assigned or transferred by the Contractor except with the prior written approval of AUI. AUI may assign this contract in whole or in part to the U.S. Government or its designee, and in the event of such assignment this contract shall continue in full force and effect, notwithstanding the termination of the Cooperative Agreement between the U.S. Government and AUI. The Contractor agrees to look solely to the U.S. Government, or its designee, as the case may be, for payment of the part so assigned; subject to such assignment and acceptance by the U.S. Government this contract does not bind or purport to bind the NSF or the U.S. Government.

GC12. AUDIT

(a) Examination of costs. The Contractor shall maintain—and AUI and NSF or representatives of either shall have the right to examine and audit—books, records, documents, and other evidence and accounting procedures and practices, sufficient to reflect properly all costs claimed to have been incurred or anticipated to be incurred in performing this contract. This right of examination shall include inspection at all reasonable times of the Contractor's plants, or parts of them, engaged in performing the contract.

(b) Cost or pricing data. If, pursuant to law, the Contractor has been required to submit cost or pricing data in connection with pricing this contract or any modification to this contract, representatives of AUI or the NSF shall have the right to examine and audit all books, records, documents, and other data of the Contractor (including computations and projections) related to negotiating, pricing, or performing the contract or modification, in order to evaluate the accuracy, completeness, and currency of the cost or pricing data. The right of examination shall extend to all documents necessary to permit adequate evaluation of the cost or pricing data submitted, along with the computations and projections used.

(c) Reports. If the Contractor is required to furnish cost, funding, or performance reports, representatives of AUI or the NSF shall have the right to examine and audit books, records, other documents, and supporting materials, for the purpose of evaluating (1) the effectiveness of the

Contractor's policies and procedures to produce data compatible with the objective of these reports and (2) the data reported.

(d) Availability. The Contractor shall make available at its office at all reasonable times the materials described above, for examination, audit, or payment under this contract, or for any shorter period specified in Subpart 4.7. Contractor Records Retention, of the Federal Acquisition Regulation, or for any longer period required by statute or by other articles of this contract. In addition:

(1) If this contract is completely or partially terminated, the records relating to the work terminated shall be made available for 3 years after any resulting final termination settlement.

(2) Records relating to appeals under the Disputes article or to litigation or the settlement of claims arising under or relating to this contract shall be made available until such appeals, litigation, or claims are disposed of.

(e) The Contractor shall insert an article containing all the terms of this article, including this paragraph (e), in all subcontracts over $10,000 under this contract, altering the article only as necessary to identify properly the NSF and AUI.

GC13. EXAMINATION OF RECORDS

(a) The Contractor agrees that the Comptroller General of the United States or any of his/her duly authorized representatives shall, until the expiration of three years after final payment under this contract or such lesser time specified in the Federal Acquisition Regulations (Subpart 4.7, Contractor Records Retention) have access to and the right to examine any directly pertinent books, documents, papers, and records of the Contractor involving transactions related to this contract.

(b) The Contractor further agrees to include in all his/her subcontracts hereunder a provision to the effect that the Subcontractor agrees that the Comptroller General of the United States or any of his/her duly authorized representatives shall, until the expiration of three years after final payment under the subcontract or such lesser time specified in the Federal Acquisition Regulation Subpart 4.7 have access to and the right to examine any directly pertinent books, documents, papers, and records of such Subcontractor, involving transactions related to the subcontract. The term "subcontract" as used in this article excludes subcontracts or purchase orders for public utility services at rates established for uniform applicability to the general public, plus any applicable reasonable connection charge.

(c) The periods of access and examination described in (a) and (b), above, for records which relate to (1) appeals under the "Disputes" article of this contract, (2) litigation or the settlement of claims arising out of the performance of this contract, or (3) costs and expenses of this contract to

which exception has been taken by the Comptroller General or any of his/her duly authorized representatives, shall continue until such appeals, litigations, claims, or exceptions are disposed of.

GC14. U.S. GOVERNMENT PROPERTY

The Contractor assumes the risk of, and shall be responsible for any loss of or damage to U.S. Government property or AUI property in its possession, except for reasonable wear and tear, and except to the extent that such property is consumed in the performance of this contract. The term "U.S. Government property" shall be taken to mean property, title to which is vested in the U.S. Government. The term "AUI property" shall be taken to mean property, title to which is vested in AUI.

GC15. INSURANCE

Where the Contractor is required to work on a site or sites owned or operated by AUI or the U.S. Government:

(a) The Contractor will maintain policies providing the following insurance protection for the Contractor, which insurance shall apply to all operations of the Contractor under this contract and employees of the Contractor engaged therein. The Contractor shall also provide an endorsement to its liability policies naming AUI as additional insured.

(1) WORKER'S COMPENSATION—Coverage, as provided in the Worker's Compensation Law, including occupational disease coverage, by the law of the State where the work is performed. Where all or any portion of this contract is performed in more than one State, Worker's Compensation coverage shall not be less than that of the State requiring the highest limits.

(2) GENERAL LIABILITY—Insurance with limits of $1,000,000/$5,000,000 for bodily injury liability and $500,000 property damage in the comprehensive policy form.

(3) VEHICLE PUBLIC LIABILITY AND PROPERTY DAMAGE—Insurance with limits of $1,000,000/$5,000,000 for bodily injury liability and $500,000 for property damage liability on the comprehensive policy form covering all owned, non-owned, and hired vehicles which will be used in connection with the work to be done under this contract.

(b) The Contractor may purchase at its own expense such additional or other insurance protection as it may deem necessary. AUI may allow or restrict access to the site of the work to such personnel of any insurance carrier providing additional or other insurance coverage to that referred to in the foregoing paragraph (a) as AUI may deem necessary for the proper servicing of such insurance.

(c) The Contractor shall furnish three copies of a certificate of insurance naming Associated Universities, Inc., as an additional insured, to show compliance with subparagraph (a) above. The Contractor shall furnish AUI with renewal notices of all applicable insurance policies.

(d) The Contractor shall require that its subcontractors, any tier, working on the site shall maintain as a minimum the insurance coverage set out in paragraph (a) above, and shall provide that such subcontractors provide AUI with certificates of insurance as provided in paragraph (c) above.

GC16. TERMINATION FOR DEFAULT

(a) (1) AUI may, subject to paragraphs (c) and (d) below, by written notice of default to the Contract, terminate this contract in whole or in part if the Contractor fails to:

(i) Deliver the supplies or to perform the services within the time specified in this contract or any extension;

(ii) Make progress, so as to endanger performance of this contract (but see subparagraph (a)(2);

(iii) Perform any of the other provisions of this contract (but see subparagraph (a)(2) below).

(2) AUI's right to terminate this contract under subdivisions (1)(ii) and (1)(iii) above, may be exercised if the Contractor does not cure such failure within twenty days (or more if authorized in writing by AUI) after receipt of the notice from AUI specifying the failure.

(b) If AUI terminates this contract in whole or in part, it may acquire, under the terms and in the manner AUI considers appropriate, supplies or services similar to those terminated, and the Contractor will be liable to AUI for any excess costs for those supplies or services. However, the Contractor shall continue the work not terminated.

(c) Except for defaults of subcontractors at any tier, the Contractor shall not be liable for any excess cost if the failure to perform the contract arises from causes beyond the control and without the fault or negligence of the Contractor. Examples of such causes include (1) acts of God or of the public enemy, (2) acts of the Government in its sovereign capacity, (3) fires, (4) floods, (5) epidemics, (6) quarantine restrictions, (7) strikes, (8) freight embargoes, and (9) unusually severe weather. In each instance the failure to perform must be beyond the control and without the fault or negligence of the Contractor.

(d) If the failure to perform is caused by the default of a subcontractor at any tier, and if the cause of the default is beyond the control of both the Contractor and subcontractor, and without fault or negligence of either, the Contractor shall not be liable for any excess costs for failure to perform, unless the subcontracted supplies or services were obtainable from other sources in sufficient time for the Contractor to meet the required delivery schedule.

(e) If this contract is terminated for default, AUI may require the Contractor to transfer title and deliver, as directed by AUI any (1) completed supplies, and (2) partially completed supplies and materials, parts, tools, dies, jigs, fixtures, plans, drawings, information, and contract rights (collectively referred to as "manufacturing materials" in this clause) that the Contractor has specifically produced or acquired for the terminated portion of this contract. Upon direction of AUI, the Contractor shall also protect and preserve property in its possession in which AUI or the Government has an interest.

(f) AUI shall pay contract price for completed supplies delivered and accepted. The Contractor and AUI shall agree on the amount of payment for manufacturing materials delivered and accepted and for the protection and preservation of the property. Failure to agree will be a dispute under the Disputes clause. AUI may withhold from these amounts any sum it determines to be necessary for protection against loss because of outstanding liens or claims of former lien holders.

(g) If, after termination, it is determined that the Contractor was not in default, or that the default was excusable, the rights and obligations of the parties shall be the same as if the termination had been issued for the convenience of AUI.

(h) The rights and remedies of AUI in this clause are in addition to any other rights and remedies provided by law or under this contract.

GC17. TERMINATION FOR CONVENIENCE

(a) The performance of work under this contract may be terminated by AUI in accordance with this article in whole, or from time to time in part, whenever AUI shall determine that such termination is in the best interest of AUI. Any such termination shall be effected by delivery to the Contractor of a Notice of Termination specifying the extent to which performance of work under the contract is terminated, and the date upon which such termination becomes effective.

(b) After receipt of a Notice of Termination, and except as otherwise directed by AUI, the Contractor shall:

(1) Stop work under the contract on the date and to the extent specified in the Notice of Termination;

(2) Place no further orders or subcontracts for materials, services, or facilities except as may be necessary for completion of such portion of the work under contract as is not terminated;

(3) Terminate all orders and subcontracts to the extent that they relate to the performance of work terminated by the Notice of Termination;

(4) Assign to AUI, in the manner, at the time, and to the extent directed by AUI, all of the right, title, and interest of the Contractor under the orders and subcontracts so terminated, in

which case AUI shall have the right, in its discretion, to settle or pay any or all claims arising out of termination of such orders and subcontracts;

(5) Settle all outstanding liabilities and all claims arising out of such termination of orders and subcontracts, with the approval or ratification of AUI to the extent it may require, which approval or ratification shall be final for all the purposes of this article;

(6) Transfer title to the U.S. Government and deliver in the manner, at the times, and to the extent, if any, as directed by AUI:

(i) The fabricated or unfabricated parts, work in progress, completed work, supplies, and other material produced as part of, or acquired in connection with the performance of, the work terminated by the Notice of Termination, and

(ii) The completed or partially completed plans, drawings, information, and other property which, if the contract has been completed, would have been required to be furnished to AUI.

(7) Use its best efforts to sell, in the manner, at the times, to the extent, and at the price or prices directed or authorized by AUI, any property of the types referred to in (6) above. The Contractor may acquire any such property under the conditions prescribed and at a price or prices approved by AUI. The proceeds of any such transfer or disposition shall be credited to the price or cost of the work covered by this contract or paid as AUI may direct;

(8) Complete performance of such part of the work as shall not have been terminated by the Notice of Termination; and

(9) Take such action as may be necessary, or as AUI may direct, for the protection and preservation of the property related to this contract.

(c) After receipt of a Notice of Termination, the Contractor shall submit to AUI its termination claim, in the form and with the certification prescribed by AUI. Such claim shall be submitted promptly but in no event later than six (6) months from the effective date of termination, unless one or more extensions in writing are granted by AUI upon written request of the Contractor within such six month period or authorized extension thereof.

(d) Subject to the provisions of paragraph (c), the Contractor and AUI may agree upon the whole or any part of the amount or amounts to be paid to the Contractor by reason of the total or partial termination of work pursuant to this article, which amount or amounts may include a reasonable allowance for profit on work done. Such agreed amount or amounts, exclusive of settlement costs, shall not exceed the total contract price as reduced by the amount of payments otherwise made and as further reduced by the contract price of work not terminated. The contract shall be amended accordingly, and the Contractor shall be paid the agreed amount.

(e) In arriving at the amount due the Contractor under this article, there shall be deducted:

(1) All unliquidated advance or other payments on account made to the Contractor, applicable to the terminated portion of this contract,

(2) Any claim which AUI may have against the Contractor in connection with this contract, and

(3) The agreed price for, or the proceeds of sale of, any materials, supplies, or other things kept by the Contractor or sold, pursuant to the provisions of this claim, and not otherwise recovered by or credited to AUI.

(f) If the termination hereunder is partial, prior to the settlement of the terminated portion of this contract, the Contractor may file with AUI a request in writing for an equitable adjustment of the price or prices specified in the contract relating to the continued portion of the contract (the portion not terminated by the Notice of Termination), and such equitable adjustment as may be agreed upon shall be made in such price or prices.

GC18. DISPUTES

Any controversy or claim arising out of or relating to this contract, or the breach thereof, shall be settled by arbitration in accordance with the rules of the American Arbitration Association. Hearings shall be held in the City of Charlottesville, Commonwealth of Virginia, unless an alternate site is designated by mutual agreement. Judgment upon the award rendered by the arbitrators may be entered in any court having jurisdiction thereof. Pending the final decision of any dispute under or in connection with this contract that may arise prior to the completion of performance hereunder, the Contractor shall diligently proceed with the performance of its undertakings.

GC19. RESERVED

GC20. PATENT RIGHTS

1. Definitions

(a) "Invention" means any invention or discovery which is or may be patentable or otherwise protectable under Title 25 of the United States Code (USC), or any novel variety of plant which is or may be protected under the Plant Variety Protection Act (USC 2321 et. seq.).

(b) "Subject invention" means any invention of the Contractor conceived or first actually reduced to practice in the performance of work under this contract, provided that in the case of a variety of plant, the date of determination (as defined in Section 41(d) of the Plant Variety Protection Act, 7 USC 2401(d) must also occur during the period of contract performance.

(c) "Practical application" means to manufacture in the case of a composition or product, to practice in the case of a process or method, or to operate in the case of a machine or system; and, in each case, under such conditions as to establish that the invention is being utilized and that its benefits are, to the extent permitted by law or U.S. Government regulations, available to the public on reasonable terms.

(d) "Made" when used in relation to any invention means the conception or first actual reduction to practice of such invention.

(e) "Small business firm" means a domestic small business concern as defined at Section 2 of Public Law 85-536 (15 USC 632) and implementing regulations of the Administrator of the Small Business Administration. For the purpose of this article, the size standards for small business concerns involved in U.S. Government procurement and subcontracting/subawarding at 13 CFR 121.3-8 and 13 CFR 121.3-12, respectively, will be used.

(f) "Nonprofit organization" means a university or other institution of higher education or an organization of the type described in Section 501(c)(3) of the Internal Revenue Code of 1954 (26 USC 501(c)) and exempt from taxation under Section 501(a) of the Internal Revenue Code of (25 USC 501(a)) or any nonprofit scientific or educational organization qualified under a state nonprofit organization statute.

2. Allocation of Principal Rights

The Contractor may retain the entire right, title, and interest throughout the world to each subject invention subject to the provisions of this article and 35 USC 203. With respect to any subject invention in which the Contractor retains title, the U.S. Government shall have a non-exclusive, non-transferable, irrevocable, paid-up license to practice or have practiced for or on behalf of the United States the subject invention throughout the world. If the grant indicates it is subject to an identified international agreement or treaty, the NSF also has the right to direct the grantee to convey to any foreign participant such patent rights to subject inventions as are required to comply with that agreement or treaty.

3. Invention Disclosure, Election of Title and Filing of Patent Application by Contractor

(a) The Contractor will disclose each subject invention to the NSF within two months after the inventor discloses it in writing to Contractor personnel responsible for patent matters. The disclosure to NSF shall be in the form of a written report and shall identify the agreement under which the invention was made and the inventor(s). It shall be sufficiently complete in technical detail to convey a clear understanding to the extent known at the time of the disclosure, of the nature, purpose, operation, and the physical, chemical, biological, or electrical characteristics of the invention. The disclosure shall also identify any publication, on sale or in public use of the invention and whether a manuscript describing the invention has been accepted for publication at the time of

disclosure. In addition, after disclosure to NSF, the Contractor will promptly notify NSF of the acceptance of any manuscript describing the invention for publication or of any on sale or public use planned by the Contractor.

(b) The Contractor will elect in writing whether or not to retain title to any such invention by notifying NSF within two years of disclosure to NSF. However, in any case where publication, on sale, or public use has initiated the one-year statutory period wherein valid patent protection can still be obtained in the United States, the period for election of title may be shortened by NSF to a date that is no more than 60 days prior to the end of the statutory period.

(c) The Contractor will file its initial patent application on a subject invention to which it elects to retain title within one year after election of title or, if earlier, prior to the end of any statutory period wherein valid patent protection can be obtained in the United States after a publication, on sale, or public use. The Contractor will file patent applications in additional countries or international patent offices within either ten months of the corresponding initial patent application or six months from the date permission is granted by the Commissioner of Patents and Trademarks to file foreign patent applications where such filing has been prohibited by a Secrecy Order.

(d) Requests for extension of the time for disclosure election, and filing under subparagraphs (a), (b), and (c) may, at the discretion of NSF be granted.

4. Conditions When the U.S. Government May Obtain Title

The Contractor will convey to NSF, upon written request, title to any such invention:

(a) If the Contractor fails to disclose or elect title to the subject invention within the times specified in 3., above, or elects not to retain title; provided that NSF may only request title within 60 days after learning of the failure of the Contractor to disclose or elect within the specified times.

(b) In those countries in which the Contractor fails to file patent applications within the times specified in 3., above; provided, however, that if the Contractor has filed a patent application in a country after the times specified in 3., above, but prior to its receipt of the written request of NSF, the Contractor shall continue to retain title in that country.

(c) In any country in which the Contractor decides not to continue the prosecution of any application for, to pay the maintenance fees on, or defend in reexamination or opposition proceeding on, a patent on a subject invention.

5. Minimum Rights to Contractor and Protection of the Contractor Right to File

(a) The Contractor will retain a non-exclusive, royalty-free, license throughout the world in each subject invention to which the U.S. Government obtains title, except if the Contractor fails to disclose the invention within the times specified in 3., above. The Contractor's license extends to

its domestic subsidiary and affiliates, if any, within the corporate structure of which the Contractor is a party and includes the right to grant sublicenses of the same scope to the extent the Contractor was legally obligated to do so at the time the contract was awarded. The license is transferable only with the approval of NSF except when transferred to the successor of that party of the Contractor's business to which the invention pertains.

(b) The Contractor's domestic license may be revoked or modified by NSF to the extent necessary to achieve expeditious practical application of the subject invention pursuant to an application for an exclusive license submitted in accordance with applicable provisions at 37 CFR Part 404 and NSF licensing regulations (if any). This license will not be revoked in that field of use or the geographical areas in which the Contractor has achieved practical application and continues to make the benefits of the invention reasonably accessible to the public. The license in any foreign country may be revoked or modified at the discretion of NSF to the extent the Contractor, its licensees, or the domestic subsidiaries or affiliates have failed to achieve practical application in that foreign country.

(c) Before revocation or modification of the license, NSF will furnish the Contractor a written notice of its intention to revoke or modify the license, and the Contractor will be allowed 30 days (or such other time as may be authorized by NSF for good cause shown by the Contractor) after the notice to show cause why the license should not be revoked or modified. The Contractor has the right to appeal, in accordance with applicable regulations in 37 CFR Part 404 and NSF regulations (if any) concerning the licensing of U.S. Government-owned inventions, any decision concerning the revocation or modification of its license.

6. Contractor Action to Protect the U.S. Government's Interest

(a) The Contractor agrees to execute or to have executed and promptly deliver to NSF all instruments necessary to: (1) establish or confirm the rights the U.S. Government has throughout the world in those subject inventions to which the Contractor elects to retain title, and (2) convey title to NSF when requested under paragraph 4., above, and to enable the U.S. Government to obtain patent protection throughout the world in that subject invention.

(b) The Contractor agrees to require, by written agreement, its employees, other than clerical and non-technical employees, to disclose promptly in writing to personnel identified as responsible for the administration of patent matters and in a format suggested by the Contractor each subject invention made under contract in order that the Contractor can comply with disclosure provisions of paragraph 3., above, and to execute all papers necessary to file patent applications on subject inventions and to establish the U.S. Government's right in the subject inventions. The disclosure format should require, as a minimum, the information required by 3(a), above. The Contractor shall instruct such employees through employee agreements or other suitable educational programs on the importance of reporting inventions in sufficient time to permit the filing of patent applications prior to United States or foreign statutory bars.

(c) The Contractor will notify NSF of any decision not to continue the prosecution of a patent application, pay maintenance fees, or defend in a reexamination or opposition proceeding on a patent, in any country, not less than 30 days before the expiration of the response period reburied by the relevant patent office.

(d) The Contractor agrees to include, within the specification of any United States patent applications and any patent issuing thereon covering a subject invention, the following statement:

"This invention was made with U.S. Government support under (identify the agreement) awarded by the NSF. The U.S. Government has certain rights in this invention."

7. Subcontracts

The Contractor will include this article, suitably modified to identify the parties, in all subcontracts, regardless of tier, for experimental, developmental, or research work. The Subcontractor will retain all rights provided for the Contractor in this article, and the Contractor will not, as part of the consideration for awarding the subcontract, obtain rights in the subcontractors subject inventions.

8. Reporting on Utilization of Subject Inventions

The Contractor agrees to submit on request periodic reports no more frequently than annually on the utilization of a subject invention or on efforts at obtaining such utilization that are being made by the Contractor or its licensees or assignees. Such reports shall include information regarding the status of development, date of first commercial sale or use, gross royalties received by the Contractor, and such other data and information as NSF may reasonably specify. The Contractor also agrees to provide additional reports as may be requested by NSF in connection with any march-in proceeding undertaken by NSF in accordance with paragraph 10. of this article. As required by 35 USC 202(c)(5), NSF agrees it will not disclose such information outside the U.S. Government without permission of the Contractor.

9. Preference for United States Industry

Notwithstanding any other provision of this article, the Contractor agrees that neither it nor any assignee will grant to any person the exclusive right to use or sell any subject invention in the United States unless such person agrees that any products embodying the subject invention or produced through the use of the subject invention will be manufactured substantially in the United States. However, in individual cases, the requirement for such an agreement may be waived by NSF upon a showing by the Contractor or its assignee that reasonable but unsuccessful efforts have been made to grant licenses on similar terms to potential licensees that would be likely to manufacture substantially in the United States or that under the circumstances domestic manufacture is not commercially feasible.

10. March-in Rights

The Contractor agrees that with respect to any subject invention in which it has acquired title, NSF has the right in accordance with procedures in 37 CFR 401.6 and NSF regulations at 45 CFR 650.13 to require the Contractor, an assignee, or exclusive licensee of a subject invention to grant a nonexclusive, partially exclusive, or exclusive license in any field of use to a responsible applicant or applicants, upon terms that are reasonable under the circumstances, and if the Contractor, assignee, or exclusive licensee refuses such a request, NSF has the right to grant such a license itself if NSF determines that:

(a) Such action is necessary because the Contractor or assignee has not taken, or is not expected to take within a reasonable time, effective steps to achieve practical application of the subject invention in such field of use;

(b) Such action is necessary to alleviate health or safety needs which are not reasonably satisfied by the Contractor, assignee, or their licensees;

(c) Such action is necessary to meet requirements for public use specified by Federal regulations and such requirements are not reasonably satisfied by the Contractor, assignee, or licensee; or

(d) Such action is necessary because the agreement required by paragraph 9. of this article has not been obtained or waived or because a licensee of the exclusive right to use or sell any subject invention in the United States is in breach of such agreement.

11. Special Provisions for Awards With Nonprofit Organizations

If the Contractor is a nonprofit organization, it agrees that:

(a) Rights to a subject invention in the United States may not be assigned without the approval of NSF, except where such assignment is made to an organization which has as one of its primary functions the management of inventions, provided that such assignee will be subject to the same provisions as the Contractor;

(b) The Contractor will share royalties collected on a subject invention with the inventor, including Federal employee co-inventors (when the agency deems it appropriate) when the subject invention is assigned in accordance with 35 USC 202(e) and 37 CFR 401.10;

(c) The balance of any royalties or income earned by the Contractor with respect to subject inventions, after payment of expenses (including payments to inventors) incidental to the administration of subject inventions, will be utilized for the support of scientific research or education; and

(d) It will make efforts that are reasonable under the circumstances to attract licensees of subject invention that are small business firms and that it will give a preference to a small business firm when licensing a subject invention if the Contractor determines that the small business firm has a plan or proposal for marketing the invention which, if executed, is equally as likely to bring the invention to practical application as any plans or proposals from applicants that are not small business firms; provided that the Contractor is also satisfied that the small business firm has the capability and resources to carry out its plan or proposal. The decision whether to give a preference in any specific case will be at the discretion of the Contractor. However, the Contractor agrees that the Secretary of Commerce may review the Contractor licensing program and decisions regarding small business applicants, and the Contractor will negotiate changes to its licensing policies, procedures, or practices with the Secretary when the Secretary's review discloses that the Contractor could take reasonable steps to implement more effectively the requirements of this paragraph 11(d).

12. Communications

All disclosures, elections, confirmations of the U.S. Government license, copies of patents, and other routine communications should be sent to the NSF Patent Assistant, Office of the General Counsel, National Science Foundation, 4201 Wilson Blvd., Arlington, VA 22230. Requests for waivers and other exceptional communications with the Foundation regarding this clause should be addressed to the NSF Intellectual Property Attorney, Office of the General Counsel, National Science Foundation, 4201 Wilson Blvd., Arlington, VA 22230.

GC21. AUTHORIZATION AND CONSENT

The U.S. Government has given AUI in its Cooperative Agreement its authorization and consent for all use and manufacture of any invention described in and covered by a patent of the United States in performance of the contract or any part hereof or any amendment hereto or any subcontract hereunder (including any lower-tier subcontract). AUI extends this authorization and consent to the Contractor.

GC22. NOTICE AND ASSISTANCE REGARDING PATENT AND COPYRIGHT INFRINGEMENT

1. The Contractor shall report to AUI, promptly and in reasonable written detail, each notice or claim of patent or copyright infringement based on the performance of this contract of which the Contractor has knowledge.

2. In the event of any claim or suit against the U.S. Government on account of any alleged patent or copyright infringement arising out of the performance of this contract or out of the use of any supplies furnished or work or services performed hereunder, the Contractor shall furnish to the U.S. Government, when requested by the NSF Grants and Agreements Officer, all evidence and information in possession of the Contractor pertaining to such suit or claim. Such evidence and information shall be furnished at the expense of the U.S. Government except where the Contractor has agreed to indemnify the U.S. Government.

GC23. CLEAN AIR AND WATER

1. "Air Act," as used in this article, means the Clean Air Act (42 USC 7401 et. seq.).

"Clean air standard," as used in this article, means:

(a) Any enforceable rules, regulations, guidelines, standards, limitations, orders, controls, prohibitions, work practices, or other requirements contained in, issued under, or otherwise adopted under the Air Act or Executive Order 11738;

(b) An applicable implementation plan as described in Section 110(d) of the Air Act (42 USC 7410 (d));

(c) An approved implementation procedure or plan under Section 111(c) or Section 111(d) of the Air Act (42 USC 7411 (c) or (d)); or

(d) An approved implementation procedure under Section 111(d) of the Air Act (42 USC 7412(d)).

"Clean water standard," as used in this article, means any enforceable limitation, control, condition, prohibition, standard, or other requirement promulgated under the Water Act or contained in a permit issued to a discharger by the Environmental Protection Agency or by a State under an approved program, as authorized by Section 402 of the Water Act (33 USC 1342), or by local government to ensure compliance with pretreatment regulations as required by Section 307 of the Water Act (33 USC 1317).

"Compliance," as used in this article, means complied with:

(a) Clean air or water standards; or

(b) A schedule or plan ordered or approved by a court of competent jurisdiction, the Environmental Protection Agency, or an air or water pollution control agency under the requirements of the Air Act or Water Act and related regulations.

"Facility," as used in this article, means any building, plant, installation, structure, mine, vessel, or other floating craft, location, or site of operations, owned, leased, or supervised by a Contractor or Subcontractor used in the performance of a contract or subcontract. When a location or site of operations includes more than one building, plant, installation, or structure, the entire location or site shall be deemed a facility except when the Administrator, or a designee, of the Environmental Protection Agency, determines that independent facilities are colocated in one geographical area.

"Water Act," as used in this article, means Clean Water Act (33 USC 1251 et. seq.).

2. The Contractor agrees:

(a) To comply with all the requirements of Section 114 of the Clean Air Act (42 USC 7414) and Section 308 of the Clean Water Act (33 USC 1318) relating to inspection, monitoring, entry, reports, and information, as well as other requirements specified in Section 114 and Section 308 of the Air Act and the Water Act, and all regulations and guidelines issued to implement those acts before the award of this contract;

(b) That no portion of the work required by this contract will be performed in a facility listed on the Environmental Protection Agency List of Violating Facilities on the date when this contract was awarded unless and until the EPA eliminates the name of the facility from the listing;

(c) To use best efforts to comply with clean air standards and clean water standards at the facility in which the contract work is being performed; and

(d) To insert the substance of this article into any non-exempt subcontract, including this subparagraph 2(d).

GC24. NATIONAL SECURITY: CLASSIFIABLE RESULTS ORIGINATING UNDER THIS AGREEMENT

1. The NSF does not have original classification authority and does not normally support classified projects. It therefore does not expect that results of NSF-supported research projects will be classifiable, except in very rare instances.

2. Executive Order 12356 (47 Federal Register 14874-1982) states that basic scientific research information not clearly related to the national security may not be classified (Section 1.6(b). Nevertheless, some information concerning, among other things, scientific, technological, or economical matters relating to the national security or cryptology may require classification (Section 1.3(a)).

3. There may therefore be cases when a Contractor originates information during the course of an NSF-supported project that AUI and/or the Contractor believes requires classification under Executive Order 12356 (Section 1.2(e)).

4. In such a case, the Contractor has the responsibility promptly to :

1. submit the information directly to the U.S. Government agency with appropriate subject matter interest and classification authority, or, if uncertain which agency should receive the information, to the Director of the Information Security Oversight Office, General Services Administration;

2. protect the information as though it were classified until it is informed that the information does not require classification, but no longer than thirty (30) days after receipt by the agency with subject matter interest or by the General Services Administration; and

3. notify AUI and the cognizant NSF Program Officer.

5. The Executive Order requires the agency with appropriate subject matter interest and classification authority to decide within thirty (30) days whether to classify the material. If it determines the information to require classification, the Contractor shall cooperate with that agency, the NSF, or other appropriate agencies in securing all related project notes and papers.

GC25. HEALTH AND SAFETY

1. The Contractor shall take all reasonable precautions in the performance of the work under this contract to protect the health and safety of employees and of the public and to minimize danger from all hazards to life and property and shall comply with all health, safety, and fire protection regulations and requirements (including reporting requirements) required by Federal, State, and local authorities, including but not limited to, OSHA 29CFR1910, OSHA29CFR1926, and EPA 40CFR260-299.

2. The Contractor shall maintain an accurate record of all cases of death, occupational disease, or injury arising out of, or in the course of, employment incident to performance of the work under this contract. In addition, the Contractor shall promptly furnish AUI details of any deaths, serious occupational diseases, injuries resulting in permanent handicaps, and major accidents occurring in connection with this contract.

3. The Contractor further agrees to indemnify and hold harmless the U.S. Government, the NSF, and AUI and their respective officers, agents and employees from any loss, damage, fine, penalty or any expense whatsoever as a result of Contractor's or its Subcontractor(s) failure to comply with OSHA and any standards or regulations issued thereunder.

4. The Contractor shall comply with any requirements established by AUI for operations on site including, but not limited to, those listed in paragraph 5 below. In the event that the Contractor fails to comply with any such safety regulations or requirements, AUI may without prejudice to any other legal or contractual rights, issue an order stopping all or any part of the work. Thereafter a start order for resumption of the work may be issued at the discretion of AUI.

5. Rules

(a) [Reserved.]
(b) The Contractor shall meet with AUI's safety and contracting representatives prior to starting the site work to review safety matters. The Contractor is responsible for informing

its employees of AUI site specific safety rules. AUI's Safety Manual will be available to the Contractor. The Contractor shall provide AUI with a copy of its safety policy manual appropriate to the work being performed.

(c) The Contractor shall ensure that its employees wear required PPE (hard hats, safety shoes, eye and ear protections, etc.). The Contractor is responsible for the training of its employees in the work practices necessary to perform their job safety.

(d) The Contractor shall promptly report all accidents, fires or medical problems resulting from the performance of work to AUI's Safety representative. The Contractor is responsible for providing its employees with medical care and first aid treatment.

(e) The Contractor will not enter any AUI facility without prior authorization and unless required in the performance of the work. The Contractor shall abide by all posted safety signs, including "No Smoking" and "Do Not Enter" signs.

(f) The Contractor will maintain at all times clean work areas free from exposure to physical or environmental hazards and will dispose of any discarded materials in a proper and legal manner.

(g) Contractors bringing chemicals on AUI property must provide the AUI Safety representative with the appropriate material safety data sheets (MSDSs) and comply with State and Federal Hazard Communication requirements.

(h) The Contractor is required to vacate buildings immediately when fire alarm sounds.

(i) AUI expressly prohibits illegal drugs or alcoholic beverages on AUI premises.

(j) AUI expressly prohibits possession or use of firearms on AUI premises.

6. The Contractor will be solely responsible for initiating, formulating, supervising, reviewing, and overseeing any and all safety precautions, practices, procedures, and programs which are or should be provided in connection with the work. Contractor will take all necessary or proper precautions for the safety of and will provide the necessary protection to prevent damage, injury, or loss to:

(a) All employees on the work and any other person who may be affected thereby whether or not such person is involved with the work.

(b) All the work and all materials or equipment to be incorporated therein whether in storage on or off the site.

(c) Other property at the site or adjacent thereto, including trees, shrubs, lawns, walks, pavements, roadways, structures and utilities not designated for removal, relocation or replacement in the course of construction.

GC26. DRUG FREE WORKPLACE

1. Definitions. As used in this clause.

(a) "Controlled substance" means a controlled substance in schedules I through V of Section 202 of the Controlled Substance Act (21 U.S.C. 812) and as further defined in regulation 21 CFR 1308.11-1308.15.

(b) "Conviction" means a finding of guilt (including a plea of nolo contendere) or imposition of sentence, or both, by any judicial body charged with the responsibility to determine violations of the Federal or State criminal drug statutes.

(c) "Criminal drug statute" means a Federal or non-Federal criminal statute involving the manufacture, distribution, dispensing, possession or use of any controlled substance.

(d) "Drug-free workplace" means the site(s) for the performance of the work done by the Contractor in connection with a specific agreement/contract at which employees of the Contractor are prohibited from engaging in the unlawful manufacture, distribution, dispensing, possession, or use of a controlled substance.

(e) "Employee" means an employee of a Contractor directly engaged in the performance of work under a Government contract/agreement. Directly engaged is defined to include all direct cost employees and any other Contractor employee who has other than a minimal impact on, or involvement in, contract/agreement performance.

(f) "Individual" means a Contractor that has no more than one employee including the Contractor.

2. The Contractor, if other than an individual, shall, within 30 calendar days after award (unless longer period is agreed to in writing for awards of 30 calendar days or more performance duration); or as soon as possible for contracts/agreements of less than 30 calendar days performance duration:

(a) Publish a statement notifying its employees that the unlawful manufacture, distribution, dispensing, possession, or use of a controlled substance is prohibited in the Contractor's workplace and specifying the actions that will be taken against employees for violations of such prohibition;

(b) Establish an ongoing drug-free awareness program to inform such employees about:

(i) The dangers of drug abuse in the workplace;

(ii) The Contractor's policy of maintaining a drug-free workplace;

(iii) Any available drug counseling, rehabilitation, and employee assistance programs; and

(iv) The penalties that may be imposed upon employees for drug abuse violations occurring in the workplace.

(c) Provide all employees engaged in performance of the agreement with a copy of the statement required by subparagraph (2)(a) of this clause;

(d) Notify such employees in writing in the statement required by subparagraph (2)(a) of this clause that, as a condition of employment on this agreement, the employee will:

(i) Abide by the terms of the statement; and

(ii) Notify the employer in writing of the employee's conviction under a criminal drug statute for a violation occurring in the workplace no later than 5 calendar days after such conviction.

(e) Notify AUI in writing within 10 calendar days after receiving notice under subdivision (2)(d)(ii) of this clause, from an employee or otherwise receiving actual notice of such conviction. The notice shall include the position title of the employee.

(f) Within 60 calendar days after receiving notice under subdivision (2)(d)(ii) of this clause of a conviction, take one of the following actions with respect to any employee who is conviction of a drug abuse violation occurring in the workplace:

(i) Taking appropriate personnel action against such employee, up to and including termination; or

(ii) Require such employee to satisfactorily participate in a drug abuse assistance or rehabilitation program approved for such purposes by a Federal, State, or local health. law enforcement, or other appropriate agency.

(g) Make a good faith effort to maintain a drug-free workplace through implementation of subparagraphs (2)(a) through (2)(f) of this clause.

3. The Contractor, if an individual, agrees by award of the Agreement or acceptance of a purchase order, not to engage in the unlawful manufacture, distribution, dispensing, possession, or use of a controlled substance in the performance of this Agreement.

4. In addition to other remedies available to AUI and the Government, the Contractor's failure to comply with the requirements of paragraphs (2) or (3) of this clause may, pursuant to FAR 23.506, render the Contractor subject to suspension of agreement payments, termination of the agreement for default, or suspension or debarment.

GC27. CONTRACT WORK HOURS AND SAFETY STANDARDS ACT—OVERTIME COMPENSATION (JULY 1995)

This contract is subject to the Contract Work Hours and Safety Standards Act and to the applicable rules, regulations and interpretations of the Secretary of Labor.

1. Overtime Requirements—No Contractor or Subcontractor contracting for any part of the work which may require or involve the employment of laborers or mechanics (see Federal Acquisition Regulation (FAR) 22.300) shall require or permit any such laborers or mechanics in any workweek in which the individual is employed on such work to work in excess of 40 hours in such workweek unless such laborer or mechanic receives compensation at a rate not less than 1½ times the basic rate of pay for all hours worked in excess of 40 hours in such workweek.

2. Violation, liability for unpaid wages, and liquidated damages—In the event of any violation of the provisions set forth in paragraph (1) of this article, the Contractor and any Subcontractor responsible therefor shall be liable for the unpaid wages. In addition, such Contractor and Subcontractor shall be liable to the United States (in the case of work done under agreement for the District of Columbia or territory, to such District or to such territory), for liquidated damages. Such liquidated damages shall be computed with respect to each individual laborer or mechanic employed in violation of the provisions set forth in paragraph (1) of this article in the sum of $10 for each calendar day on which such individual was required or permitted to work in excess of the standard workweek of 40 hours without payment of the overtime wages required by provisions set forth in paragraph (1) of this article.

3. Withholding for unpaid wages and liquidated damages—AUI shall upon its own action or upon written request of an authorized representative of the Department of Labor withhold or cause to be withheld, from any moneys payable on account of work performed by the Contractor or Subcontractor under any such agreement or any other Federal agreement with AUI, or any other Federally assisted agreement subject to the Contract Work Hours and Safety Standards Act which is held by AUI, such sums as may be determined to be necessary to satisfy any liabilities of such Contractor or Subcontractor for unpaid wages and liquidated damages as provided in the provisions set forth in paragraph (2) of this article.

4. Payrolls and basic records

(a) The Contractor or Subcontractor shall maintain payrolls and basic payroll records during the course of contract work and shall preserve them for a period of three years from the completion of the contract for all laborers and mechanics working on the contract. Such records shall contain the name and address of each such employee, social security number, correct classifications, hourly rates of wages paid, daily and weekly number of hours worked, deductions made, and actual wages paid. Nothing in this paragraph shall require the duplication of records required to be maintained for construction work by Department of Labor regulations at 29 CFR 5.5(a)(3) implementing the Davis-Bacon Act.

(b) The records to be maintained under paragraph (4)(a) of this article shall be made available by the Contractor or Subcontractor for inspection, copying, or transcription by authorized representatives of AUI, the NSF Grants and Agreements Officer or the Department of Labor. The Contractor or Subcontractor shall permit such representatives to interview employees during working hours on the job.

5. Subcontracts—The Contractor or Subcontractor shall insert in any subcontracts exceeding $100,000 the provisions set forth in paragraphs (1) through (5) of this article and also an article requiring the subcontractors to include these provisions in any lower tier subcontract. The Contractor shall be responsible for compliance by any Subcontractor or lower tier Subcontractor with the provisions set forth in paragraphs (1) through (5) of this article.

GC28. WITHHOLDING OF FUNDS

1. There may be withheld from the Contractor so much of the accrued payments or advances as may be considered necessary (1) to pay laborers and mechanics, including apprentices, trainees, watchmen, and guards, employed by the Contractor or any Subcontractor on the work the full amount of wages required by this contract, and (2) to satisfy any liability for liquidated damages under paragraph 2. of the article entitled "Contract Work Hours and Safety Standards Act—Overtime Compensation."

2. If the Contractor or Subcontractor fails to pay any laborer, mechanic, apprentice, trainee, watchman, or guard, employed or working on the site of the work, all or part of the wages required by this contract, AUI or the NSF, may take such action as may be necessary to cause suspension of any further payments or advances until such violations have ceased.

GC29. SUBCONTRACTS

All subcontractors and lower-tier subcontractors are subject to approval by AUI. The Contractor agrees to insert the articles hereof entitled "Contract Work Hours and Safety Standards Act—Overtime Compensation," "Withholding of Funds," "Subcontracts," "Contract Termination—Debarment," and "Equal Opportunity" in all subcontracts. The term "Contractor" as used in such article in any subcontract shall be deemed to refer to the Subcontractor.

GC30. CONTRACT TERMINATION—DEBARMENT

A breach of the articles hereof entitled"Contract Work Hours and Safety Standards Act—Overtime Compensation," "Withholding of Funds," and "Subcontracts," may be grounds for termination of this contract and for debarment as provided in 29 CFR 5.12.

GC31. DISPUTES CONCERNING LABOR STANDARDS

The United States Department of Labor has set forth in 29 CFR Parts, 5, 6, and 7 procedures for resolving disputes concerning labor standards requirements. Such disputes shall be resolved in accordance with those procedures and not the Disputes clause of this agreement. Disputes within the meaning of this clause include disputes between the Contractor (or any of its subcontractors) and AUI, or their employees or their representatives.

GC32. NOTICE OF LABOR DISPUTES

Whenever an actual or potential labor dispute is delaying or threatens to delay the performance of the work, the Contractor shall immediately notify AUI in writing. Such notice shall include all relevant information concerning the dispute and its background.

GC33. EQUAL OPPORTUNITY

1. If, during any 12-month period (including the 12 months preceding the award of this contract), the Contractor has been or is awarded nonexempt Federal contracts/awards and/or subcontracts/subawards that have an aggregate value in excess of $10,000, the Contractor shall comply with subparagraphs 2.a. through 2.k. below. Upon request, the Contractor shall provide information necessary to determine the applicability of this article.

2. During performing of this contract, the Contractor agrees as follows:

(a) The Contractor shall not discriminate against any employee or applicant for employment because of race, color, religion, sex, or national origin.

(b) The Contractor shall take affirmative action to ensure that applicants are employed, and that employees are treated during employment, without regard to their race, color, religion, sex, or national origin. This shall include, but not be limited to, (1) employment, (2) upgrading, (3) demotion, (4) transfer, (5) recruitment or recruitment advertising, (6) layoff or termination, (7) rates of pay or other forms of compensation, and (8) selection for training, including apprenticeship.

(c) The Contractor shall post in conspicuous places available to employees and applicants for employment the notices that explain this article.

(d) The Contractor shall state, in all solicitations or advertisement for employees placed by or on behalf of the Contractor, that all qualified applicants will receive consideration for employment without regard to race, color, religion, sex, or national origin.

(e) The Contractor shall send, to each labor union or representative of workers with which it has a collective bargaining agreement or other contract or understanding, the notice advising the labor union or worker's representative of the Contractor's commitments under this article, and post copies of the notice in conspicuous places available to employees and applicants for employment.

(f) The Contractor shall comply with Executive Order 11246, as amended, and the rules, regulations, and orders of the Secretary of Labor.

(g) The Contractor shall furnish to AUI and the NSF all information required by Executive Order 11246, as amended, and by the rules, regulations, and orders of the Secretary of Labor. Standard Form 100 (EEO-1), or any successor form, is the prescribed form to be filed within 30 days following the award, unless filed within 12 months preceding the date of the award.

(h) The Contractor shall permit access to its books, records, and accounts by the awarding agency or the Office of Federal Contract Compliance Programs (OFCCP) for the purpose of investigation to ascertain the Contractor's compliance with the applicable rules, regulations, and orders.

(i) If the OFCCP determines that the Contractor is not in compliance with this article or any rule, regulation, or order of the Secretary of Labor, this agreement may be canceled, terminated, or suspended in whole or in part and the Contractor may be declared ineligible for further U.S. Government awards under the procedures authorized in Executive Order 11246, as amended. In addition, sanctions may be imposed and remedies invoked against the Contractor as provided in Executive Order 11246, as amended, the rules, regulations, and orders of the Secretary of Labor, or as otherwise provided by law.

(j) The Contractor shall include the terms and conditions of subparagraph 2.a. through 2.k. of this article in every subcontract or purchase order that is not exempted by the rules, regulations, or orders of the Secretary of Labor issued under Executive Order 11246, as amended, so that these terms and conditions will be binding upon each subcontract or vendor.

(k) The Contractor shall take such action with respect to any subcontract or purchase order as the NSF may direct as a means of enforcing these terms and conditions, including sanctions for noncompliance provided that, if the Contractor becomes involved in, or is threatened with, litigation with a subcontract or vendor as a result of any direction, the Contractor may request the United States to enter into the litigation process to protect the interests of the United States.

3. Notwithstanding any other article in this contract, disputes relative to this article will be governed by the procedures in 41 CFR 60-1.1.

GC34. NONDISCRIMINATION

1. The Contractor and its subcontractors are subject to the provisions of Title VI of the Civil Rights Act of 1964 (PL 88-352) and the regulations issued pursuant thereto by the Foundation (45 CFR 611). No person on the basis of race, color, sex, national origin, or handicap shall be excluded from participation in, be denied benefits of, or otherwise be subjected to discrimination under the contract. In addition, if the project involves an education activity or program, as defined by Title IX of the Education Amendments of 1972 (PL-3181 20 USC 1681-1686), no person on the basis of sex shall be excluded from participation in the project. Further, by acceptance of the contract, the Contractor ensures AUI and the Foundation that it will comply with Section 504 of the

Rehabilitation Act of 1973 (29 USC 794) and the Foundation's implementing regulations (45 CFR 605) effective March 1, 1982.

2. The Contractor shall provide to AUI within thirty (30) days of award an Assurance of Compliance with Title VI of the Civil Rights Act of 1964. Civil Rights Act assurances may be filed with AUI in one of two ways: (1) by written notification that the appropriate Assurance of Compliance form has been executed and filed either with the Foundation or the U.S. Department of Health and Human Services; or (2) by executing and filing with AUI an NSF Assurance of Compliance Form.

3. The Contractor agrees to comply with the Age Discrimination Act of 1975 as implemented by the Department of Health and Human Service regulations at 45 CFR 90 and the regulations of the Foundation at 45 CFR 617.

4. The Contractor, by virtues of its acceptance of this contract, ensures AUI, the NSF, and the U.S. Department of Labor that it is compliant pursuant to Section 504 of the Rehabilitation Act of 1973.

GC35. CONTINGENT FEES

The Contractor warrants that no person or selling agency has been employed or retained to solicit or secure this contract upon an agreement or understanding for a commission, percentage, brokerage, or contingent fee, excepting bona fide established commercial or selling agencies maintained by the Contractor for the purpose of securing business. For breach or violation of this warranty, AUI shall have the right to annul this contract without liability, or in its discretion to deduct from the contract price or consideration, or otherwise recover, the full amount of such commission, percentage, brokerage, or contingent fee.

GC36. OFFICIALS NOT TO BENEFIT

No member of or delegate to Congress or Resident Commissioner shall be admitted to any share or part of this contract or to any benefit that may arise therefrom, but this provision shall not be construed to extend to this contract if made with a corporation for its general benefit.

GC37. PRICING OF ADJUSTMENTS

When costs are a factor in any determination of a contract price adjustment pursuant to the "Changes" article or any other provision of this contract, such costs shall be in accordance with the contract cost principles and procedures in Part 31 of the Federal Acquisition Regulations in effect on the date of this contract.

GC38. COST ACCOUNTING STANDARDS

The applicable Cost Accounting Standards found at FAR 52.230-2 (Cost Accounting Standards), 52.230-3 (Disclosure and Consistency of Cost Accounting Practices), and 52.230-4 (Consistency in Cost Accounting Practices) are hereby incorporated by reference.

GC39. PROGRESS PAYMENTS

Progress payments shall be made to the Contractor when requested as work progresses, but not more frequently than monthly in amounts approved by AUI, under the following conditions:

(a) Computation of amounts: (1) Unless the Contractor requests a smaller amount, each progress payment shall be computed as (i) 90 percent of the Contractor cumulative total costs under this contract, as shown by records maintained by the Contractor for the purpose of obtaining payment under U.S. Government contracts, plus (ii) progress payments to subcontracts (see paragraph (j), below), all less the sum of all previous progress payments made by AUI under this contract. All progress payment requests and all payments shall be in United States dollars.

(2) The following conditions apply to the timing of including costs in progress payment requests:

(i) The costs of supplies and services purchased by the Contractor directly for this contract may be included only after payment by cash, check, or other form of actual payment.

(ii) Costs of the following may be included when incurred, even if before payment, when the Contractor is not delinquent in payment of the costs of contract performance in the ordinary course of business:

(A) Materials issued from the Contractor's stores inventory and placed in the production process for use on this contract.

(B) Direct labor, direct travel, and other direct in-house costs.

(C) Properly allocable and allowable indirect costs.

(iii) Accrued costs of Contractor contributions under employee pension, profit sharing, and stock ownership plans shall be excluded until actually paid unless:

(A) The Contractor's practice is to contribute to the plans quarterly or more frequently; and

(B) The contribution does not remain unpaid 30 days after the end of the applicable quarter or shorter payment period (any contributions remaining unpaid shall be excluded from the Contractor's total costs for progress until paid).

(iv) If the contract is subject to the special transition method authorized in Cost Accounting Standard (CAS) 410, Allocation of Business Unit General and Administrative Expense to Final Cost Objective, General and Administrative expenses (G&A) shall not be included in progress payment requests until the suspense account prescribed in CAS 410 is less than:

(A) Five million dollars; or

(B) The value of the work-in-process inventories under contracts entered into after the suspense account was established (only a pro rata share of the G&A allocable to the excess of the inventory over the suspense account value is including in progress payment requests under this contract).

(3) The Contractor shall not include the following in total costs for progress payment purposes in subparagraph (a)1.(i), above:

(i) Costs that are not reasonable, allocable to this contract, and consistent with sound and generally accepted accounting principles and practices.

(ii) Costs incurred by subcontractors or suppliers.

(iii) Costs ordinarily capitalized and subject to depreciation or amortization except for the properly depreciated or amortized portion of such costs.

(iv) Payments made or amounts payable to subcontractors or suppliers, except for:

(A) Completed work, including partial deliveries, to which the Contractor has acquired title; and

(B) Work under cost-reimbursement or time-and-material subcontracts to which the Contractor has acquired title.

(4) The amount of unliquidated progress payments may exceed neither: (i) the progress payments made against incomplete work (including allowable unliquidated progress payments to subcontractors) nor (ii) the value, for progress payment purposes, of the incomplete work. Incomplete work shall be considered to be the supplies and services required by this contract, for which delivery and invoicing by the Contractor and acceptance by AUI are incomplete.

(5) The total amount of progress payments shall not exceed 90 percent of the total contract price.

(6) If a progress payment or the unliquidated progress payments exceed the amounts permitted by subparagraphs (a)4. and (a)5. above, the Contractor shall repay the amount of such excess to AUI on demand.

(b) Liquidation. Except as provided in the Termination for Convenience article, all progress payments shall be liquidated by deducting from any payment under this contract, other than advance or progress payments, the unliquidated progress payments, or 90 percent of the amount invoiced, whichever is less. The Contractor shall repay AUI any amounts required by a retroactive price reduction, after computing liquidations and payments on past invoices at the reduced prices and adjusting the unliquidated progress payments accordingly. AUI reserves the right to unilaterally change from the ordinary liquidating rate to an alternate rate when deemed appropriate for proper contract financing.

(c) Reduction or suspension. AUI may reduce or suspend progress payments, increase the rate of liquidation, or take a combination of these actions, after finding on substantial evidence any of the following conditions:

1. The Contractor failed to comply with any material requirement of this contract (which includes paragraphs (f) and (g) below and GC40 Schedule of Liquidated Damages).

2. Performance of this contract is endangered by the Contractor's (i) failure to make progress or (ii) unsatisfactory financial condition.

3. Inventory allocated to this contract substantially exceeds reasonable requirements.

4. The Contractor is delinquent in payment of the costs of performing this contract in the ordinary course of business.

5. The unliquidated progress payments exceed the fair value of the work accomplished on the undelivered portion of this contract.

6. The Contractor is realizing less profit than that reflected in the establishment of any alternate liquidation rate in paragraph (b) above, and that rate is less than the progress payment rate stated in subparagraph (a)1. above.

(d) Title.

1. Title to the property described in this paragraph (d) shall vest in the U.S. Government. Vestiture shall commence immediately upon the date of this contract, for property acquired or produced before that date. Otherwise, vestiture shall occur when the property is or should have been allocable or property chargeable to this contract.

2. "Property," as used in this article, includes all of the below-described items acquired or produced by the Contractor that are or should be allocable or properly chargeable to this contract under sound and generally accepted accounting principles and practices.

(i) Parts, materials, inventories, and work in progress;

(ii) Special tooling and special test equipment to which the U.S. Government is to acquire title under any other article of this contract;

(iii) Nondurable (i.e., noncapital) tools, jigs, dies, fixtures, molds, patterns, taps, gauges, test equipment, and other similar manufacturing aids, title to which would not be obtained as special tooling under subparagraph (ii) above; and

(iv) Drawings and technical data, to the extent the Contractor or subcontractors are required to deliver them to AUI by other articles of this contract.

3. Although title to property is in the U.S. Government under this article, other applicable articles of this contract, e.g., the termination of special tooling articles, shall determine the handling and disposition of the property.

4. The Contractor may sell any scrap resulting from production under this contract without requesting AUI's approval, but the proceeds shall be credited against the costs of performance.

5. To acquire for its own use or dispose of property to which title is vested in the U.S. Government under this article, the Contractor must obtain AUI's advance approval of the action and the terms. The Contractor shall: (i) exclude the allocable costs of the property from the costs of contract performance, and (ii) repay to AUI any amount of unliquidated progress payments allocable to the property. Repayment may be by cash or credit memorandum.

6. When the Contractor completes all of the obligations under this contract, including liquidation of all progress payments, title shall vest in the Contractor for all property (or the proceeds thereof) not:

(i) Delivered to, and accepted by, AUI under this contract; or

(ii) Incorporated in supplies delivered to, and accepted by, AUI under this contract and to which title is vested in the U.S. Government under this article.

7. The terms of this contract concerning liability for U.S. Government-furnished property shall not apply to property to which the U.S. Government acquired title solely under this article.

(e) Risk of loss. Before delivery to and acceptance by AUI, the Contractor shall bear the risk of loss for property, the title to which vests in the U.S. Government under this article, except to the

extent AUI expressly assumes the risk. The Contractor shall repay an amount equal to the unliquidated progress payments that are based on costs allocable to property that is damaged, lost, stolen, or destroyed.

(f) Control of costs and property. The Contractor shall maintain an accounting system and controls adequate for the proper administration of this article.

(g) Reports and access to records. The Contractor shall promptly furnish reports, certificates, financial statements, and other pertinent information reasonably requested by AUI for the administration of this article. Also, the Contractor shall give AUI reasonable opportunity to examine and verify the Contractor's books, records, and accounts.

(h) Special terms regarding default. If this contract is terminated under the Default article, (i) the Contractor shall, on demand, repay to AUI the amount of unliquidated progress payments, and (ii) title shall vest in the Contractor, on full liquidation of progress payments, for all property for which AUI elects not to require delivery under the Default article. AUI shall be liable for no payment except as provided by the Default article.

(i) Reservations of rights.

1. No payment or vesting of title under this article shall: (i) excuse the Contractor from performance of obligations under this contract or (ii) constitute a waiver of any of the rights or remedies of the parties under the contract.

2. AUI's rights and remedies under this article (i) shall not be exclusive but rather shall be in addition to any other rights and remedies provided by law or this contract, and (ii) shall not be affected by delayed, partial, or omitted exercise of any right, remedy, power, or privilege, nor shall such exercise or any single exercise preclude or impair any further exercise under this article or the exercise of any other right, power, or privilege of AUI.

(j) Progress payments to subcontractors. The amounts mentioned in (a)1.(ii) above shall be all progress payments to subcontractors or divisions, if the following conditions are met:

1. The amounts included are limited to: (i) the unliquidated remainder of progress payments made plus (ii) for small business concerns any unpaid Subcontractor requests for progress payments that the Contractor has approved for current payment in the ordinary course of business.

2. The Subcontractor or interdivisional order is expected to involve a minimum of approximately six months between the beginning of work and the first delivery, or if the Subcontractor is a small business concern, four months.

3. The terms of the subcontract or interdivisional order concerning progress payments are:

(i) Are substantially similar to the terms of this article, Progress Payments, for any Subcontractor that is a large business concern, or that article with its Alternate I for any Subcontractor that is a small business concern;

(ii) Are at least as favorable to AUI as the terms of this article;

(iii) Are not more favorable to the Subcontractor or division than the terms of this article are to the Contractor;

(iv) Are in conformance with the requirements of paragraph 32.504(e) of the Federal Acquisition Regulation; and

(v) Subordinate all Subcontractor rights concerning property to which AUI or the Government has title under the subcontract to AUI's right to require delivery of the property to the U.S. Government if (A) the Contractor defaults or (B) the Subcontractor becomes bankrupt or insolvent.

4. The progress payment rate in the subcontract is the customary rate used by AUI, depending on whether the Subcontractor is or is not a small business concern.

5. The parties agree concerning any proceeds received by AUI for property to which title has vested in the U.S. Government under the subcontract terms, that the proceeds shall be applied to reducing any unliquidated progress payments by AUI to the Contractor under this contract.

6. If no liquidated progress payments to the Contractor remain, but there are unliquidated progress payments that the Contractor has made to any Subcontractor, the Contractor shall be subrogated to all the rights AUI obtained through the terms required by this article to be in any subcontract, as if all such rights had been assigned and transferred to the Contractor.

7. The Contractor shall pay the Subcontractor's progress payment request under subdivision (j)1.(ii) above, within a reasonable time after receiving AUI progress payment covering those amounts.

8. To facilitate small business participation in subcontracting under this contract, the Contractor agrees to provide progress payments to small business concerns, in conformity with the standards for customary progress payments stated in Subpart 32.5 of the Federal Acquisition Regulation. The Contractor further agrees that the need for such progress payments shall not be considered as a handicap or adverse factor in the award of subcontracts.

(k) Limitations on Undefinitized Contract Actions. Notwithstanding any other progress payment provisions in this contract, progress payments may not exceed 90 percent of costs incurred on work accomplished under undefinitized contract actions. A "contract action" is any action resulting in a contract, as defined in Subpart 2.1, including contract modifications for additional

supplies or services, but not including contract modifications that are within the scope and under the terms of the contract, such as contract modifications issued pursuant to the Changes article, or funding and other administrative changes. This limitation shall apply to the costs incurred, as computed in accordance with paragraph (a) of this article, and shall remain in effect until the contract action is definitized. Costs incurred which are subject to this limitation shall be segregated on Contractor progress payment requests and invoices from those eligible for higher progress payment rates. For purposes of progress payment liquidation, as described in paragraph (b) of this article, progress payments for undefinitized contract actions shall be liquidated at 90 percent of the amount invoiced for work performed under the undefinitized contract action as long as the contract action remains undefinitized. The amount of unliquidated progress payments for undefinitized contract actions shall not exceed 90 percent of the maximum liability of AUI under the undefinitized contract action or such lower limit specified elsewhere in the contract. Separate limits may be specified for separate actions.

GC40. SCHEDULE OF LIQUIDATED DAMAGES

(a) The Contractor shall promptly pay liquidated damages to AUI for failure by the Contractor to complete certain portions of the Work as follows:

(1) In the event that the Contractor does not deliver all required items for the PDR by the date specified in the approved project schedule, the agreed amount of liquidated damages shall be as follows:

Weeks Late	Total Amount of Damages
1 Week	U.S. $ 5,000
2 Weeks	U.S. $10,000
3 Weeks	U.S. $15,000
4 Weeks	U.S. $20,000
5 Weeks	U.S. $25,000
6 Weeks	U.S. $30,000
7 Weeks	U.S. $35,000
8 Weeks or more	U.S. $40,000

(2) In the event that the Contractor does not deliver all required items for the CDR by the date specified in the approved project schedule, the agreed amount of liquidated damages shall be as follows:

Weeks Late	Total Amount of Damages
1 Week	U.S. $ 5,000
2 Weeks	U.S. $10,000
3 Weeks	U.S. $15,000
4 Weeks	U.S. $20,000
5 Weeks	U.S. $25,000
6 Weeks	U.S. $30,000
7 Weeks	U.S. $35,000
8 Weeks or more	U.S. $40,000

(3) In the event that the Contractor does not deliver the complete design documentation package by the date specified in the approved project schedule, the agreed amount of liquidated damages shall be as follows:

Weeks Late	Total Amount of Damages
1 Week	U.S. $ 5,000
2 Weeks	U.S. $10,000
3 Weeks	U.S. $15,000
4 Weeks	U.S. $20,000
5 Weeks	U.S. $25,000
6 Weeks	U.S. $30,000
7 Weeks	U.S. $35,000
8 Weeks or more	U.S. $40,000

(4) In the event the Contractor does not deliver the completed factory fabrication of the prototype ALMA U.S. antenna by the date specified in the approved project schedule, the agreed amount of liquidated damages shall be as follows:

Weeks Late	Total Amount of Damages
1 Week	U.S. $ 5,000

Weeks Late	Total Amount of Damages
2 Weeks	U.S. $10,000
3 Weeks	U.S. $15,000
4 Weeks	U.S. $20,000
5 Weeks	U.S. $25,000
6 Weeks	U.S. $30,000
7 Weeks	U.S. $35,000
8 Weeks or more	U.S. $40,000

(5) In the event the Contractor does not deliver the completed ALMA U.S. prototype antenna, assembled on site and ready for acceptance by the date specified in the approved project schedule, the agreed amount of liquidated damages shall be as follows:

Weeks Late	Total Amount of Damages
1 Week	U.S. $ 5,000
2 Weeks	U.S. $10,000
3 Weeks	U.S. $15,000
4 Weeks	U.S. $20,000
5 Weeks	U.S. $25,000
6 Weeks	U.S. $30,000
7 Weeks	U.S. $35,000
8 Weeks or more	U.S. $40,000

(b) Damages are not cumulative, and Total Damages will not exceed $40,000 for each portion of the work as defined above.

(c) In the event that actual delivery occurs at a time other than at the end of a complete week of delay, the liquidated damages shall be prorated in the proportion to the amount of time that has elapsed as a part of such week.

(d) AUI and the Contractor acknowledge and agree that the sum agreed upon as liquidated damages is substantially less than the actual losses that would to be incurred by AUI as a result of

delay in completion of the work, so that the liquidated damages, if sought by AUI, are reasonable and do not constitute a penalty.

(e) In the event the Contractor is liable for liquidated damages under the terms of this clause, the damage amount owed shall be deducted from the progress payment following completion of the phase during which the damage was incurred.

(f) If the Contractor incurs damages under this clause, but recovers and delivers the prototype antenna by the contractual delivery date, the damages paid to AUI will be refunded in total without interest.

GC41. TITLE TO MATERIALS AND SUPPLIES

Unless otherwise provided in this contract, title to the materials and supplies purchased hereunder shall pass directly from Seller to Government at the point of delivery shown herein, subject to the right of AUI to inspect and reject, in accordance with specifications and terms and conditions hereof.

GC42. RESPONSIBILITY FOR SUPPLIES

Except as otherwise provided in this contract, (i) the Contractor shall be responsible for the supplies covered by this contract until they are delivered at the designated delivery point, regardless of the point of inspection, (ii) after delivery to AUI at the designated point and prior to acceptance or rejection by AUI and giving notice thereof by AUI, AUI shall be responsible for the loss or destruction of or damage to the supplies only if such loss, destruction, or damage results from the negligence of officers, agents or employees of AUI acting within the scope of their employment; and (iii) the Contractor shall bear all risks as to rejected supplies after notice of rejection, except that AUI shall be responsible for the loss, or destruction of, or damage to the supplies only if such loss, destruction or damage to the supplies results from the gross negligence of officers, agents, or employees of AUI acting within the scope of their employment.

GC43. MATERIALS AND PROPERTY FURNISHED

(a) When AUI furnishes parts, tooling, equipment or other property, title to which is in the U.S. Government, the Contractor's packing sheet and final invoice must contain this statement: "All parts, tooling, or other property furnished or acquired for this contract (except that which became normal industrial waste or was replaced at the Contractor's expense) have been returned in the form of parts, equipment, and tooling." Title to all such equipment and tooling furnished by AUI shall remain in the U.S. Government, and AUI shall at all times have the right to immediate repossession thereof.

(b) If AUI furnishes any material, title to which is in the U.S. Government, for fabrication hereunder, the Contractor agrees not to use any other material in such fabrication without AUI's

written consent. AUI reserves the right to retain 10 percent of the total amount of the Contractor's invoice until all requirements of this article have been fulfilled.

(c) Except as otherwise provided in this contract, the Contractor shall return to AUI the U.S. Government property furnished or acquired under this contract in as good condition as when received except for reasonable wear and tear or for utilization of the property in accordance with the requirements of this contract.

GC44. CONSTRUCTION DRAWINGS AND SHOP DRAWINGS

(a) The Contractor shall keep on the work site a copy of the drawings and specifications and shall at all times give AUI access thereto. Anything mentioned in the specifications and not shown on the drawings, or shown on the drawings and not mentioned in the specifications, shall be of like effect as is shown or mentioned in both. In case of a difference between drawings and specifications, the matter shall be promptly submitted to AUI, who shall promptly make a determination in writing. Any adjustment by the Contractor without such a determination shall be at its own risk and expense. AUI shall furnish from time to time such detailed drawings and other information as considered necessary, unless otherwise provided. "Drawings and specifications" shall be understood to mean all drawings and specifications produced under this contract, including those prepared by Contractor as part of the engineering effort under this contract after review and approval by AUI.

(b) Wherever in the specifications or upon the drawings the word "directed," "required," "ordered," "designated," "prescribed," or words of like import are used, it shall be understood that the "direction," "requirement," "order," "designation," or "prescription" of AUI is intended and similarly the words "approved," "acceptable," "satisfactory," or words of like import shall be "approved by," "acceptable to," or "satisfactory to" AUI unless expressly stated.

(c) Where "as shown," "as indicated," "as detailed," or words of similar import are used, it shall be understood that the reference is made to the drawings accompanying this contract unless stated otherwise. The word "provided" as used herein shall be understood to mean "provide complete in place," that is "furnished and installed."

(d) "Shop drawings" means drawings submitted to AUI by the Contractor or any Subcontractor pursuant to a construction contract, showing in detail:

(1) the proposed fabrication and assembly of structural elements, and

(2) the installation (i.e., form, fit, and attachment detail) of materials or equipment. It includes drawings, diagrams, layouts, schematics, descriptive literature, illustrations, schedules, performance and test data, and similar materials furnished by the Contractor to explain in detail specific portions of the work required by the contract. AUI may duplicate, use, and disclose in any manner and for any purpose shop drawings delivered under this contract.

(e) If this contract requires shop drawings, the Contractor shall coordinate all such drawings and review them for accuracy, completeness, and compliance with contract requirements and shall indicate its approval thereon as evidence of such coordination and review. Shop drawings submitted to AUI without evidence of the Contractor's approval may be returned for resubmission. AUI will indicate an approval or disapproval of the shop drawings and if not approved as submitted shall indicate AUI's reason therefor. Any work done before such approval shall be at the Contractor's risk. Approval by AUI shall not relieve the Contractor from responsibility for any errors or omissions in such drawings, nor from responsibility for complying with the requirements of this contract, except with respect to variations described and approved in accordance with (f) below.

(f) If shop drawings show variations from the contract requirements, the Contractor shall describe such variations in writing, separate from the drawings, at the time of submission. If AUI approves any such variation, AUI shall issue an appropriate contract modification, except that, if the variation is minor or does not involve a change in price or in time of performance, a modification need not be issued.

(g) The Contractor shall submit for approval three (3) printed copies and one (1) editable electronic copy of all shop drawings as called for under the various headings of these specifications. If agreed between AUI and the Contractor, shop drawing submittals and approvals may be conducted at the Contractor's facility. Three sets (unless otherwise indicated) of all shop drawings will be retained by AUI and one set will be returned to the Contractor. Upon completing the work under this contract, the Contractor shall furnish a complete set of all shop drawings as finally approved. These drawings shall show all changes and revisions made up to the time the equipment is completed and accepted.

GC45. SUPERINTENDENCE BY CONTRACTOR

The Contractor shall establish an office at the assembly site during the progress of the work and shall have a competent superintendent, satisfactory to AUI, on the site at all times, with authority to act for it.

AUI may require the Contractor to remove from the work any employee who AUI deems incompetent, careless, insubordinate or otherwise objectionable or whose continued employment on the work is deemed by AUI to be contrary to the public interest.

GC46. OTHER CONTRACTS

AUI may undertake or award other contracts for additional work and the Contractor shall fully cooperate with such other contractors and AUI employees and carefully fit his/her own work to such additional work as may be directed by AUI. The Contractor shall not commit or permit any act which will interfere with the performance of work by any other contractor or by AUI employees. In the case of a conflict, the necessary coordination shall be directed by AUI.

GC47. SUSPENSION OF WORK

(a) AUI may order the Contractor, in writing, to suspend, delay, or interrupt all or any part of the work of the contract for the period of time that AUI determines appropriate for the convenience of AUI.

(b) If the performance of all or any part of the work is, for an unreasonable period of time, suspended, delayed, or interrupted (1) by an act of AUI in administration of this contract, or (2) by AUI's failure to act within the time specified in the contract (or within a reasonable time not specified), an adjustment shall be made for any increase in the cost of performance of this contract (excluding profit) necessarily caused by the unreasonable suspension, delay, or interruption, and the contract modified in writing accordingly. However, no adjustment shall be made under this article for any suspension, delay, or interruption to the extent that performance would have been so suspended, delayed, or interrupted by another cause, including the fault or negligence of the Contractor, or for which an equitable adjustment is provided for or excluded under any other term or condition of this contract.

(c) A claim under this article shall not be allowed (1) for any costs incurred more than 20 days before the Contractor shall have notified AUI in writing of the act, or failure to act, involved (but this requirement shall not apply as to a claim resulting from a suspension order), and (2) unless the claim, in an amount stated, is asserted in writing as soon as practicable after the termination of the suspension, delay, or interruption, but not later than the date of final payment under the contract.

GC48. DIFFERING SITE CONDITIONS

(a) The Contractor shall within twenty-four (24) hours, and before conditions are disturbed, notify AUI in writing of: (1) subsurface or latent physical conditions at the site differing materially from those indicated in this contract, or (2) unknown physical conditions at the site, of an unusual nature, differing materially from those ordinarily encountered and generally recognized as inherent in work of the character provided for in this contract. AUI shall promptly investigate the conditions, and if they find that such conditions do materially so differ and cause an increase or decrease in the Contractor's cost of, or the time required for, performance of any part of the work under this contract, whether or not changed as a result of such conditions, an equitable adjustment shall be made and the contract modified in writing accordingly.

(b) No claim of the Contractor under this article shall be allowed unless the Contractor has given the notice required in (a) above; provided, however, the time prescribed therefor may be extended by AUI.

(c) No claim by the Contractor for an equitable adjustment hereunder shall be allowed if asserted after final payment under this contract.

GC49. Site Investigation and Conditions Affecting the Work

(a) The Contractor acknowledges that it has taken steps reasonably necessary to ascertain the nature and location of the work, and that it has investigated and satisfied itself as to the general and local conditions which can affect the work or its cost, including but not limited to (1) conditions bearing upon transportation, disposal, handling, and storage of materials; (2) the availability of labor, water, electric power, and roads; (3) uncertainties of weather, river stages, tides, or similar physical conditions at the site; (4) the conformation and conditions of the ground; and (5) the character of equipment and facilities needed prior to and during the work performance. The Contractor also acknowledges that it has satisfied itself as to the character, quality, and quantity of surface and subsurface materials or obstacles to be encountered insofar as this information is reasonably ascertainable from an inspection of the site, including all exploratory work done by AUI, as well as from any drawings and specifications made a part of this contract. Any failure of the Contractor to take the actions described and acknowledged in this paragraph will not relieve the Contractor from responsibility for estimating properly the difficulty and cost of successfully performing the work, or for proceeding to successfully perform the work without additional expense to AUI.

(b) AUI assumes no responsibility for any conclusions or interpretations made by the Contractor based on the information made available by AUI. Nor does AUI assume responsibility for any understanding reached or representation made concerning conditions which can affect the work by any of its officers or agents before the execution of this contract, unless that understanding or representation is expressly stated in this contract.

GC50. Protection of Existing Vegetation, Structures, Equipment, Utilities, and Improvements

(a) The Contractor shall preserve and protect all structures, equipment, and vegetation (such as trees, shrubs, and grass) on or adjacent to the work site, which are not to be removed and which do not unreasonably interfere with the work required under this contract. The Contractor shall avoid damaging vegetation that will remain in place. If any limbs or branches of trees are broken during contract performance, or by the careless operation of equipment, or by workmen, the Contractor shall trim those limbs or branches with a clean cut and paint the cut with a tree-pruning compound as directed by AUI.

(b) The Contractor shall protect from damage all existing improvements and utilities (1) at or near the work site and (2) on adjacent property of a third party, the locations of which are made known to or should be known by the Contractor. The Contractor shall repair any damage to those facilities, including those that are the property of a third party, resulting from failure to comply with the requirements of this contract or failure to exercise reasonable care in performing the work. If the Contractor fails or refuses to repair the damage promptly, AUI may have the necessary work performed and charge the cost to the Contractor.

GC51. OPERATIONS AND STORAGE AREAS

(a) The Contractor shall confine all operations (including storage of materials) on AUI or U.S. Government premises to areas authorized or approved by AUI. The Contractor shall hold and save AUI and the U.S. Government, its officers and agents, free and harmless from liability of any nature occasioned by the Contractor's performance.

(b) Temporary buildings (e.g., storage sheds, shops, offices) and utilities may be erected by the Contractor only with the approval of AUI and shall be built with labor and materials furnished by the Contractor without expense to AUI. The temporary buildings and utilities shall remain the property of the Contractor and shall be removed by the Contractor at its expense upon completion of the work unless an alternate agreement is made between the Contractor and AUI. With the written consent of AUI, the buildings and utilities may be abandoned and need not be removed.

(c) The Contractor shall, under regulations prescribed by AUI, use only established roadways, or use temporary roadways constructed by the Contractor when and as authorized by AUI. When materials are transported in prosecuting the work, vehicles shall not be loaded beyond the loading capacity recommended by the manufacturer of the vehicle or prescribed by any Federal, State, or local law or regulation. When it is necessary to cross curbs or sidewalks, the Contractor shall protect them from damage. The Contractor shall repair or pay for the repair of any damaged curbs, sidewalks, or roads.

GC52. CLEANING UP

The Contractor shall at all times keep the site, including storage areas used by him/her, free from accumulations of waste material or rubbish and prior to completion of the work shall remove any rubbish from the premises and all tools, scaffolding, equipment, and materials not the property of the U.S. Government or AUI. Upon completion of the construction, the Contractor shall leave the work and premises in a clean, neat, and workmanlike condition satisfactory to AUI.

GC53. SUBCONTRACTORS

Within seven days after award of any construction subcontract by the Contractor, he/she shall deliver to AUI a statement setting forth the name and address of the Subcontractor(s) and a summary description of the work to be subcontracted. The Contractor shall at the same time furnish a statement signed by its Subcontractor(s) acknowledging the inclusion in its subcontract of the articles of this contract entitled "Contract Work Hours and Safety Standards Act—Overtime Compensation," "Drug Free Workplace," "Withholding of Funds," "Subawards (Labor Standards)," "Agreement Termination—Debarment," "Equal Opportunity," and "Disputes Concerning Labor Standards." Nothing contained in this contract shall create any contractual relation between any such Subcontractor and AUI.

GC54. USE AND POSSESSION PRIOR TO COMPLETION

(a) AUI shall have the right to take possession of or jointly use any completed or partially completed part of the work. Before taking possession of or using any work, AUI shall furnish the Contractor a list of items of work remaining to be performed or corrected on those portions of the work that AUI intends to take possession of or use. However, failure of AUI to list any item of work shall not relieve the Contractor of responsibility for complying with the terms of the contract. AUI's possession or joint use shall not be deemed an acceptance of any work under the contract.

(b) While AUI has such possession or use, the Contractor shall be relieved of the responsibility for the loss of or damage to the work resulting from AUI's possession or joint use, notwithstanding the terms of the article in this contract entitled "Permits and Responsibility for Work." If prior possession or use by AUI delays the progress of the work or causes additional expense to the Contractor, an equitable adjustment shall be made in the contract price or the time of completion, and the contract shall be modified in writing accordingly.

GC55. FINAL PAYMENT

Following the successful completion of the antenna acceptance testing, in accordance with the approved Acceptance Test Procedures, the Contractor shall provide a completed Release of Claims (Attachment C) and a final progress payment request. Upon receipt and acceptance of the Release of Claims and final payment request, AUI shall issue a Final Payment, including retainage, to the Contractor.

ATTACHMENT C

RELEASE OF CLAIMS

Contractor _____

Contract _____

I hereby certify that the following work under Contract No. _____ (hereinafter referred to as the "Contract") between the above named Contractor and Associated Universities, Inc., (hereinafter referred to as AUI) which is a contract under Cooperative Agreement No. NSF AST-9223814 between AUI and the U.S. Government, has been completed.

In consideration of the total payment on account of the Contract in the sum of $_____ made by AUI, the undersigned Contractor hereby releases AUI, its officers, agents and employees and the Government of the United States, its agents and employees, from any and all claims arising under the Contract or in connection with the work, described above, required to be performed thereunder, and hereby agrees to indemnify AUI and the U.S. Government against, and to save each of them harmless from, any claims by any person arising out of or in any way connected with the Contract or the work thereunder. The following are excepted from the foregoing release and agreement:

_____

_____

_____

Witness:

_____
(Contractor)

_____ By_____

_____ _____
(Address) (Title)

ATTACHMENT D

GLOSSARY

AAB - Antenna Assembly Building

ACU - Antenna Control Unit

ALMA - Atacama Large Millimeter Array

AUI - Associated Universities, Incorporated

BIMA - Berkeley Illinois Maryland Association

BUS - Back-up Structure

CAS - Cost Accounting Standards

CDR - Critical Design Review

CFR - Code of Federal Regulations

CFRP - Carbon Fiber Reinforced Plastic

CPU - Central Processing Unit

DC - Direct Current

EEO - Equal Employment Opportunity

EPA - Environmental Protection Agency

ESO - European Southern Observatory

FAR - Federal Acquisition Regulation

FEA - Finite Element Analysis

FOB - Free-On-Board

G - Gravity

G&A - General and Administrative

GHz - Gigahertz

Hz - Hertz

IRAM - Institut de Radio Astronomie Millimétrique

kVA - kilo-volts-amps

kW - kilowatts

LO - Local oscillator

LSA - Large Submillimeter Array

HVAC - Heating Ventilation and Air conditioning

m - meter

mm - millimeter

MIL-STD - Military Standard

MHz - Megahertz

MSDS - Material Safety Data Sheet

MTBF - Mean Time Before Failure

ms - milliseconds

NEC - National Electric Code

NEMA - National Electrical Manufacturers Association

NRAO - National Radio Astronomy Observatory

NSF - National Science Foundation

OEM - Original Equipment Manufacture

OFCCP - Office of Federal Contract Compliance Programs

OVRO - Owens Valley Radio Observatory

PCU - Portable Control Unit

PDR - Preliminary Design Review

PPE - Personal Protective Equipment

RFI/EMI - Radio Frequency Interference/ Electromagnetic Interference

RFP - Request For Proposal

RMS - Root-Mean-Squared

RSS - Root-Sum-Squared

SEC - Socorro Electric Cooperative

TBD - To Be Determined

μm - Micrometers (microns)

tons - (short) - (2,000 pounds or 907.2 kilograms)

UPS - Uninterruptible Power Supply

U.S. - United States

USC - United States Code

WBS - Work Breakdown Structure

WWW - World Wide Web

VA - Volts-Amps

VAC - Volts Alternating Current

VLA - Very Large Array

ALMA-US ICD No. 1

WBS 3.2.8.10 / 4.1

Antenna / Receiver Interface

Authors: J. Kingsley / V.Gasho / J. Payne / G. Moorey

Date: 2000-JAN-24

Version: A

Issued by: Antenna and Receiver Groups

		Date:
Approved by:	Peter Napier, ALMA-US Division Head 1	2000-JAN-24
	Graham Moorey, ALMA-US Division Head 2	2000-JAN-24
	Darrel Emerson, ALMA-US Systems Engineering	2000-JAN-24
Approved by:	Torbin Andersen, ALMA-EURO Team Leader 1	2000-JAN-24
	_____ALMA-EURO Team Leader 2	_____
	_____ALMA-EURO System Engineering_____	

Revision Control

1. Revision Version #_____
   Date:
   Revised by:
   Reason for / items changed:

2. Revision Version #_____
   Date:
   Revised by:
   Reason for / items changed:

etc.

1.0 Description

To define receiver mechanical interfaces to antenna.

2.0 Related Documents and Drawings

U.S. Prototype Antenna Purchase Order Section 3.5.4 Receiver Cabin
U.S. Prototype Antenna Purchase Order Section 3.6.4 Receiver Package Interface
U.S. Prototype Antenna Purchase Order Section 3.6.6 Receiver Package Installation Interface
U.S. Prototype Antenna Purchase Order Section Appendix A Antenna Optical Configuration
ALMA-US ICD No. 3 Antenna / Site Electrical Power Interface
ALMA-US ICD No. 6 Antenna / Cable Wrap Interface
ALMA-US ICD No. 7 Antenna / Helium Compressor Interface

2.1 Related Interface Control Drawings

03031000M003B – ALMA Evaluation Receiver, Revision B, 2000-JAN-24
03031000M010B – Equipment View, Receiver Cabin, Revision B, 2000-JAN-24
03020810M010B – Receiver Interface Plate, Revision B, 2000-JAN-24

3.0 Physical System Interfaces

3.1 Mechanical interface

Contractor will provide a removable receiver interface plate on antenna to conform to the specifications in AUI drawing number 03020810M001B and meet all pertinent specification in the U.S. Prototype Antenna Purchase Order such as Pointing Accuracy (3.4.2), Fast Motion Capability (3.4.4), Path Length Errors (3.4.5) and Survival Conditions (3.3.2.5). The AUI/ESO receiver package will conform to the AUI drawing number 0303100M003B.

The angular stability of the receiver and interface plate shall be better than 0.03 of the total angle subtended by the subreflector. This plate shall be attached to the antenna by a method so that it can be easily be removed and installed while preserving the location to the antenna. The plate shall be level with respect to gravity with the antenna pointing at the zenith to a tolerance of +/- 1/20 degree and a lateral tolerance of +/-0.25 mm.

The interface for the installation mechanism for the receiver shall be provided by lifting eyes at several locations on the receiver frame and/or the bottom surface of the receiver frame, to be negotiated.

Full access around the receiver is required and access to the volume above the receiver as specified in NRAO drawing number 03020810M001B is also required.

3.2 Mass, if relevant

The receiver mass is variable between 0 kg and 550 Kg and may require the Contractor to provide adjustable or removable counter weight to balance the antenna in elevation.

3.3 Electrical power

The receiver will require electrical power at a connector TBD and location that is TBD in the receiver cabin. The voltage at this single phase connector shall be 230 VAC at a TBD kVA.

3.4 Electronic interface, including computer hardware

Not relevant

3.5 Thermal control interface

One of the flexible ducts specified in the U.S. Prototype Antenna Purchase Order Section 3.5.4 Receiver Cabin will be routed to the receiver frame. The thermal capacity and flow of this duct is TBD.

4.0 Software/Control Function Interface

4.1 Monitor and Control software interface

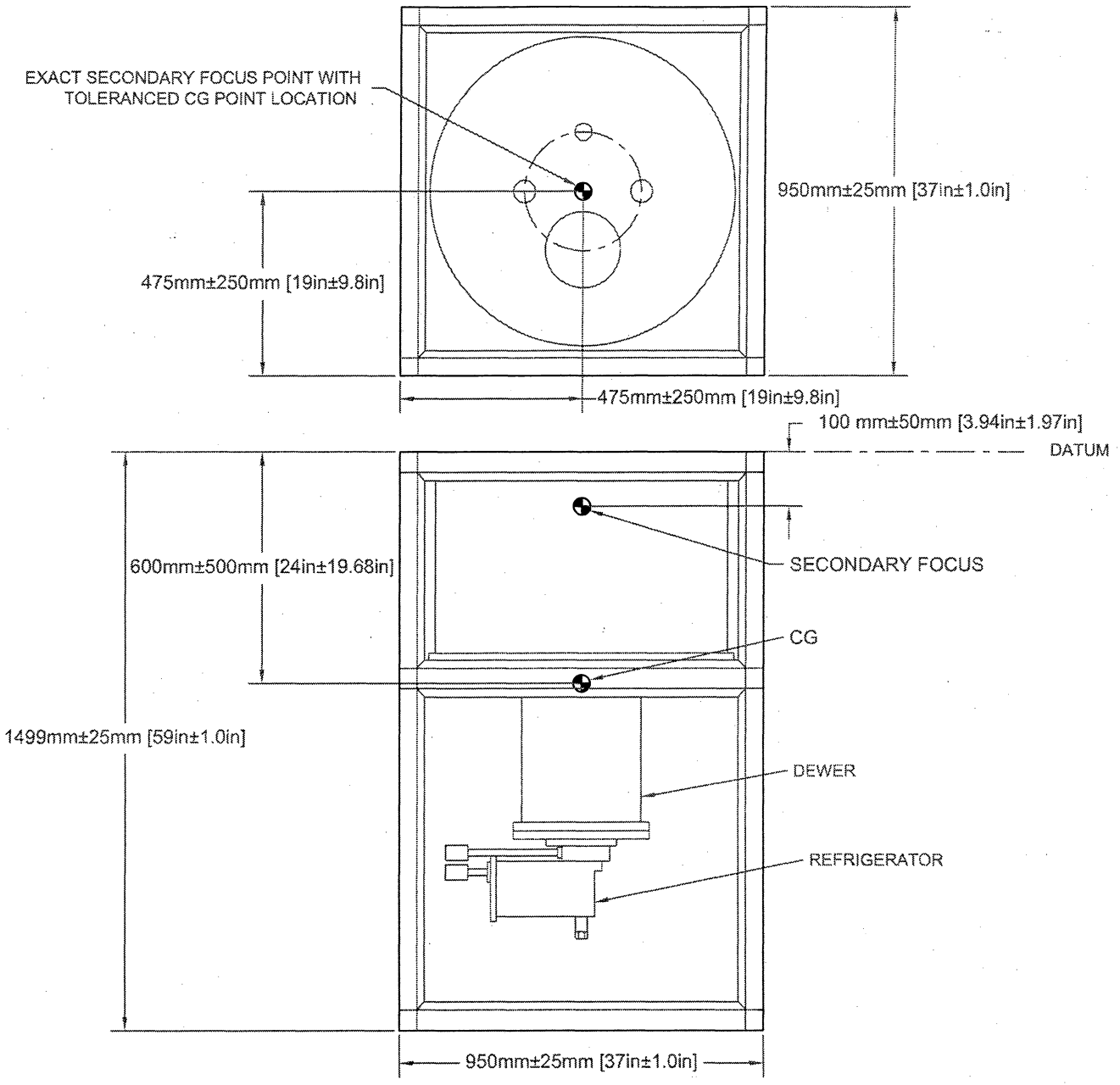
Not relevant

4.2 Other software or control interface

Not relevant

5.0 Safety Issues

Not aware of any

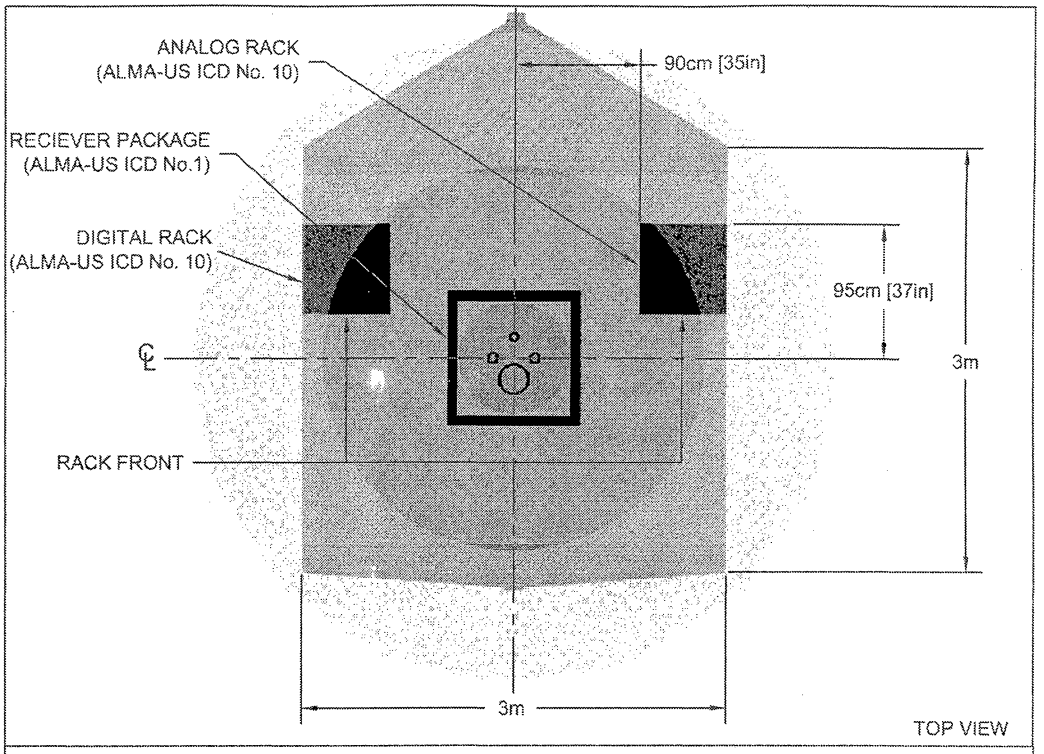


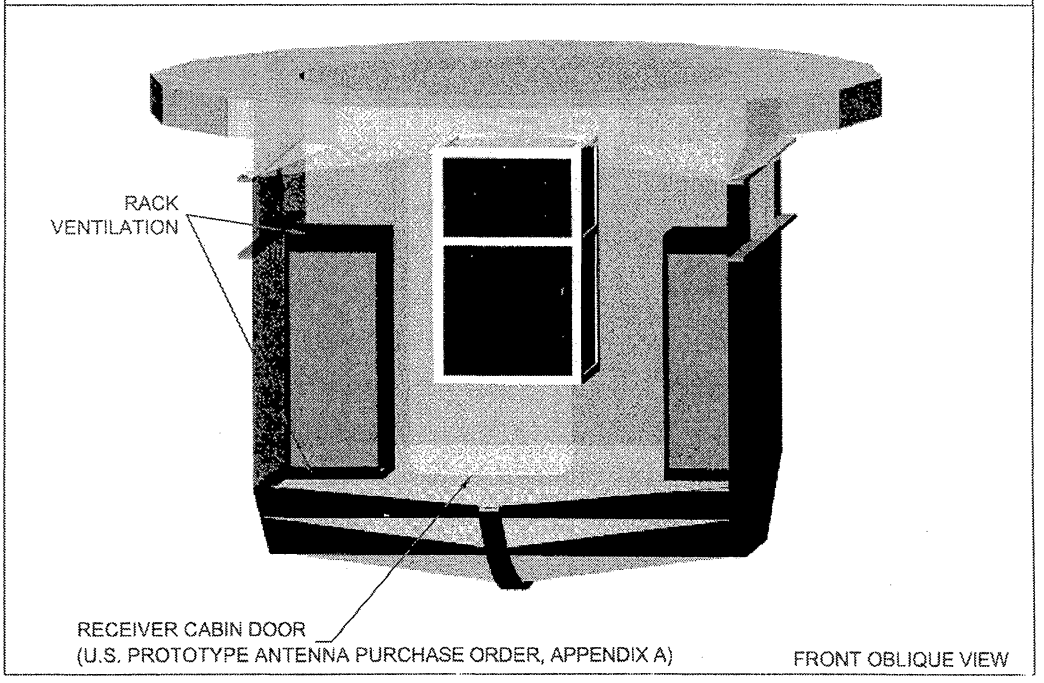
NOTES:

1.) FRAME MEMBERS, DEWAR, FFEDS AND REFIGERATOR IS AN EXAMPLE LAYOUT.

2.) HIGH PRESSURE GAS LINES CONNECT TO RECEIVER, SEE ALMA-US ICD No. 6 and 7.

CONTRACT NO.		NATIONAL RADIO ASTRONOMY OBSERVATORY operated by ASSOCIATED UNIVERSITIES INC. in agreement with THE NATIONAL SCIENCE FOUNDATION	
METRIC THIRD ANGLE PROJECTION	APPROVALS / DATE	TITLE: ALMA EVALUATION RECEIVER DIMENTIONS	MMA-TUCSON 949 N. CHERRY AVE. CAMPUS BLDG 65 TUCSON, AZ 85721-0655
	DRAWN V.L. GASHO 2000-01-24		
	CHECKED J. CHENG 2000-01-24		
	ENGR. J.S. KINGSLEY 2000-01-24		
	SYSTEMS GROUP D.T. EMERSON 2000-01-24		
		SIZE A / CAGE CODE / DWG NO. 03031000M003B / REV. B	
		SCALE NONE / CALC. WT / ACT. WT / SHEET 1/1	





METRIC

THIRD ANGLE PROJECTION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MILLIMETERS
TOLERANCES ARE:

DECIMALS ANGLES
.X±0.8 ±0.5°
.XX±0.25

DO NOT SCALE DRAWING

TREATMENT

FINISH

SIMILAR TO | SPECIAL MARKING SYM.

CONTRACT NO.

APPROVALS	DATE
DRAWN V.L. GASHO	2000-01-24
CHECKED J. CHENG	2000-01-24
ENGR. J. KINGSLEY	2000-01-24
SYSTEMS GROUP D. EMERSON	2000-01-24

NATIONAL RADIO ASTRONOMY OBSERVATORY

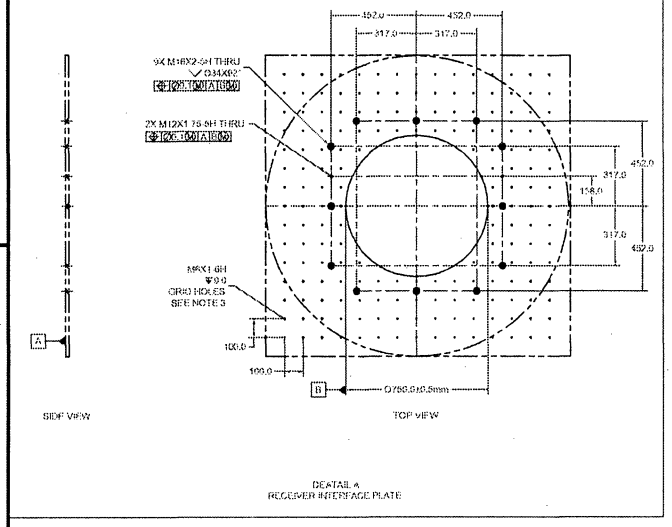
operated by ASSOCIATED UNIVERSITIES INC. in agreement with
THE NATIONAL SCIENCE FOUNDATION

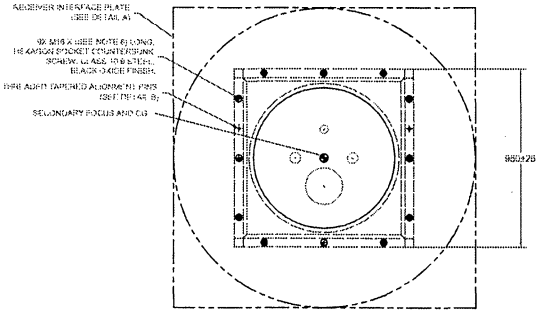
TITLE
EQUIPMENT VIEW
RECEIVER CABIN

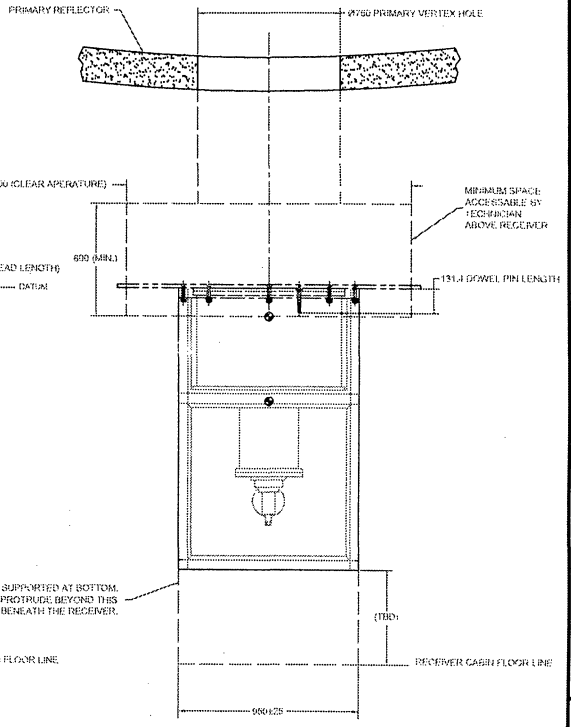
MMA-TUCSON
949 N. CHERRY AVE.
CAMPUS BLDG. 65
TUCSON, AZ 85721-0655

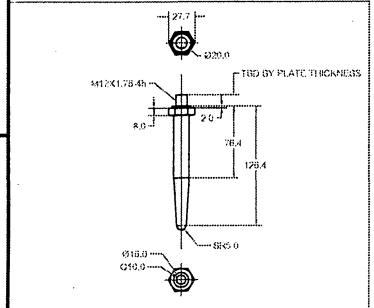
SIZE	CAGE CODE	DWG NO.	REV.
A		03031000N010B	B

SCALE	CALC. WT	ACT. WT	SHEET
NONE			1/1









NOTES:
1. QTY. 2 PER ASSEMBLY.
2. MATERIAL: AISI 4130 OR DIN EQUIVALENT

NOTES:
1. PLATE WILL BE DESIGNED TO SUPPORT A RECEIVER MASS FROM 0 KG TO 650 KG.
2. CONTRACTOR WILL SPECIFY THE OUTSIDE DIMENSIONS AND THICKNESS OF THE PLATE.
3. THE PLATE SHALL ONLY BE ATTACHED TO THE ANTENNA THROUGH THE USE OF EASILY REMOVABLE FASTENERS. THE DETAILS OF THE ANTENNA TO PLATE INTERFACE SHALL BE PROVIDED BY THE CONTRACTOR TO AIE.
4. GRID HOLES ARE FOR MOUNTING AUI OPTICAL DEVICES. HOLES WILL BE EQUALLY SPACED 100 mm APART AND SHALL NOT BE LESS THAN 12 mm FROM ANY EDGE.
5. UNTOLERANCED DIMENSIONS LOCATING TRUE POSITION ARE BASIC.
6. SCREW LENGTH WILL BE A MINIMUM OF 74 mm PLUS THE PLATE THICKNESS

METRIC

THIRD ANGLE PROJECTION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MILLIMETERS
TOLERANCES ARE:
DECIMALS ANGLES
X±1 ±1°
X±0.1 ±0.5'
XX±0.01
DO NOT SCALE DRAWING

TREATMENT

FINISH

SIMILAR TO | SUPERSEDES

CONTRACT NO.

APPROVALS	DATE
DRAWN V.L. GASHO	2000-01-24
CHECKED J. Cheng	2000-01-24
ENGR. J.S. KINGSLEY	2000-01-24
SYSTEMS GROUP D.T. EMERSON	2000-01-24

NATIONAL RADIO ASTRONOMY OBSERVATORY
operated by ASSOCIATED UNIVERSITIES INC. in agreement with THE NATIONAL SCIENCE FOUNDATION

TITLE: RECEIVER INTERFACE PLATE

ALMA-TUCSON
949 N. CHERRY AVE.
CAMPUS BLDG. 65
TUCSON, AZ 85721-0655

SIZE	CAGE CODE	DWG NO.	REV.
B		03020810M001B	B

SCALE 1:25 | SHEET 1/1

ALMA-US ICD No. 2

WBS 3.2.8.10/ 10.7.1

Antenna / Apex Interface

Authors: J. S. Kingsley / V. Gasho / D. Emerson / A. Perfetto

Date: 2000-JAN-24

Version: A

Issued by: Antenna and Systems Groups

		Date:
Approved by: Peter Napier,	ALMA-US Division Head 1	2000-JAN-24
Darrel Emerson,	ALMA-US Division Head 2	2000-JAN-24
Darrel Emerson,	ALMA-US Systems Engineering	2000-JAN-24
Approved by: Torbin Andersen,	ALMA-EURO Team Leader 1	2000-JAN-24
_____	ALMA-EURO Team Leader 2	_____
_____	ALMA-EURO System Engineering	_____

Revision Control

1. Revision Version #_____
   Date:
   Revised by:
   Reason for / items changed:

2. Revision Version #_____
   Date:
   Revised by:
   Reason for / items changed:

etc.

1.0 Description

To define apex mechanical interfaces to the antenna. This interface will provide a mounting flange and space requirement for a nutating device and holography receiver. The subreflector and apex interface cylinder will be specified.

2.0 Related Documents and Drawings

U.S. Prototype Antenna Purchase Order, Appendix A, Antenna Optical Configuration
U.S. Prototype Antenna Purchase Order, Section 3.5.5 Apex Equipment

2.1 Related Interface Control Drawings

03020810M002A Apex Interface, Revision B, 2000-JAN-24

3.0 Physical System Interfaces

3.1 Mechanical interface

The contractor shall provide an apex interface to the specifications of drawing number 03020810M002A. As specified in the drawing 03020810M002A APEX INTERFACE the required volumes A and B shall be provided for additional AUI equipment such as calibrator, nutator and holography receiver. The flanges for bolting with dowel pins will be provided on the top of the quadrupod as shown in the drawing. A flange shall also be provided at the front of the focus stage with the bolt and dowel pin pattern shown in the Apex Detail. Detailed material properties that are selected by the Contractor for the Apex Interface Cylinder and Subreflector shall be approved by AUI. The subreflector ribs and supporting structure shall be determined by the Contractor to meet U.S. Prototype Antenna Purchase Order specification and be approved by AUI.

The antenna shall meet all requirements specified in Contract while a 20 Newton-mm torque is applied at the subreflector mounting flange with a 10 Hz low jerk square wave that has a 10 milliseconds rise time. This action will be primarily applied in the cross elevation direction but shall meet specifications in all directions of this nutation motion.

3.2 Mass, if relevant

Apex shall meet performance specifications with vendor supplied Apex Interface Cylinder, Subreflector and an additional mass that can vary from 0 to 20 kg.

3.3 Electrical power

Not relevant

3.4 Electronic interface, including computer hardware

Not relevant

3.5 Thermal control interface

Not relevant

4.0 Software/Control Function Interface

4.1 Monitor and Control software interface

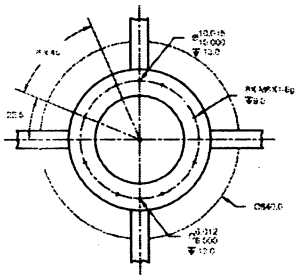
Not relevant

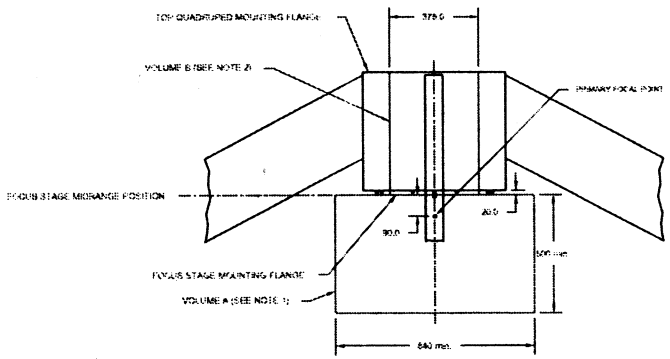
4.2 Other software or control interfaces

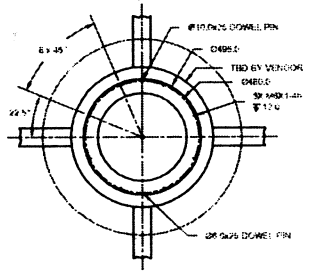
Not relevant

5.0 Safety Issues

Not aware of any

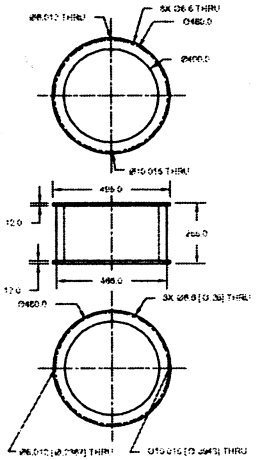






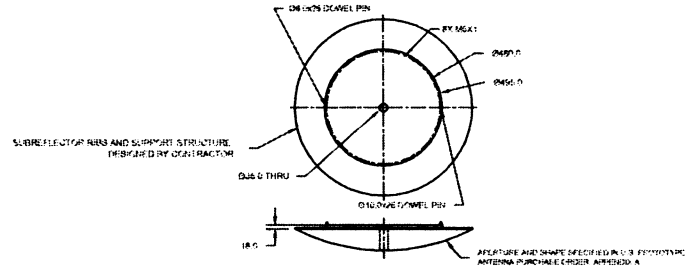
APEX DETAIL

NOTES:
1) SUBREFLECTOR VOLUME FOR NUTATOR IS Ø840 X 900 AND VOLUME TRAVELS WITH FOCUS STAGE
2) PARABOLOID BACK RELIEF FOR CALIBRATION SYSTEM AND HOLOGRAPHY RECEIVERS IS Ø75 THRU HOLE



APEX INTERFACE CYLINDER

NOTES:
1) MATERIAL: ALUMINUM WITH DETAILED MATERIAL SPECIFICATIONS APPROVED BY AUI



SUBREFLECTOR

NOTES:
1) MATERIAL: ALUMINUM WITH DETAILED MATERIAL SPECIFICATIONS APPROVED BY AUI

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MILLIMETERS TOLERANCES ARE: DECIMALS ANGLES X±1 ±1° .X±0.1 ±0.5° .XX±0.01	CONTRACT NO.
DO NOT SCALE DRAWING	
TREATMENT	
FINISH	
BREAK EDGES	BREAK INSIDE

METRIC
THIRD ANGLE PROJECTION

APPROVALS	DATE
DRAWN J.S. Kingsley	2000-01-24
CHECKED V.L. GASHO	2000-01-24
ENGR. J.S. Kingsley	2000-01-24
SYSTEMS GROUP D. Emerson	2000-01-24

NATIONAL RADIO ASTRONOMY OBSERVATORY
operated by ASSOCIATED UNIVERSITIES INC. in agreement with THE NATIONAL SCIENCE FOUNDATION

TITLE: APEX INTERFACE

ALMA-TUCSON
949 N. CHERRY AVE.
CAMPUS BLDG. 65
TUCSON, AZ 85721-0655

SIZE	CAGE CODE	DWG NO.	REV
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ALMA-US ICD No. 3

WBS 3.0/2.3

Antenna/Site Electric Power Interface

Author: C. Dichirico

Date: 2000-JAN-25

Version: B

Issued by: ESO Garching Technical Division

			Date:
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CHANGE RECORD

VERSION	DATE	SECTION/PAGE AFFECTED	REASON/INITIATION/ /DOCUMENTS/REMARKS
Draft	27-Oct-1999	All	Draft
A	12-Dec-1999	Sections 2.2, 3.1, 3.3.2.5	Teleconference 06-Dec-99
B	25-Jan-2000	Sections 2.1, 2.2	

TABLE OF CONTENTS

1. Scope

This document describes the requirements and establishes the detailed specifications for the interface and connections between the ALMA site power distribution system and the ALMA antenna internal power system.

2. Applicable Documents

The following documents of the exact issue shown form a part of this ICD to the extent specified herein. Where no issue or date is indicated, the latest editions/revisions thereof and any amendments or supplements thereto in effect on the date of the Contract Documents shall be taken as valid. In the event of conflict between the documents referenced herein and the contents of this ICD, the contents of this ICD shall be considered a superseding requirement.

2.1 Specifications and standards

AD-01 RESERVED

AD-02 IEC 60309-1 (1997-08)
Plugs, socket-outlets and couplers for industrial purposes – Part 1: General requirements

AD-03 IEC 60309-2 (1997-10)
Plugs, socket-outlets and couplers for industrial purposes – Part 2: Dimensional interchangeability requirements for pin and contact-tube accessories

AD-04 IEC 60529
Degrees of protection provided by enclosures (IP Code)

AD-05 IEC 60038
IEC standard voltages

AD-06 IEC 61000
Electromagnetic compatibility (EMC) (the entire series)

AD-07 CISPR 11
Industrial, scientific and medical (ISM) radio frequency equipment – Electromagnetic disturbance characteristics – Limits and methods of measurement

AD-08 IEC 60364
Electrical installations of buildings (the entire series)

2.2 Interface control drawings

AD-09 Drawing No. 03020810E001, Rev. B, 1999-12-16
ALMA Antenna Electrical Power – Preliminary Power Layout

3. Physical System Interface

3.1 Mechanical interface

Note. The requirements within the present section "3.1 Mechanical interface" are based onto the applicable drawing AD-09.

The electric power connection between the ALMA site power distribution system and the ALMA antenna shall be realized at the base of the antenna (at the so-called electrical service entrance).

This connection (interface) shall be realized by means of two appliance couplers (definition 6.2) to be located at the antenna base.

The first appliance coupler shall provide the connection to the ALMA site power distribution system. The second appliance coupler shall provide the connection to the transporter power.

The two appliance inlets (definition 6.2.2) shall be mounted onto the outside walls of the antenna base.

It shall not be possible:

- to mate the connector (definition 6.2.1) of the ALMA site power distribution system with the antenna appliance inlet dedicated to the transporter power;
- to mate the connector of the transporter power with the antenna appliance inlet dedicated to the ALMA site power distribution system.

ALMA antenna shall be suitable to be operated at 400 VAC, 50 or 60 Hz, with 50 Hz being the rated frequency at the ALMA site.

Appliance couplers shall have the following characteristics according to IEC 60309-1 and IEC 60309-2 (AD-02 and AD-03):

1. enclosure in aluminum or sheet steel (as examples: MENNEKES® appliance inlet IP 67, product group 2350, I = 200 A, 5 poles, part number 75266; MENNEKES® connector IP 67, product group 3313, I = 200 A, 5 poles, part number 75216);
2. watertight construction (also IPX7), that is, the one marked with the "two drops" symbol;
3. red colour coded (if available with aluminum or sheet steel enclosure);
4. rated current I = 125 A (I = 125 A corresponding to I = 100 A of the U.S. Series II): it shall be possible to supply this rated current at the ALMA site;
5. three-phase, 5 contacts, 3P + N + PE type, 50 and 60 Hz, earthing contact position 6 (table 104 of IEC 60309-2) provided that this type may be safely operated at ALMA site.

Appliance couplers shall be suitable to be safely operated at the ALMA site that is located at about 5100 m above sea level. The impact of all the environmental conditions at this site shall be taken into account, in particular, without being limited to, the strong UV radiation as well as the effects of the lower dielectric strength and of the reduced cooling capacity of air. Appliance couplers will not be accepted only because they are the products of a company regularly engaged in the manufacture of these accessories or because they are the standard units in regular production at the manufacturer's place of business. Appliance couplers will be accepted only if their ability to safely operate at the ALMA site is declared by their manufacturer or otherwise demonstrated. Compliance with the environmental conditions at ALMA site shall be demonstrated also for the products listed under point 1 above.

For what not otherwise specified, the appliance couplers shall comply with IEC 60309-1 and IEC 60309-2 (AD-02 and AD-03).

3.2 Mass

Not relevant.

3.3 Electric Power

3.3.1 General

According to AD-01, the electrical service entrance of the ALMA antenna will have to be dimensioned for a maximum demand S = 75 kVA to be supplied by means of a three-phase four-wire system with nominal voltage 230/400 V with a range ±10%. (This range is not to be confused with the compatibility level ? U = ±10% nor with the immunity limit ? U = ±12% specified below.)

ALMA site power distribution system will be a TN-S system. The interface being specified shall therefore be comprised of four live conductors (namely, the phase conductors L1, L2, L3 and the neutral conductor N) as well as of the protective conductor PE (U.S.: equipment grounding conductor).

The neutral conductor N will be earthed in only one point (typically, the neutral point of the low-voltage winding of the distribution transformers of ALMA site power distribution system will be earthed). Apart from this single point, the neutral conductor shall be kept insulated from the protective conductor PE as well as from any other conductors of the earthing system (earth electrodes, earthing conductors, equipotential bonding conductors, etc.). In particular, this insulation shall be maintained at the interface being specified.

Conversely, the protective conductor PE (U.S.: equipment grounding conductor) shall be earthed to the local ALMA antenna earth electrode (thereby realizing an equipotential bonding).

3.3.2 EMC and Power Quality – Compatibility levels

The compatibility levels (definition 6.10) listed within this section characterize the power quality that the ALMA site power distribution system is expected to exhibit at the interface being specified.

3.3.2.1 Harmonic voltages - Compatibility levels for individual harmonic voltages

Compatibility levels for individual harmonic voltages at the interface being specified will be as in the following table.

Odd harmonics non-multiple of 3		Odd harmonics multiple of 3		Even harmonics	
Harmonic order n	Harmonic voltage %	Harmonic order n	Harmonic voltage %	Harmonic order n	Harmonic voltage %
5	6	3	5	2	2
7	5	9	1.5	4	1
11	3.5	15	0.3	6	0.5
13	3	21	0.2	8	0.5
17	2	>21	0.2	10	0.5
19	1.5			12	0.2
23	1.5			>12	0.2
25	1.5				
>25	0.2+0.5*25/n				

3.3.2.2 Harmonic voltages - Compatibility levels for total harmonic distortion

The compatibility level for the voltage total harmonic distortion at the interface being specified will be D = 8%.

3.3.2.3 Transient harmonic voltages

The compatibility levels of individual voltage harmonics and voltage THD refer to continuous values. For transient harmonics, values up to and including 1.5 times the permanent limits are allowed during a maximum duration of 10% of any observation period of 2.5 minutes.

3.3.2.4 Interharmonics

TBD

3.3.2.5 Voltage fluctuations – rectangular (step) voltage changes

The compatibility levels for rectangular (step) voltage changes will be those standardized by Figure 1 of IEC 61000-2-2 (a part of AD-06).

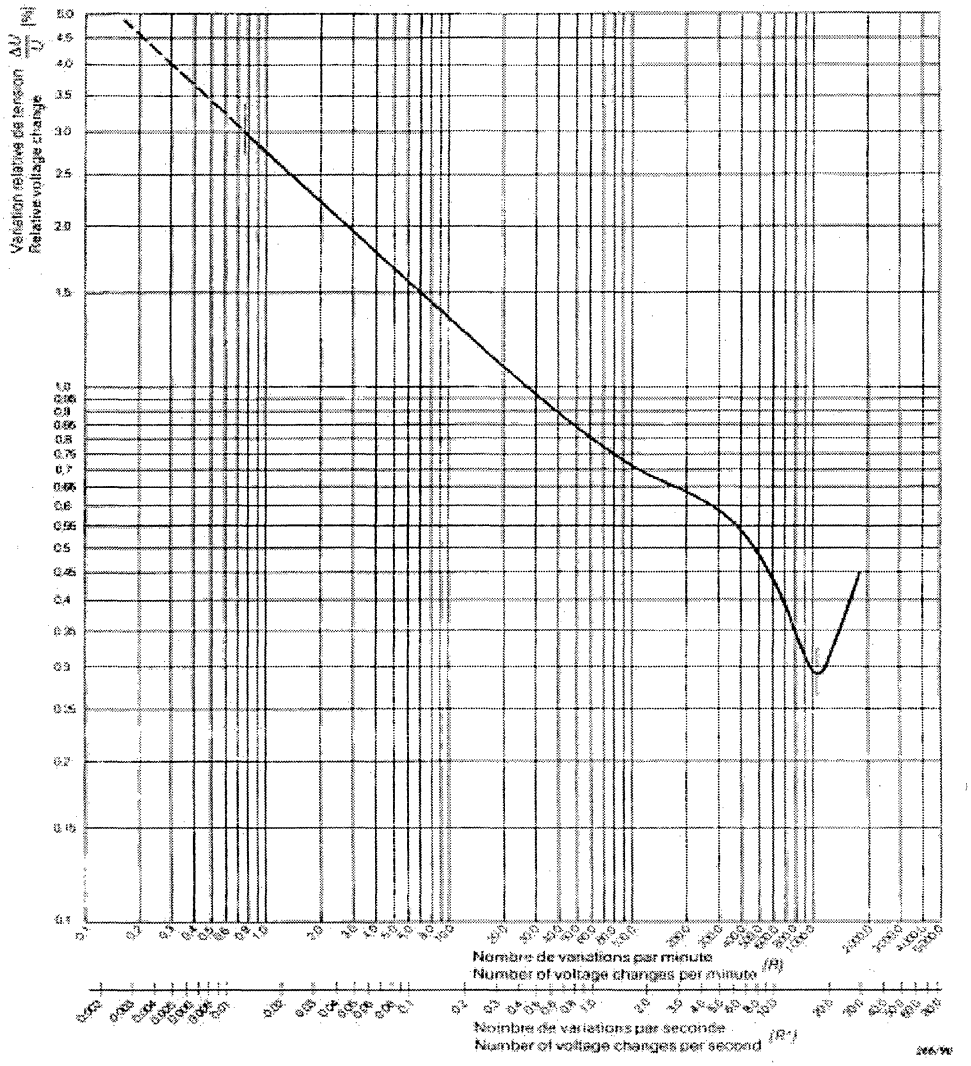

Figure 1 - Step voltage changes and light flicker: Magnitude of maximum permissible percentage voltage changes $\Delta U/U$ (%) with respect to number of voltage changes per second or minute

3.3.2.6 Voltage fluctuations – voltage fluctuations causing flicker

The compatibility levels of voltage fluctuations causing flicker will be 3% of the nominal supply voltage 400 VAC.

3.3.2.7 Voltage fluctuations – infrequent step voltage changes

The compatibility levels for infrequent (some per day) step voltage changes will be 10% of the nominal supply voltage.

3.3.2.8 Voltage dips

TBD

3.3.2.9 Three-phase voltage unbalance

The compatibility level for negative sequence voltage unbalance will be

$$\tau = U_{neg}/U_{pos} = 2\%$$

3.3.2.10 Power frequency variation

The compatibility level for variation of the fundamental frequency (f_n = 50 Hz) will be

±2% i.e., ±1 Hz

3.3.2.11 DC components in the AC power system

TBD

3.3.2.12 Mains signalling

TBD

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3.3.3 EMC and Power Quality – Emission limits

The conducted electromagnetic disturbances emitted by ALMA antenna in correspondence of the interface being specified shall not exceed the limits set in the present section.

3.3.3.1 Harmonic currents

It is expected that the short-circuit ratio R_{sce} of the ALMA antenna be equal to or higher than 33. (The definition of short-circuit ratio R_{sce} is given by IEC 61000-3-4, a part of AD-06). In such a case, the harmonic currents injected by ALMA antenna into ALMA site power distribution system at the interface being specified shall not exceed the percent ratios indicated by the following table.

Harmonic number n	Admissible harmonic current I_n/I_1 * %	Harmonic number N	Admissible harmonic current I_n/I_1 * %
3	21.6	21	= 0.6
5	10.7	23	0.9
7	7.2	25	0.8
9	3.8	27	= 0.6
11	3.1	29	0.7
13	2	31	0.7
15	0.7	=33	= 0.6
17	1.2		
19	1.1	Even	= 8/n or = 0.6

* I_1 = rated fundamental current; I_n = harmonic current component

The steps to be taken in case the short-circuit ratio R_{sce} of the ALMA antenna exceeds 33 are TBD.

3.3.3.2 Voltage fluctuations and flicker

Voltage fluctuations and flicker injected into ALMA site power distribution system by ALMA antenna in correspondence of the interface being specified shall not exceed the limits standardized by IEC 61000-3-5 (a part of AD-06).

3.3.3.3 Radio-frequency terminal disturbance voltage

ALMA antenna shall not emit conducted radio-frequency terminal disturbance voltages at the interface being specified in excess of the values given by the following table when measured according to the methods standardized by CISPR 11 (AD-07).

Mains terminal disturbance voltage limits dB(μV)		
Frequency band MHz	Quasi-peak	Average
0.009 – 0.15	TBD	TBD
0.15 – 0.50	66 Decreasing linearly with logarithm of frequency to 56	56 Decreasing linearly with logarithm of frequency to 46
0.50 – 5	56	46
5 – 30	60	50
30 – 12000	TBD	TBD
Note – Care shall be taken to comply with leakage current requirements.		

3.3.4. EMC and Power Quality – Immunity limits

ALMA antenna shall be immune to the conducted electromagnetic disturbances injected into it by ALMA site power distribution system in correspondence of the interface being specified. The immunity exhibited by ALMA antenna shall comply with the immunity limits specified by the present section.

The following functional/performance criteria shall be adopted for the ALMA antenna when connected at the interface being specified.

Performance criterion A
The equipment shall continue to operate as intended.
No degradation of performance or loss of function is allowed, below a performance level (to be specified) when the equipment is used as intended.

Performance criterion B
The equipment shall continue to operate as intended after the application of the disturbance.

No degradation of performance or loss of function is allowed below a performance level (performance level TBD), when the equipment (ALMA antenna) is used as intended.

During the application of the disturbance, degradation of performance is allowed; however no change of actual operating state or stored data is allowed.

Performance criterion C
Temporary loss of function is allowed, provided that the loss of function is self recoverable or can be restored by the operation of the controls.

Performance criterion D
Degradation or loss of function is not recoverable due to damage to equipment (components).

3.3.4.1 Harmonic voltages – individual harmonics

The immunity limits for individual harmonic voltages shall be the products of the compatibility levels specified by section 3.3.2.1 by an immunity factor = 1.6.

Performance criterion: A

3.3.4.2 Harmonic voltages – Total Harmonic Distortion THD

The immunity limit for the total distortion factor shall coincide with the compatibility level specified by section 3.3.2.2, that is, D = 8%.

Performance criterion: A

3.3.4.3 Rectangular (step) voltage fluctuations

The immunity limit for rectangular (step) voltage changes shall be

$$? U = \pm 12\% \text{ of } U_n$$

with repetition period T = 5÷10 s and duration t = 2÷3 s.

Performance criterion: A

3.3.4.4 Voltage dips

The immunity limits for voltage dips shall be

$? U_1$ = -30% of U_n for 10 ms – performance criterion B

$? U_2$ = -50% of U_n for 100 ms – performance criterion C

3.3.4.5 Voltage interruptions

The immunity limit for short AC voltage interruptions (? U = -95%) shall be a duration of 5000 ms with performance criterion C.

3.3.4.6 Voltage (current) surges

The immunity limits to voltage surges shall be the open-circuit test voltages

U = 2.0 kV ±10% line-to-line (differential mode)

U = 4.0 kV ±10% line-to-earth (common mode)

with Tr/Th = 1.2/50 μs.

Should the ALMA power input have an impedance lower than that of the ALMA site power distribution system at the interface being specified, ALMA power input shall be immune to corresponding current surges with Tr/Th = 8/20 μs.

Performance criterion: B

3.3.4.7 Fast transient bursts

The immunity limit for fast transient bursts shall be the open-circuit test voltage

$$U = 4.0 \text{ kV} \pm 10\%$$

with Tr/Th = 5/50 ns and

repetition rate f = 2.5 kHz ±20%

Performance criterion: B

4. Software/Control Function Interface

Interface to Monitor and Control will be covered in a separate ICD.

4.1 Monitor and Control software interface

Interface to Monitor and Control will be covered in a separate ICD.

4.2 Other software or control interface

5. Safety

The interface being specified shall comply with the applicable electrical safety requirements set by:

- IEC 60364 "Electrical installation of buildings" (AD-08);
- IEC 60309-1 (1997-08)
  Plugs, socket-outlets and couplers for industrial purposes – Part 1: General requirements (AD-02);
- IEC 60309-2 (1997-10)
  Plugs, socket-outlets and couplers for industrial purposes – Part 2: Dimensional interchangeability requirements for pin and contact-tube accessories (AD-03).

6. Definitions

6.1 **Plug and socket-outlet**
A means enabling the connection at will of a flexible cable to fixed wiring. It consists of two parts:

6.1.1 **Socket-outlet**
The part intended to be installed with the fixed wiring or incorporated in equipment.
A socket-outlet may also be incorporated in the output circuit of an isolating transformer.

6.1.2 **Plug**
The part integral with or intended to be attached to one flexible cable connected to the equipment or to a connector.

6.2 **Appliance coupler**
A means enabling the connection at will of a flexible cable to the equipment. It consists of two parts:

6.2.1 **Connector**
The part integral with, or intended to be attached to, one flexible cable connected to the supply.
NOTE – In general, the connector of an appliance coupler is identical to the connector of a cable coupler.

6.2.2 **Appliance inlet**
The part incorporated in, or fixed to, the equipment or intended to be fixed to it.
NOTE – In general, an appliance inlet has the same contact arrangement as a plug.

6.3 **Electromagnetic environment** (IEV 161-01-01)
The totality of electromagnetic phenomena existing at a given location.

6.4 **Electromagnetic disturbance** (IEV 161-01-05)
Any electromagnetic phenomenon which may degrade the performance of a device, equipment or system, or adversely affect living or inert matter.
Note. An electromagnetic disturbance may be an electromagnetic noise, an unwanted signal or a change in the propagation medium itself.

6.5 **Electromagnetic interference (EMI)** (IEV 161-01-06)
Degradation of the performance of an equipment, transmission channel or system caused by an electromagnetic disturbance.
Note. Disturbance and interference are respectively cause and effect.

6.6 **Electromagnetic compatibility (EMC)** (IEV 161-01-07)
The ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.

6.7 **Immunity (to a disturbance)** (IEV 161-01-20)
The ability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance.

6.8 **(Electromagnetic) susceptibility** (IEV 161-01-21)
The inability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance.
Note. Susceptibility is a lack of immunity.

6.9 **Disturbance level**
The value of a given electromagnetic disturbance, measured in a specified way.

6.10 **(Electromagnetic) compatibility level** (IEV 161-03-10)
The specified maximum electromagnetic disturbance level expected to be impressed on a device, equipment or system operated in particular conditions.
Note. In practice the electromagnetic compatibility level is not an absolute maximum level, but may be exceeded with a small probability.

6.11 **Emission level (of a disturbing source)** (IEV 161-03-11)
The level of a given electromagnetic disturbance emitted from a particular device, equipment or system in a specified way.

6.12 **Emission limit** (IEV 161-03-12)
The specified maximum emission level of a source of electromagnetic disturbance.

6.13 **Immunity level** (IEV 161-03-14)
The maximum level of a given electromagnetic disturbance incident on particular device, equipment or system for which it remains capable of operating at a required degree of performance.

6.14 **Immunity limit** (IEV 161-03-15)
The specified minimum immunity level.

6.15 **Harmonic (component)** (IEV 161-02-18)
A component of order greater than one of the Fourier series of a periodic quantity.

6.16 **(Total) harmonic factor** (IEV 161-02-23)
The ratio of the r.m.s. value of harmonic content to the r.m.s. value of an alternating quantity.

6.17 **Interharmonics**
Discrete or wide-band spectrum frequencies which are not integer multiples of the power frequency fundamental.

6.18 **Voltage fluctuation**
A cyclical variation of the voltage envelope or a series of random voltage changes, the magnitude of which does not normally exceed the range of operational voltage changes mentioned in IEC Publication 60038 (up to ±10%).

6.19 **Voltage unbalance (imbalance)** (IEV 161-08-09)
In a polyphase system, a condition in which the r.m.s. values of the phase voltages or the phase angles between consecutive phases are not all equal.

6.20 **Voltage dip** (IEV 161-08-10)
A sudden reduction of the voltage at a point in an electrical system, followed by voltage recovery after a short period of time, from half of a cycle to a few seconds.

6.21 **Short (supply) voltage interruption**
The disappearance of the supply voltage for a period of time not exceeding 1 min.

6.22 **Mains signalling**
Use of the distribution network for the transmission of signals.

6.23 **Voltage surge**

A transient voltage wave characterized by a rapid increase followed by a slower decrease.

Note: the time parameters of a voltage surge are defined as follows:

- the rise time between 10 and 90% of the peak value (10/90% rise time) according to IEV 161-02-05;
- the duration at 50% of the peak value between increase and decrease of the wave (50/50% duration).

6.24 **Burst** (IEV 161-02-07)
A sequence of a limited number of distinct pulses or an oscillation of limited duration.

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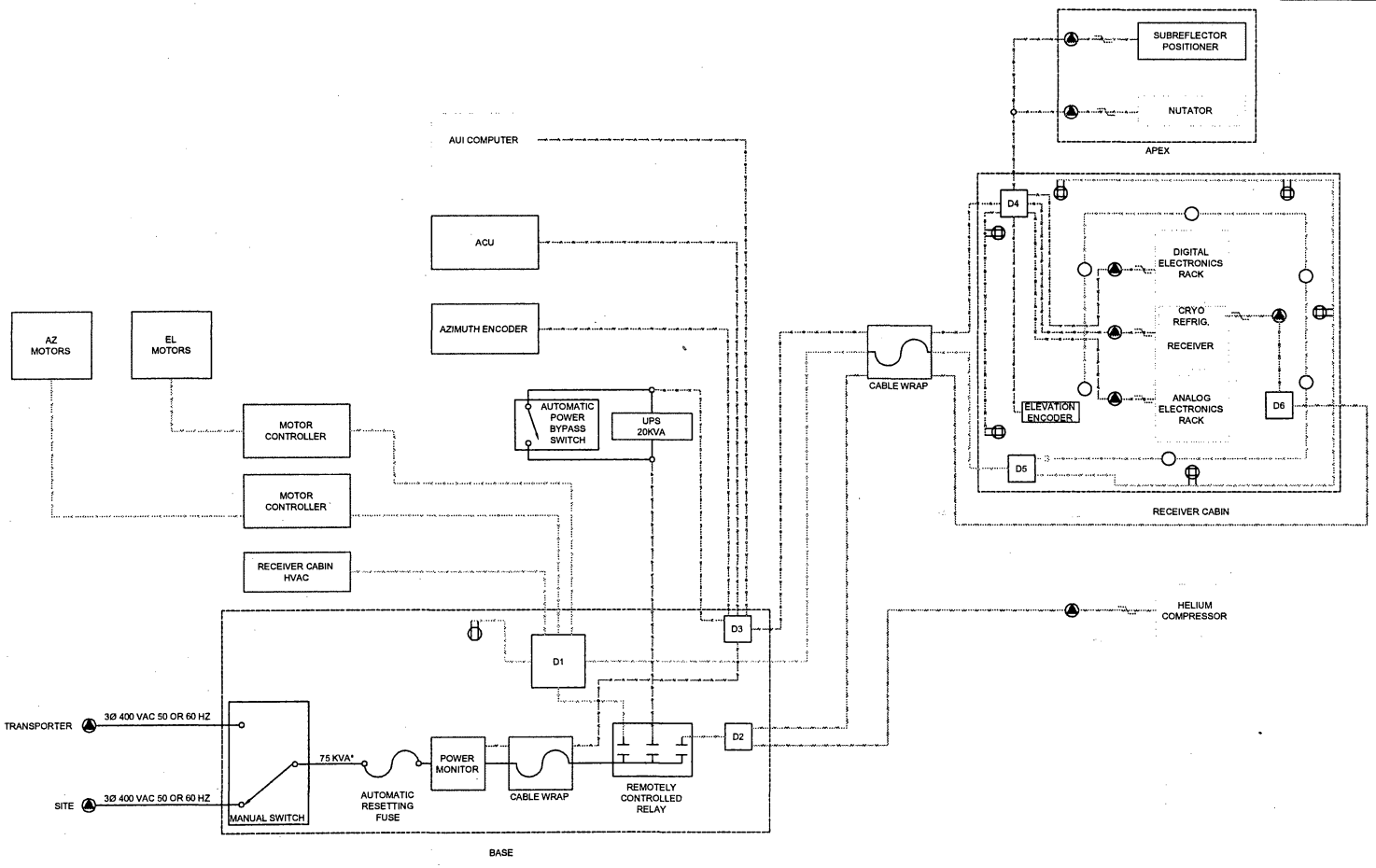
REVISION HISTORY				
SCALE	REV	DESCRIPTION	DATE	APPROVED
ALL	A	MISCELLANEOUS	1999-12-16	
ALL	B	CHANGE VOLTAGE FROM 380 VAC TO 400 VAC	1999-12-16	



- CRITICAL ELECTRONICS POWER
- CRITICAL CRYOGENICS POWER
- NON CRITICAL POWER
- COMMERCIAL POWER
- FLEXIBLE POWER CABLE
- D# DISTRIBUTION PANEL
- AUI SUPPLIED COMPONENT
- VENDOR SUPPLIED COMPONENT
- AUI/ESO SPECIFIED CONNECTOR
- QUADRUPLEX OUTLET
- LIGHT FIXTURE
- S SINGLE POLE SWITCH

NOTES:
1. CRITICAL ELECTRONICS POWER, CRITICAL CRYOGENICS POWER, AND NON-CRITICAL POWER ARE AS DEFINED IN U.S. Prototype Antenna Purchase Order (AD-01) SECTION 3.5.8.1
2. THE AUTOMATIC POWER BYPASS SWITCH IS DEFINED AS AN AUTOMATIC SWITCH THAT BYPASSES THE UPS IN CASE OF A UPS FAILURE.
3. THE MANUAL SWITCH AT THE BASE IS USED TO MANUALLY SWITCH BETWEEN SITE SUPPLIED POWER AND TRANSPORTER SUPPLIED POWER DEPENDING ON WHICH IS BEING USED AS THE PRIMARY POWER SOURCE FOR THE ANTENNA.
4. THE POWER MONITOR IS USED TO MONITOR THE FREQUENCY, CURRENT, AND VOLTAGE OF THE PRIMARY POWER SOURCE AND UPS POWER.
5. THE UPS SHALL SUPPLY 20 KVA, 1 Ø 230 VAC, FOR A MINIMUM OF 10 MINUTES.
6. ALL VALUES ARE RATED AT AN ALTITUDE OF 5000 M
7. EQUIPMENT NOT SPECIFIED IN THE BASE, RECEIVER CABIN, OR APEX IS TO BE MOUNTED OUTSIDE OF THESE AREAS SUCH AS ON THE PLATFORM OR YOKE
8. THERE WILL BE BETWEEN 2 AND 10 BRANCH CIRCUITS FROM EACH DISTRIBUTION PANEL FOR AUI/ESO EQUIPMENT. FINAL SIZE OF DISTRIBUTION PANELS WILL BE DETERMINED BY FINAL LOADS
9. DISTRIBUTION PANELS SHALL BE EASILY ACCESSIBLE BY MAINTENANCE PERSONNEL
10. TWO SEPERATE EMERGENCY LIGHTING UNITS SHALL BE INSTALLED INSIDE THE RECEIVER CABIN WITH ONE ILLUMINATING THE RECEIVER CABIN DOOR AND THE OTHER IN A SUITABLE LOCATION. THESE UNITS SHALL BE POWERED FROM THE NON-CRITICAL POWER BUS UNDER NORMAL CONDITIONS AND HAVE A STORAGE BATTERY AS THE EMERGENCY POWER SOURCE.

ALMA NRAO

	APPROVED	DATE
DRAWN	V.L. GASHO	2000-01-25
CHECKED	J. CHENG	2000-01-25
SNGR	J. KINGSLEY	2000-01-25
SYSTEM ENGR	D. EMERSON	2000-01-25

CONTRACT NO.

NATIONAL RADIO ASTRONOMY OBSERVATORY
Operated by ASSOCIATED UNIVERSITIES, INC. in cooperation with THE NATIONAL SCIENCE FOUNDATION

TITLE: ALMA ANTENNA ELECTRICAL POWER PRELIMINARY POWER LAYOUT

NRAO TUCSON
949 N. CHERRY AVE
CAMPUS BLDG 89
TUCSON, AZ 85721-0655

SIZE: D | CAGE CODE: NONE | DWG NO: 03020810E001B | REV: B

SHEET 1 of 1

ALMA-US ICD No. 4

WBS 3.2.8.10/ 2.1

Antenna / Site Foundation Interface

Authors: J. S. Kingsley / M. A. Gordon

Date: 2000-JAN-24

Version: A

Issued by: Antenna and Site Group

			Date:
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	Mark Gordon,	ALMA-US Division Head 2	2000-JAN-24
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Approved by:	T. Andersen,	ALMA-EURO Team Leader 1	2000-JAN-24
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Revision Control

1. Revision Version #_____
   Date:
   Revised by:
   Reason for / items changed:

2. Revision Version #_____
   Date:
   Revised by:
   Reason for / items changed:

etc.

1.0 Description

To define the interface between the antenna to foundation.

2.0 Related Documents and Drawings

U.S. Prototype Antenna Purchase Order Section 3.4.1 Mount Requirements
U.S. Prototype Antenna Purchase Order Section 3.4.6 Close Packing
U.S. Prototype Antenna Purchase Order Section 3.5.2 Transportability
U.S. Prototype Antenna Purchase Order Section 3.5.3 Foundation
U.S. Prototype Antenna Purchase Order Section 3.5.8 Electrical
U.S. Prototype Antenna Purchase Order Section 3.5.11 Safety
U.S. Prototype Antenna Purchase Order Section 3.6.9 Foundation Interface
U.S. Prototype Antenna Purchase Order Section 3.9.2 Design Calculation and Data
GeoTechnical Feasibility Report (Rev. A) MMA Project (May, 1999)
GeoTechnical Engineering Services, Job No. 1-90402 MMA Antenna VLA Site
ALMA-US *ICD No. 3 Antenna / Site Electrical Power Interface*
ALMA-US *ICD No. 5 Antenna / Transporter Interface*

2.1 Related Interface Control Drawings

3.0 Physical System Interfaces

3.1 Mechanical interface

The specifications for the foundation antenna interface is called out in the U.S. Prototype Antenna Purchase Order, in the sections listed above in 2.0 Related Documents. The foundation design will include conduits for power cables, fiber optical cables, coaxial cables, phone and control cables. The number of cables, size and number of conduit along with the specified cables sizes and types will be specified no later than the antenna PDR.

The orientation of the antenna shall have the center point of the cable wrap facing north. The angular tolerance of these positions shall be +/- 1 degree.

Consideration for the antenna transporter shall be incorporated into the foundation design as specified in the ALMA-US *ICD No. 5 Antenna / Transporter Interface.*

3.2 Mass, if relevant

Mass of the antenna and foundation is determined by the Contractor.

3.3 Electrical power

The required electrical power at base of antenna is 75 kVA at 400 VAC three phase able to operate at a dual frequency of 50 Hz and 60 Hz with an electrical ground. The electrical power requirements are covered in ALMA-US ICD No. 3 Antenna / Site Electrical Power Interface.

3.4 Electronic interface, including computer hardware

Not relevant

3.5 Thermal control interface

Not relevant.

4.0 Software/Control Function Interface

4.1 Monitor and Control software interface

Not relevant

4.2 Other software or control interfaces

Not relevant

5.0 Safety Issues

Not aware of any

ALMA-US ICD No. 5

WBS 3.3 / 3.7

Antenna / Transporter Interface

Authors: M. Kraus (ESO), H. Riewaldt (Lund Observatory)

Date: 1999-Dec-22

Version: A

Issued by: Antenna and System Groups

Approved at ESO by:

Team Manager 1	Torben Andersen Name	22 Jan. 2000 Date	Signed in the original Signature
Team Manager 2,if req.	_____ Name	_____ Date	_____ Signature
Systems engineering	_____ Name	_____ Date	_____ Signature

Approved at NRAO by:

Division Head 1	Peter Napier Name	2000-JAN-22 Date	Signed in the original Signature
Division Head 2	Darrel Emerson Name	2000-JAN-22 Date	Signed in the original Signature
Systems engineering	Darrel Emerson Name	2000-JAN-22 Date	Signed in the original Signature

Change Record

VERSION	DATE	SECTION/PARAGRAPH AFFECTED	REASON/INITIATION DOCUMENTS/REMARKS
A	22 Dec. 1999	All	

Table of contents

1 Scope

This document establishes the specifications for the interface between the two ALMA prototype antennas and the ALMA antenna transporter (hereinafter called antennas and transporter). Furthermore, this document defines the transport characteristics to be considered for the design of both the antennas and the transport equipment.

It is intended to make this document applicable for the design and the production of both the prototype and the production antennas as well as the transporter.

2 Documents and Acronyms

2.1 Related Documents

The following documents and drawings are available and related to this ICD:

- RD 1: U.S. Prototype Antenna Purchase Order, of 26th January 2000, with particular reference to the following sections
  - 3.4.1: Mount Requirements
  - 3.4.6: Close Packing
  - 3.5.2: Transportability
  - 3.5.3: Foundation
  - 3.6.8: Transporter Interface
  - 3.6.12: Electrical Power Interface
  - 3.9.2: Design Calculation and Data
- RD 2: ESO-Call for Tenders (CFT) for Supply of one Prototype Antenna for the Atacama Large Millimeter Array (ALMA), issue No. 1 of 30th April1999
- RD 3: ALMA-US ICD No. 3 Antenna / Site Electrical Power Interface, issue No. 1 of 27th October 1999
- RD 4: ALMA-US ICD No. 4 Antenna / Site Foundation Interface, Version B of 25th January 2000

- RD 5: ALMA Transporter Preliminary Requirements (draft), issue No. 1 of 20th December 1999
- RD 6: ALMA-US ICD No. 11 Basic Antenna Definitions, issue Version B of 25th January 2000
- RD 7: San Pedro Base (not yet available)
- RD 8: Info about the road from San Pedro to the ALMA site (not yet available)
- RD 9: ALMA array configurations (not yet available)
- RD 10: Characteristics of the Coupling Counterparts (not yet available)

2.2 Acronyms

ALMA	Atacama Large Millimeter Array
CDR	Critical Design Review
CFT	Call for Tenders (Europe)
ESO	European Southern Observatory
FEM	Finite Element Model
ICD	Interface Control Document
NRAO	National Radio Astronomy Observatory
RD	Related Document
RFP	Request for Proposals (USA)
TBD	to be determined
TBC	to be confirmed
VLA	Very Large Array (New Mexico, USA)

3 Antenna Transport

3.1 General

The ALMA shall consist of approximately 64 submillimeter radio antennas with 12-m reflectors. In a first project phase it is planned to produce two different ALMA prototype antennas. Their characteristics are defined by the U.S. Prototype Antenna Purchase Order documentation RD 1 and for the US antenna and RD 2 for the European antenna.

The two prototype antennas will be different and maybe have slightly different interfaces but both interfaces shall fulfill the specifications in this document. The transporter will be designed to be fully compatible with both prototype antennas. An example presenting an overall view of one possible layout of the antenna and the transporter is shown in the appendix.

Both antennas will be tested at the VLA site in New Mexico and then installed at the ALMA observatory in Chile. After the successful testing, approximately 64 nearly identical production antennas shall be procured.

This ICD shall be applicable for the transport equipment used for the transport tasks listed below but not for the transport of antenna parts between the antenna production site(s) and the antenna assembly site(s).

3.2 Transport Operations

During the life cycle of the antennas, it is planned to transport them as follows:

- Transport on the test site. At the VLA site in New Mexico the two prototype antennas shall be transported (TBD) from the assembly hall to the test foundation and installed there. After the test period, the antennas may be brought back to the assembly hall. This transport shall be done with standard heavy transport equipment.

- Transport between San Pedro and the ALMA observatory site. After assembly of the antennas in the San Pedro Base camp they shall be moved to the ALMA observatory site. The goal is to transport the antennas fully assembled. Also for major maintenance or overhaul, the antennas shall be moved from the observatory down to the San Pedro Base Camp and up again. Characteristics about the San Pedro Base and the road between San Pedro and the ALMA site can be found in RD 7 and RD 8.

  This transport shall be done either with the transporter or with standard heavy transport equipment.

- Array reconfiguration. On a regular basis, typically every three months the prototype and production antennas of the ALMA array shall be reconfigured or a continuos reconfiguration of moving a few antennas every day might occur. The transporter shall pick up the antenna from its current foundation, bring it to the target foundation and position it onto the target foundation. To pick up the antenna, the antenna needs to be attached to the transporter. The present ICD defines these attachment points for the antennas and the physical volume available to antenna and transporter.

  To achieve the reconfiguration of the array in the specified time, parallel operation of more than one transporter is foreseen.

  In addition, during transport, a generator on the transporter to supply electric power for cryogenic cooling and other systems must power the antenna. Hence, the present ICD is also concerned with the electric power connection between the antenna and the transporter.

  Information about the foundation arrangement is available in RD 4 and RD 9.

  The transports for the array reconfiguration shall be accomplished with the ALMA antenna transporter, which is a specially designed vehicle and can load, transport and unload the antenna without using additional equipment.

4 Mechanical Interfaces

This section gives an overview over the operating conditions and load cases as well as a general description of the mechanical interfaces between the antennas and the transporter. There shall be

- Four interface flanges for the pick-up by the transporter and the transport on the site during array reconfiguration, ref. to section 4.3. The fixation of the antenna on the transporter shall be done with these interface flanges only and the interfaces shall hold the whole antenna weight including dynamic loads.

- Crane lifting eyes for the attachment of standard lifting equipment for loading and unloading by crane, ref. to section 4.5.

- An optional transport frame for the transport by standard heavy transport equipment with the same interfaces as between the antenna and its foundation, ref. to section 4.6. During transport, the antenna can be fixed on this frame. Points for fixation of the tie-down equipment shall be provided on the antenna for the case that such a transport frame will be procured later.

The technical requirements for the transporter and the antennas are summarized in detail in RD 5, RD 1 and RD 2.

4.1 Operating Conditions and Loads

The antenna shall be transported fully assembled and aligned, if possible also between San Pedro and the observation site.

During transport, the antenna will be subject to different accelerations and forces as specified below. The transporter shall assume the antenna as a rigid body with a maximum antenna mass of 80 000 kg (TBC) and the center of gravity lying 5 ± 1 m above ground and no longer than 0.5 m from the azimuth axis.

The design of the transporter and its control system shall ensure a limit of acceleration forces on the antenna during normal operation and also in case of failure of the transporter or in case of an operator error.

The antenna shall be designed and tested to withstand the reaction forces on the anchor points created by the accelerations.

Outgoing from the following loads or operating conditions, a number of load cases will be defined in section 4.2.

Load 1: All accelerations during normal transport shall be limited to

- 0.5 G in driving direction forwards and backwards
- 0.5 G upwards (without gravity)
- 0.2 G downwards (without gravity)

Load 2: The maximal lateral acceleration shall be 0.5 G, including centrifugal and other forces during normal transport.

Load 3: Short duration transport shocks due to obstacles, holes, transporter failure or operator errors. These loads will later be studied in more detail, for now the following values are assumed:

- 1 G horizontally (all directions)
- 2 G vertically (upwards, including gravity)

Forces from acceleration and deceleration are included in these numbers. No account shall be taken for seismic shocks due to earthquakes during antenna transport.

Load 4: Short duration handling shocks during antenna handling at the foundation may occur only a few times during the life time of the antenna. They shall not be higher than:

- 2 G horizontally (all directions)
- 4 G vertically (both up and down)

Load 5: Gravity forces due to failure of one flange. The whole antenna load is carried by only two flanges at diagonal positions that each carry 50% of the load. The third active flange is balancing the antenna but not carrying any load.

When using hydraulic cylinders for the flange supports, the cylinders must not produce a downward force on the faulty support point.

The lateral stiffness of the four antenna supports shall not differ more than 20% from the average value over all four supports.

Load 6: Wind forces. The wind forces are given for two cases, during transport of the antenna and for the loaded transporter in a parked position. In both cases, the wind is measured 10 m over ground level and includes wind gusts, ref. to RD 5.

6a) During transport. The maximum wind speed during transport and also during handling at the antenna foundation will be 25 m/s peak.

6b) Parked position. The loaded transporter may experience a wind of 65 m/s peak in a parked position. An additional fixation on the tie-down points to the transporter or to the ground is possible in this case but shall not be taken into account for the design calculations.

For both cases, an equivalent wind force will be given to the transporter contractor at the latest TBD.

4.2 Load Cases

Table 1 combines the loads defined in section 4.1 to load cases that will be used for the calculation of the load forces on the interface flanges. An "x" for a load means this load shall be taken into account in this load case. The load cases are defined as follows:

I. The transporter is driving on uneven gravel with wind load on the antenna.

II. The transporter is driving over an obstacle (e.g. a stone or a hole), with wind.

III. Strong wind, the loaded transporter is in parking position and the ground might be a bit uneven.

IV. The transporter is standing still at an antenna foundation and either lifting or setting an antenna with moderate wind.

Table 1: Load Cases

Load Cases	Applied Loads						
	1	2	3	4	5	6a	6b
I. Driving on uneven gravel	x	x	-	-	x	x	-
II. Driving over an obstacle	-	x	x	-	x	x	-
III. In parking position with storm	-	-	-	-	-	-	x
IV. Antenna handling at foundation	-	-	-	x	-	x	-

4.3 Interface Flanges

There shall be four interface flanges on the yoke of the antennas and interface parts that are bolted on the interface flanges[1]. These interfaces will be used for the transport during array reconfiguration with the transporter and the transporter will lift the antenna at the four interface parts. The weight of the whole antenna and the dynamic forces due to handling and transport accelerations are taken at these four points only. There must be the necessary stiffness and stability in the specified areas of the yoke to hold the interface flanges in their positions without permanent deformation with a safety factor of 1.5.

The position of the flanges shall be symmetric and close to the lower, outer corners of the fork as indicated in Figure 1. The dimensions given with their large tolerances shall be understood as the area allowed for the antenna contractor where he might place the flanges. The exact location of the flanges shall be determined together with the antenna contractors the latest at CDR. The locations may be different on the two prototype antennas but they shall be within a tolerance of maximum ±3 mm. The dimensions shall be defined in the yoke coordinate system according to RD 6.

The general appearance of the flanges is shown in Figure 2 with the exact dimensions TBD. The characteristic of coupling counterparts of the transporter that are attached to these flanges, for instance lever arms or masses, will be defined in RD 10 for the transporter.

---

1 The interface part is connected by screws to the yoke to enable a higher degree of flexibility and a later design of the interface geometry that is more or less independent of the earlier starting antenna design. The 64 production antennas will certainly have a somewhat different interface that is welded to the yoke structure.

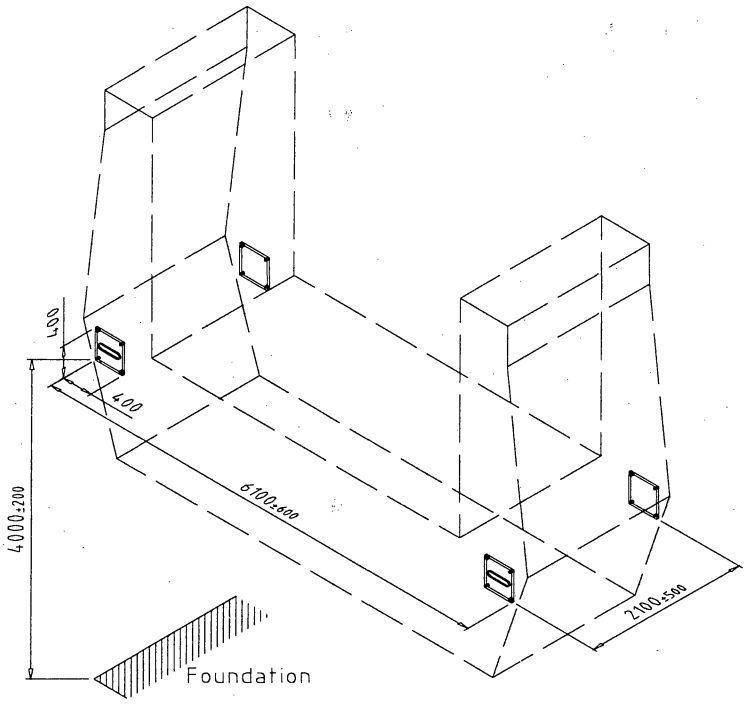

Figure 1: Position of the Interface Flanges (TBC)

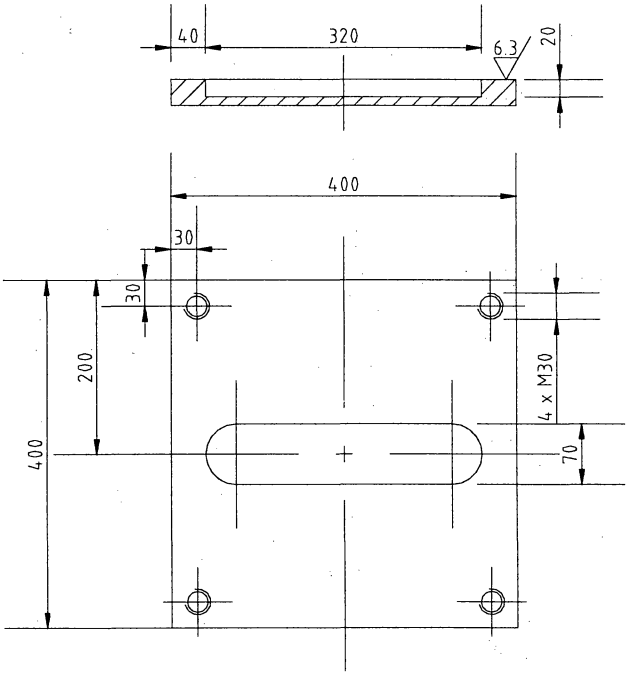

Figure 2: Interface Flange

Antenna supports on the transporter shall connect automatically to the coupling counterparts and carry the load. The antenna supports shall distribute the vertical and horizontal support forces evenly.

The lateral play in the connection between antenna support and coupling interface shall be below 10 mm after coupling is completed.

4.4 Tie-down Points

There shall be at least 4 suitable fixation points for tie-down equipment on the antenna structure, preferably on the fork, where the antenna can be fixed during transport to the trailer or during storage to the ground.

Each tie-down point shall withstand a maximum tie-down force equivalent to 20% of the antenna weight. The tie-down force shall be directed in an angle of 45° +/- 15° in direction towards the ground.

4.5 Crane Lifting Eyes

The antenna shall be equipped with two attachment points for crane lifting, preferably on the upper ends of the fork. These attachment points shall be compatible with standard crane slings or shackles.

The crane shall use long enough slings or a crane traverse to keep the angle between the slings below 30 deg.

The lifting points shall be placed symmetrically to the center of gravity. When lifting the antenna in the proper configuration (antenna pointing horizontal) the antenna axes shall not be inclined more than 2% (no wind considered).

4.6 Transport Frame

An optional transport frame might be procured at a later point of time. This inverse U-shaped frame will be used for transport and storage of the antenna. A hydraulic heavy transport trailer shall be able to move below and lift the load. The transport frame shall have an interface equal to a foundation interface on which the antenna is fixed with its anchors.

The antenna weight and the transport accelerations shall be taken by the foundation interface.

The transport frame shall have four legs where it can stand with the antenna mounted on a leveled, even ground.

5 Other Interfaces

5.1 Electric Supply

The transporter shall provide electrical power to the base of the antenna with capacity to power the cryogenic and electronic systems. This power shall also be sufficient to drive the antenna in azimuth for location on foundation. The electrical power required at the base of antenna is 20 kVA at 400 VAC three phase (TBC).

Details are TBD.

5.2 Electronic interface, including computer hardware

TBD.

5.3 Software/Control Function Interface

TBD.

6 Design Space

6.1 Space for the Antenna

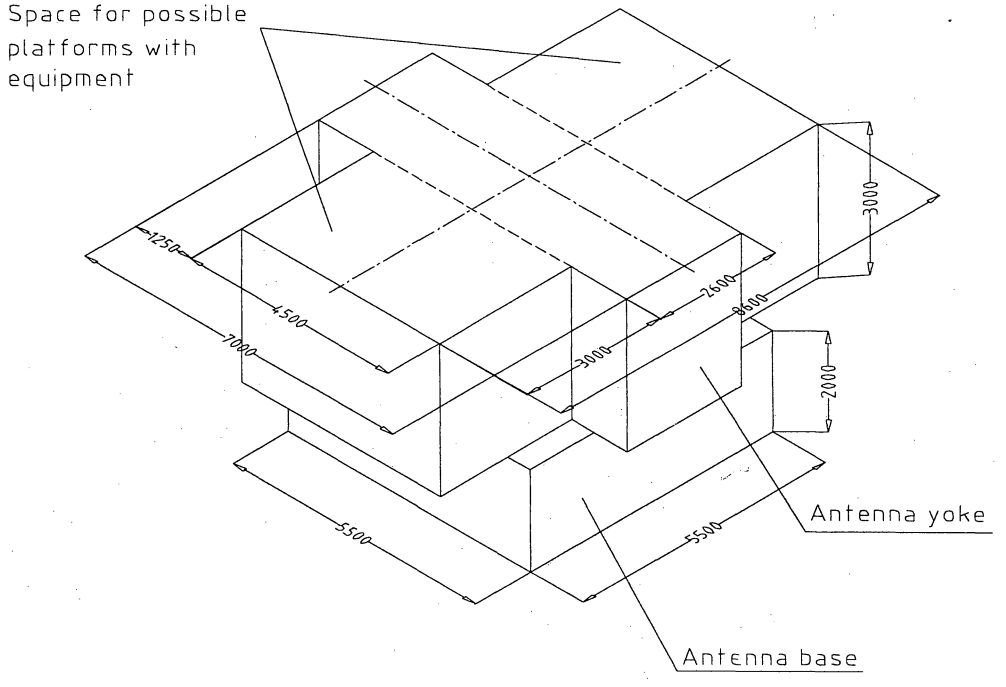

Figure 3: Design Space for the Antenna (up to 5 m over ground)

For compatibility with the transporter, the antenna shall be designed within the volume demonstrated in Figure 3 in a three-dimensional view. The volume shall include the rotation of the antenna base for rotational adjustment to the foundation.

The restrictions shown apply up to 5 m above ground level and the neighboring volume is reserved for the transporter. During normal operation, the neighboring volume may be occupied by antenna parts as well (e.g. with handrails or stair cases) but these devices shall be removable so that the antenna fits into the specified volume during transport and handling.

The time for removing antenna parts to fit the antenna into the volume specified shall be included in the 15 minutes time interval for picking up an antenna (RD 5). Accordingly, the time for re-installing of these antenna parts shall be included in the 20 minutes time interval for setting down an antenna. Removing and re-installing antenna parts shall not need more than two persons and no external crane.

6.2 Space for the Transporter

Access requirements for closing the antenna foundation anchoring shall be defined by the antenna contractor and shall be considered in the transporter design.

The transporter dimensions shall consider the limits given by the close packing arrangement of the antennas defined in RD 9.

The transporter design shall keep a minimum distance of 200 mm to any antenna parts when driving the transporter to the antenna.

7 Antenna Transport Sequence

The transport of an antenna from one base to another is a complex process in which both systems, the antenna and the transporter shall work together.

In the following the transport sequence is defined in steps. The active system responsible to achieve the respective step is listed in brackets.

As a principle, during each step only one of both systems shall be active. The other (passive) system shall be shut off or blocked safely. Movements or other activities of both systems simultaneously shall not be necessary and are not allowed.

7.1 Getting the Antenna

1. Initial configuration: antenna is anchored on foundation, both axes adjusted and blocked in transport position (antenna).

2. Transporter is positioned in pick-up position at the antenna, antenna supports are coupled to the coupling interfaces (transporter).

3. Transporter antenna supports are lifted to produce an up-lift force of ca 25% of the antenna weight to secure the antenna during coupling (transporter).

4. The electrical supply during transport is connected to the antenna and switched on (transporter).

5. The electric power supply is switched from the foundation to the generator on the transporter (antenna).

6. The antenna anchoring to the foundation and the electric/signal connections are opened (antenna).

7. The antenna is lifted off vertically (max +/- 2mm deviation laterally, max 2mm/1000mm tilt) from the station to the transport height (transporter).

8. The antenna is fastened and blocked in its transport position (transporter).

9. Protect the antenna foundation, in particular cable connections (antenna).

7.2 Transport

10. The antenna is transported to the target station (transporter).

11. During bad weather with strong winds the transporter may need to stop (transporter).

7.3 Setting the Antenna

12. Preparation of the foundation, like removal of protections, cleaning, maintenance work and checks (antenna).

13. Targets for positioning (two metal plates with crosshair or similar) will be available on the foundation (antenna).

14. The antenna is positioned over the target station laterally with a radial accuracy < 5 mm with respect to the positioning targets (transporter).

15. The antenna will be adjusted in both tilt axes better than 2mm/1000mm with respect to local gravity. Reference on the antenna shall be a horizontal, machined surface perpendicular to the azimuth axis with a size of 200 x 200mm (TBC) where a leveling instrument can be placed. Alternatively, precision levels can be permanently included in the antenna base (transporter).

16. The antenna base will be adjusted in rotation (antenna).

17. The antenna is lowered onto the foundation. The transporter provides lateral compliance for self-adjustment of the antenna base to the foundation. The force necessary for a 5 mm lateral shift shall be < 10% of antenna weight. After lowering, the antenna is still secured by the transporter (transporter).

18. For soft contact the transporter shall provide a minimum compliance in vertical direction of 10 mm/500 kN during lowering seen at the antenna flanges (transporter).

19. The antenna is anchored to the foundation (antenna).

20. The electric connection between antenna and foundation is connected (antenna).

21. The electric power supply is switched from the generator to the foundation (antenna).

22. The electric connection between antenna and transporter is opened (transporter).

23. The antenna supports on the transporter are disconnected form the coupling interfaces and the transporter is removed (transporter).

24. The antenna is checked for damages and pointing (antenna).

8 Scope of Delivery

This chapter shall define and clarify the scope of delivery for both the antenna and transporter contractors only in the area of the transport interface and shall not reduce the scope of delivery as defined in the contracts.

8.1 Deliveries of the antenna contractor(s)

- Four interface flanges as defined in section 4.3 are welded into the yoke at the defined positions. This includes removable surface protection on the flanges and fasteners that hold the protection on the flange.

- One precise machined surface 200 x 200mm (TBC) on the antenna for leveling measurement or precision bubble levels included in the base.

- Means for the fine centering during lowering of the antenna on the station compatible with the pre-adjustment and compliance provided by the transporter.

- FEM analysis for the antenna and the interface for all transport load cases.

- FE model or equivalent full or reduced model of the antenna and the interface for dynamic FEM analysis of the transport.

- Access (ladders etc.) to all interface points.

- All special tools and equipment for antenna anchoring to the foundation.

- Load pattern on the anchoring counterparts.

8.2 Deliveries of the transporter contractor(s)

- Targets to be cast into the foundations for the antenna pre- by the transporter.
- Two sets of four coupling interfaces with all necessary screws, keys and special tools necessary to bolt the coupling interfaces onto the antennas.
- Measuring equipment for lateral positioning, rotating and leveling of the antenna with regard to the target foundation.
- Electric cables for power supply during transport and other connecting devices if necessary.
- Crane traverse and slings with shackles rated for the antenna mass for crane lifting.
- Optionally, transport frame prepared for antenna anchoring counterparts.
- Tie-down equipment to be used together with the transport frame.
- FEM analysis for all transport load cases. The antenna shall be considered as a rigid body in all FE models.
- FE model or equivalent full or reduced model of the transporter for dynamic FEM analysis of the transport.
- Tests with test load and acceleration measurements to verify the max. acceleration requirements.

Note: the equipment necessary for standard heavy transport may be contracted separately from the transporter

Appendix

Figure 4 shows an early design of a transporter that carries the antenna at the base. Although the drawing shows the overall transport principle, it should be noted that it is now foreseen to carry the antenna at four attachment points on the lower side of the yoke and not at the base.

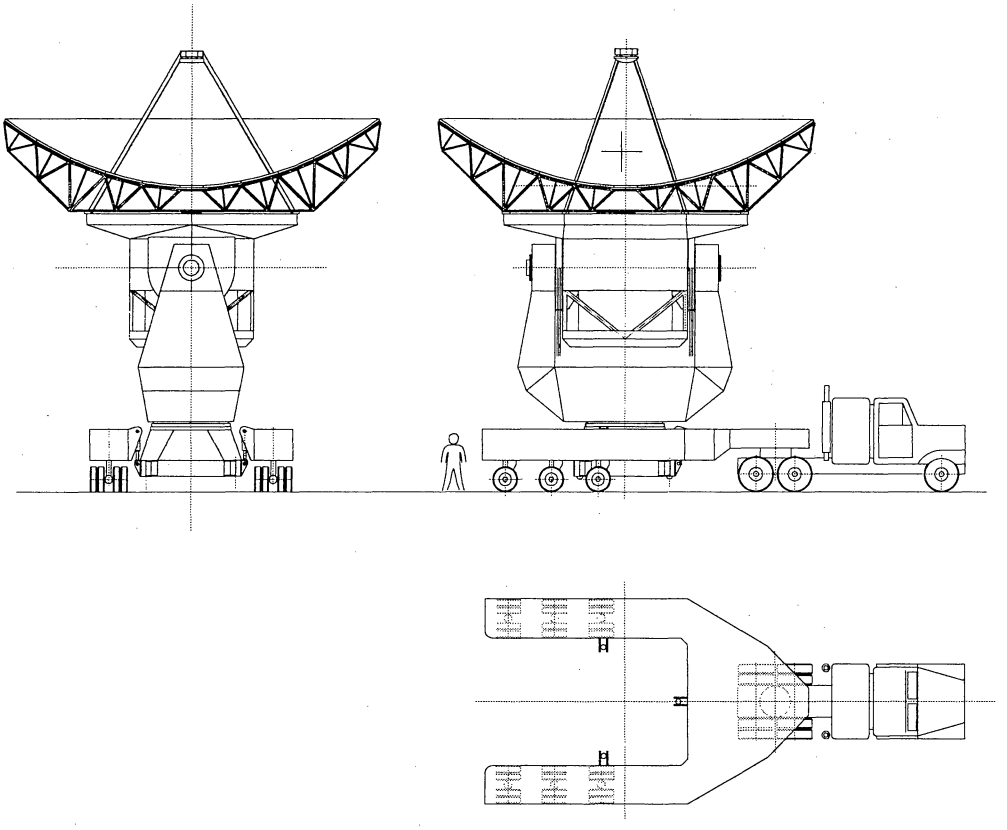

Figure 4: Transporter with antenna

ALMA-US ICD No. 6

WBS 3.2.8.10 / 10.6

Antenna / Cable Wrap Interface

Authors: J. Kingsley / D. Emerson

Date: 2000-JAN-24

Version: A

Issued by: Antenna and Systems Groups

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	Darrel Emerson, ALMA-US Systems Engineering	2000-JAN-17
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_____	ALMA-EURO System Engineering	_____

Revision Control

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   Revised by:
   Reason for / items changed:

2. Revision Version #_____
   Date:
   Revised by:
   Reason for / items changed:

etc.

1.0 Description

To define the interface between the antenna and cable wraps including the on-axis cable wraps.

2.0 Related Documents and Drawings

U.S. Prototype Antenna Purchase Order Section 3.4.1 Mount Requirements
U.S. Prototype Antenna Purchase Order Section 3.5.10 Disassembly
U.S. Prototype Antenna Purchase Order Section 3.6.2 Interface to Cable Wraps
U.S. Prototype Antenna Purchase Order Section 3.6.3 Interface to On-Axis Cable Wraps
ALMA ICD No. 7 Antenna / Helium Compressor Interface

2.1 Related Interface Control Drawings

03020810M004 - On-Axis Cable Wrap Interface, 2000-JAN-24

3.0 Physical System Interfaces

3.1 Mechanical interface

As specified in the RFP the antenna contractor will make provisions for cable wraps and on-axis cable wraps in the azimuth and elevation axis. The cable wraps are specified in the U.S. Prototype Antenna Purchase Order, Section 3.6.2 Interface To Cable Wraps. The drawing number 03020810M004 On-Axis Cable Wrap Interface specifies the required space and flanges for the on-axis cable wraps.

The Contractor will provide space in the cable wraps for AUI required cables as listed in the table in Appendix A of this ICD. These cables will be provided and installed by AUI. The cable wraps with the exception of the on-axis cable wraps will all have a minimum bending radius of 0.5 meters.

3.2 Mass, if relevant

Not relevant

3.3 Electrical power

Not relevant

3.4 Electronic interface, including computer hardware

Not relevant

3.5 Thermal control interface

Not relevant

4.0 Software/Control Function Interface

4.1 Monitor and Control software interface

Not relevant

4.2 Other software or control interface

Not relevant

5.0 Safety Issues

Not relevant

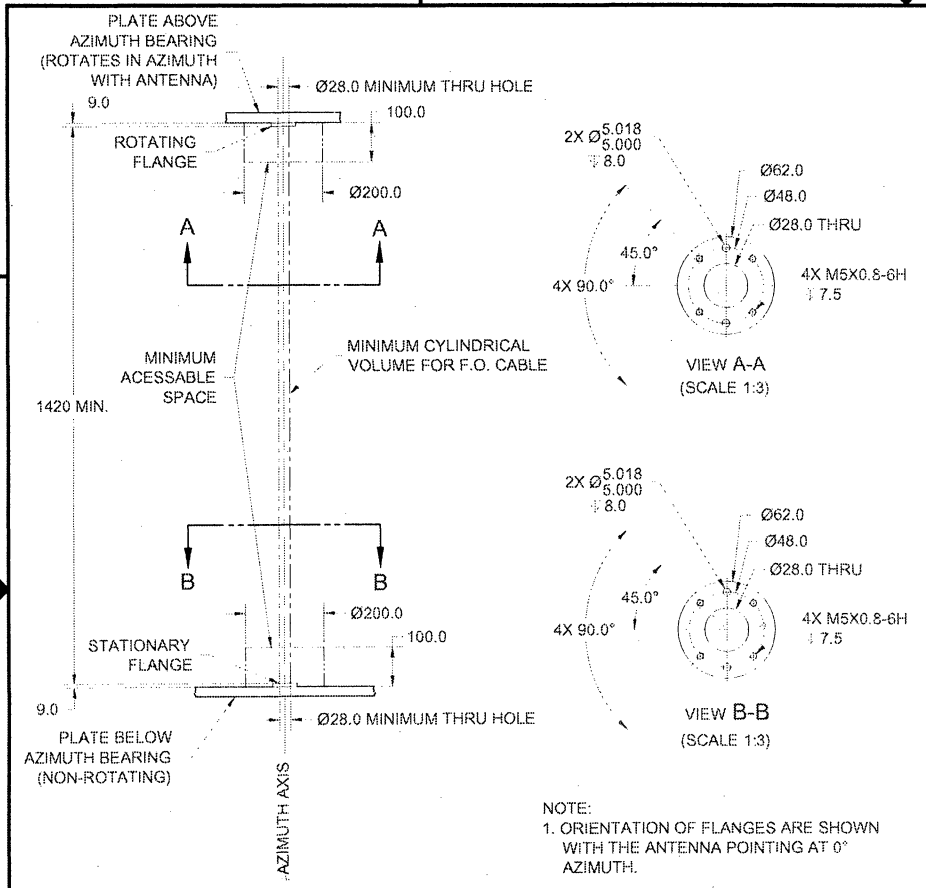
APPENDIX A

CABLE AND HOSE SIZES

AUI Additional Cables Required in Azimuth & Elevation Cable Wraps.

Quantity	Cable	Cable Diameter	Connector Dia.
6	High Pressure Gas Lines	20 mm	40 mm
4	Fiber Optic Cable	10 mm	20 mm
4	15 Twisted Pair	25 mm	75 mm
4	RG-9 Coaxial	20 mm	35 mm

AUI will provide and install above cables in Contractor provided cable wraps.

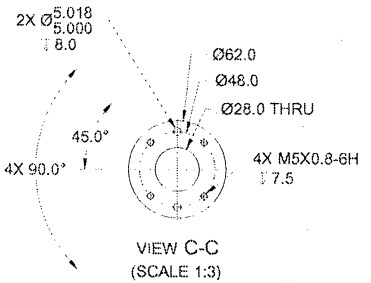


VIEW A-A
(SCALE 1:3)

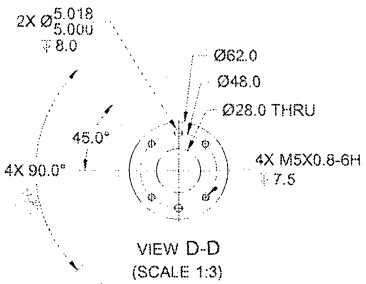
VIEW B-B
(SCALE 1:3)

NOTE:
1. ORIENTATION OF FLANGES ARE SHOWN WITH THE ANTENNA POINTING AT 0° AZIMUTH.

AZIMUTH ON-AXIS CABLE WRAP INTERFACE



VIEW C-C
(SCALE 1:3)



VIEW D-D
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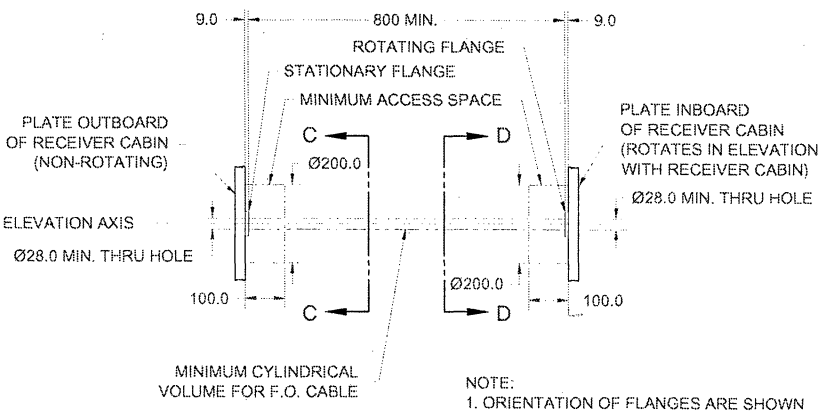

NOTE:
1. ORIENTATION OF FLANGES ARE SHOWN WITH THE ANTENNA POINTING AT 46° ELEVATION.

ELEVATION ON-AXIS CABLE WRAP INTERFACE

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MILLIMETERS. TOLERANCES ARE: DECIMALS ANGLES x±1 ±1° .X±0.1 ±0.5° .XX±0.01	CONTRACT NO.	NATIONAL RADIO ASTRONOMY OBSERVATORY operated by ASSOCIATED UNIVERSITIES INC. in agreement with THE NATIONAL SCIENCE FOUNDATION
METRIC	APPROVALS / DATE	TITLE: ON-AXIS CABLE WRAP INTERFACE
THIRD ANGLE PROJECTION	DRAWN V.L. GASHO 2000-01-24	ALMA-TUCSON 949 N. CHERRY AVE. CAMPUS BLDG. 65 TUCSON, AZ 85721-0655
DO NOT SCALE DRAWING	CHECKED J. CHENG 2000-01-24	
TREATMENT	ENGR. J.S. KINGSLEY 2000-01-24	
FINISH	SYSTEMS GROUP D. EMERSON 2000-01-24	SIZE B · CAGE CODE · DWG NO. 03020810M004 · REV
SIMILAR TO		SCALE 1:12 · DO NOT SCALE DRAWING · WT · SHEET 1/1

ALMA-US ICD No. 7

WBS 3.2.8.10 / 4.10

Antenna / Helium Compressor Interface

Authors: J. Kingsley / G. Moorey

Date: 2000-JAN-24

Version: A

Issued by: Antenna and Receiver Groups

		Date:
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	Graham Morrey, ALMA-US Division Head 2	2000-JAN-24
	Darrel Emerson, ALMA-US Systems Engineering	2000-JAN-24
Approved by: Torbin Andersen,	ALMA-EURO Team Leader 1	2000-JAN-24
	_____ALMA-EURO Team Leader 2 _____	
	_____ALMA-EURO System Engineering _____	

Revision Control

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2. Revision Version #_____
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   Reason for / items changed:

etc.

1.0 Description

To define the interface between the antenna and helium compressor.

2.0 Related Documents and Drawings

U.S. Prototype Antenna Purchase Order, Section 3.6.7 Helium Compressor Interface
U.S. Prototype Antenna Purchase Order, Section 3.5.8 Electrical
ALMA-US ICD No. 1 Antenna / Receiver Interface
ALMA-US ICD No. 3 Antenna / Site Electrical Power Interface
ALMA-US ICD No. 6 Antenna / Cable Wrap Interface

2.1 Related Interface Control Drawings

03020810M003 - Helium Compressor Interface, 2000-JAN-24

3.0 Physical System Interfaces

3.1 Mechanical interface

The requirements for the helium compressor are specified in drawing number 03020810M003. The minimal bending radius of the helium lines routed from the compressor to the receiver cabin shall be no less than 0.5 meters.

3.2 Mass, if relevant

The mass of the helium compressor is 136 kg +/- 50kg.

3.3 Electrical power

An electrical connector shall be provided by the Contractor in the space of the helium compressor. The connectors location and type are TBD at or before the PDR. The connector requires a voltage that is 3 phase 400 VAC capable of carrying 50 amps of current.

3.4 Electronic interface, including computer hardware

Not relevant

3.5 Thermal control interface

Provide ventilation to dissipate 20 kW of heat to ambient air at an altitude of 5000 m, with no more than a 10 C average air temperature rise in the overall compressor volume.

4.0 Software/Control Function Interface

4.1 Monitor and Control software interface

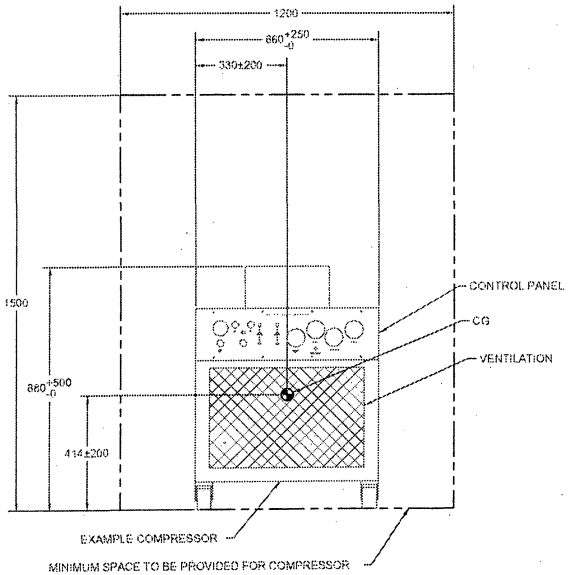
Not relevant

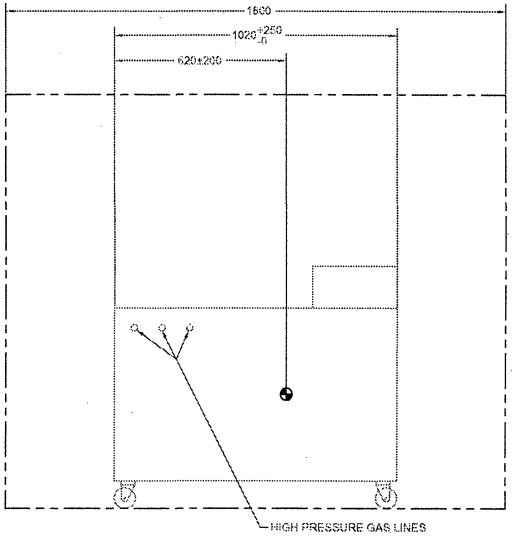
4.2 Other software or control interface

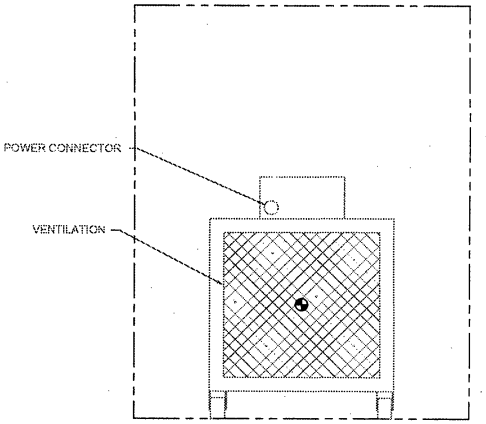
Not relevant

5.0 Safety Issues

Not aware of any.







NOTES:
1. COMPRESSOR MASS IS 136±50 KG
2. PROVIDE MOUNTING FOR ONE COMPRESSOR.
3. PROVIDE SPACE 1500 mm x 1200 mm x 1600 mm (H x W x D) MINIMUM FOR COMPRESSOR.
4. MOUNTING WILL BE ABOVE THE AZIMUTH BEARING AND BELOW THE ELEVATION BEARING
5. THE COMPESSOR SHALL NOT ROTATE WITH THE ELEVATION AXIS.
6. COMPRESSOR MUST BE ACCESSIBLE FOR SERVICING AND EASILY REMOVED AND REPLACED.
7. PROVIDE POWER CONNECTION FOR COMPRESSOR PER ALMA-US ICD No. 3.
8. PROVIDE ROUTING OF 6 EACH 20 mm HIGH PRESSURE GAS LINES FROM COMPRESSOR TO THE RECEIVER FRAME.
9. VENTILATION SHOWN MUST PROVIDE 20 KW OF HEAT DISSIPATION TO AMBIENT AIR.

METRIC

THIRD ANGLE PROJECTION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MILLIMETERS
TOLERANCES ARE:
DECIMALS ANGLES
X±1 ±1°
X±0.1 ±0.5°
X±0.01
DO NOT SCALE DRAWING

TREATMENT

FINISH

SIMILAR TO | NEXT ASSY

CONTRACT NO.

APPROVALS	DATE
DRAWN V.L. GASHO	2000-01-24
CHECKED J. CHENG	2000-01-24
ENGR. J.S. KINGSLEY	2000-01-24
SYSTEMS GROUP D. EMERSON	2000-01-24

NATIONAL RADIO ASTRONOMY OBSERVATORY
operated by ASSOCIATED UNIVERSITIES INC. in agreement with THE NATIONAL SCIENCE FOUNDATION

TITLE: HELIUM COMPRESSOR INTERFACE

ALMA-TUCSON
949 N. CHERRY AVE.
CAMPUS BLDG. 65
TUCSON, AZ 85721-0655

SIZE: B | CAGE CODE | DWG NO.: 03020810M003 | REV.

SCALE: 1:17 | CALC WT | ACT WT | SHEET: 1/1

ALMA-US ICD No. 8

WBS 3.2.8.10 / 10.10.6

Antenna / Optical Pointing Telescope Interface

Authors: J. Kingsley / D. Emerson / J. Mangum

Date: 2000-JAN-24

Version: A

Issued by: Antenna and Systems Groups

		Date:
Approved by: Peter Napier,	ALMA-US Division Head 1	2000-JAN-24
	Darrel Emerson, ALMA-US Division Head 2	2000-JAN-24
	Darrel Emerson, ALMA-US Systems Engineering	2000-JAN-24
Approved by: Torbin Andersen,	ALMA-EURO Team Leader 1	2000-JAN-24
	_____ ALMA-EURO Team Leader 2 _____	
	_____ ALMA-EURO System Engineering_____	

Revision Control

1. Revision Version #_____
   Date:
   Revised by:
   Reason for / items changed:

2. Revision Version #_____
   Date:
   Revised by:
   Reason for / items changed:

etc.

1.0 Description

To define the antenna and optical pointing telescope interface.

2.0 Related Documents and Drawings

U.S. Prototype Antenna Purchase Order, Section 3.5.1.1 Optical Telescope for Pointing Test
U.S. Prototype Antenna Purchase Order, Section 3.6.10 Optical Telescope Interface

2.1 Related Interface Control Drawings

03020810M006 - Optical Telescope Interface, 2000-JAN-24

3.0 Physical System Interfaces

3.1 Mechanical interface

As specified in the U.S. Prototype Antenna Purchase Order the antenna contractor will provide a suitable mounting location representative of the primary reflector with a clear view in the direction of the antenna boresight, that will accommodate the optical pointing telescope. The optical pointing telescope will be provided by the antenna group with mount to attach to antenna Contractor's mounting location. NRAO drawing number 03020810M006 Optical Pointing Telescope Interface specifies the mounting flange and space requirements of this device.

3.2 Mass, if relevant

The mass of the optical pointing telescope is 12 kg +/- 5kg.

3.3 Electrical power

The contractor shall provide routing for electrical power cables and other cables to the optical pointing telescope from the receiver cabin. The minimal pass holes shall be no less than 50 mm. These cables shall be provided and installed by AUI.

3.4 Electronic interface, including computer hardware

Not relevant

3.5 Thermal control interface

Thermal controls as required to meet the stability specifications.

4.0 Software/Control Function Interface

4.1 Monitor and Control software interface

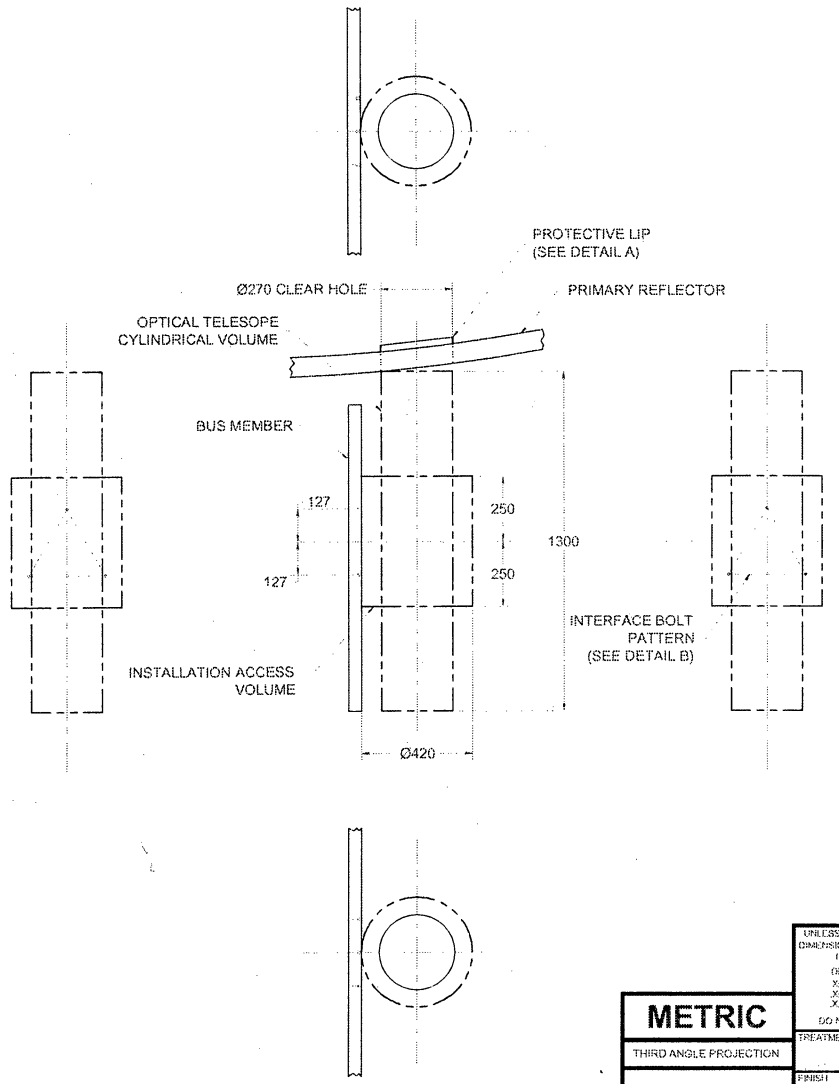
Not relevant

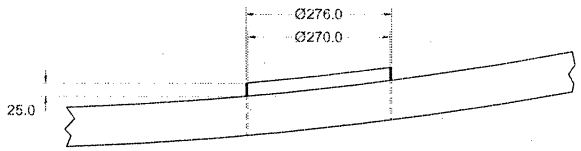
4.2 Other software or control interface

Not relevant

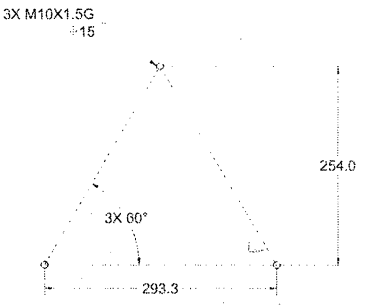
5.0 Safety Issues

Not aware of any





DETAIL A
PROTECTIVE LIP
(SCALE 1:9)



DETAIL B
BOLT PATTERN
(SCALE 1:6)

METRIC

THIRD ANGLE PROJECTION

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN MILLIMETERS
TOLERANCES ARE:
DECIMALS ANGLES
X±1 ±1°
XX±0.1 ±0.5°
XXX±0.01
DO NOT SCALE DRAWING

TREATMENT

FINISH

SIMILAR TO | MATERIAL SPEC

CONTRACT NO.

APPROVALS	DATE
DRAWN V.L. GASHO	2000-01-24
CHECKED J. CHENG	2000-01-24
ENGR. J.S. KINGSLEY	2000-01-24
SYSTEMS GROUP D. EMERSON	2000-01-24

ALMA
NRAO

NATIONAL RADIO ASTRONOMY OBSERVATORY
operated by ASSOCIATED UNIVERSITIES INC. in agreement with
THE NATIONAL SCIENCE FOUNDATION

TITLE
OPTICAL TELESOPE
INTERFACE

ALMA-TUCSON
949 N. CHERRY AVE.
CAMPUS BLDG. 65
TUCSON, AZ 85721-0655

SIZE	CAGE CODE	DWG NO.	REV
B		03020810M006	

SCALE 1:18 | CALC WT | ACT WT | SHEET 1/1

ALMA-US ICD No. 9

WBS 3.2.8.10 / 9.4.1

Antenna / Monitor and Control Interface

Authors: J. Kingsley / M. Brooks
Date: 2000-JAN-25

Version: A

Issued by: Antenna and Software Groups

		Date:
Approved by:	Peter Napier, ALMA-US Antenna Division Head	2000-JAN-25
	Brian Glendenning, ALMA-US Computing Division Head 2	2000-JAN-25
	Darrel Emerson, ALMA-US Systems Engineering	2000-JAN-25
Approved by:	_____ ALMA-EURO Team Leader 1	_____
	_____ ALMA-EURO Team Leader 2 (if req.)	_____
	_____ ALMA-EURO Systems Engineering	_____

Revision Control

1. Revision Version A
   Date: January 25, 2000
   Revised by: Mick Brooks
   Reason for / items changed: Reviewed draft

Table of Contents

1.0 Description

The purpose of this draft document is to define the interface between the Contractor's antenna control equipment and ALMA's monitor and control (M&C) system. This document is at present providing a definition for control of the antenna mount only. It is intended to add interface definitions for metrology, sub-reflector and other vendor-supplied subsystems to this ICD as agreed between ALMA and the Contractor during the initial design phase.

This draft document has to evolve by negotiation between ALMA and the Contractor during design. There shall be two notable revisions, at PDR and CDR. The ICD as finalised for the CDR shall be applicable for the implementation phase.

2.0 Related Documents and Drawings

2.1 Applicable Documents

[1] US Prototype Antenna Purchase Order 3.4.7 Solar Observing, Version A, 2000-January-25
[2] US Prototype Antenna Purchase Order 3.5.1 Metrology, Version A, 2000-January-25
[3] US Prototype Antenna Purchase Order 3.5.11 Optical Pointing Telescope, Version A, 2000-January-25
[4] US Prototype Antenna Purchase Order 3.5.4 Receiver Cabin, Version A, 2000-January-25
[5] US Prototype Antenna Purchase Order 3.5.5 Apex Equipment, Version A, 2000-January-25
[6] US Prototype Antenna Purchase Order 3.5.6 Servo and Control, Version A, 2000-January-25
[7] US Prototype Antenna Purchase Order 3.5.8 Electrical, Version A, 2000-January-25
[8] US Prototype Antenna Purchase Order 3.5.11 Safety, Version A, 2000-January-25
[9] US Prototype Antenna Purchase Order 3.6.1 Monitor and Control Digital Interface, Version A, 2000-January-25
[10] ALMA-US Computing Memo #7 ALMA Monitor and Control Bus Draft Specifications, Version 1.1, 1999-December-09

2.2 Reference Documents

[11] "CAN System Engineering", Wolfhard Lawrenz, Springer-Verlag, 1997 (Sections 1 & 2)

2.3 Related Interface Control Drawings

[12] ALMA-US ICD 3 Antenna Site Electrical Power Interface, Version A, 2000-January-25

2.4 Standards

[13] ANSI/IEEE Std 1014-1987.
"IEEE Standard for a Versatile Backplane Bus: VME bus."

[14] ISO/IEC 8802-3: 1992
"Information Processing Systems - Local Area Networks - Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD). Access methods and Physical Layer Specifications." "Ethernet standard."

[15] ANSI working committee X3T9.5, standards X3.139-1987, X3.148-1988, DIS 9314-3 R8 and R4.

[16] EIA Standard RS-232-C.
"Interface between data terminal and data communication equipment employing serial binary data interchange".
August 1969, reaffirmed June, 1981.

[17] ISO 11898:1993 Road vehicles - Interchange of digital information - Controller area network (CAN) for high-speed communication

3.0 Physical System Interfaces

3.1 Mechanical interface

Not applicable.

3.2 Mass

Not relevant

3.3 Electrical power

See [13] for electrical power.

3.4 Electronic interface

3.4.1 Computer Hardware and Software

All embedded microprocessor systems shall be based on PowerPC processors and VME backplanes, unless separate agreement is made. All software shall be written for VxWorks V5.4 or later and the source code shall be available to ALMA. All VxWorks microprocessor systems shall have Ethernet interfaces for debugging and testing, specifically for use with the Tornado toolset.

All application programming for processors in the control unit shall be written in C or

C++. Executable code shall be stored in non-volatile electronic memory, avoiding mechanically driven peripherals such as disk drives.

3.4.2 Location

The Contractor shall locate the interface connector (see Section 3.4.3) on his equipment in such a way that a cable from there to the center of the receiver room will not exceed 15 m in length, including, if necessary, the traversal of any cable wraps around the antenna motion axes.

3.4.3 Monitor and Control Interface

The serial bus outlined in [9] interfaces between ALMA's system and the Contractor's ACU and shall be a CAN bus as described in [10]. The connector type shall be a 9-pin D shell connector with pin allocation as given in ***Section 2.1.2*** *of [10]. The diagram is reproduced here and represents the bus stub connector. The ACU shall provide a female connector for connection to the CAN bus.*

Note that the reset pin (pin 9) is non-standard but is required. Pin 9 is defined in the CAN standard for use in supply power to bus devices. It will not be used for this purpose within ALMA. Instead it shall be used to indicate a request for CAN nodes to reset their communications circuitry.

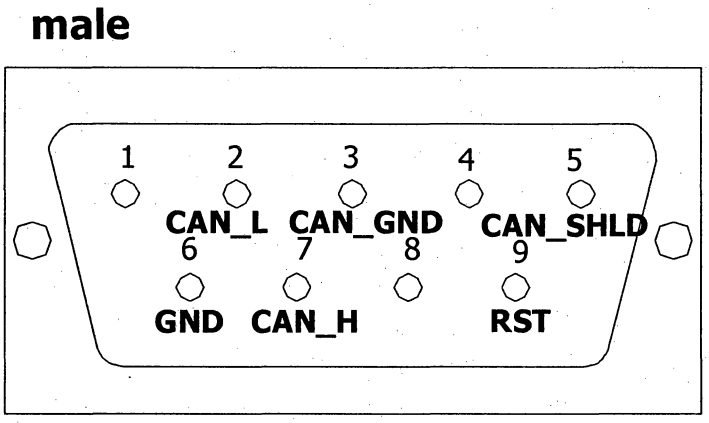


Figure 1: CAN standard D-connector pin allocations

Bus termination resistors shall not be included on the Contractor's side, but will be provided by ALMA externally.

Table 1: CAN D connector pin definitions

Pin	Signal	Description
1	-	Reserved
2	CAN_L	CAN_L bus line (dominant low)
3	CAN_GND	CAN Ground

Pin	Signal	Description
4	-	Reserved
5	CAN_SHLD	CAN Bus Shield
6	GND	CAN Ground
7	CAN_H	CAN_H bus line (dominant high)
8	-	Reserved
9	RST	Global Slave Node Reset

3.4.4 Timing Interface

In addition to the serial bus, the ACU will receive a precise timing reference signal. This will be a periodic pulse, supplied by differential signaling conforming to RS485. The pulse period shall be 50 milliseconds and of a duration no less than 1 microsecond. The leading edge of each pulse marks a timing event.

ALMA shall supply further details of the physical interface of such a timing signal during the design phase.

3.4.5 Ethernet Interface

The Ethernet interface, to be provided for debugging and maintenance, shall conform to [14]. Details of the connector to be used shall be provided by ALMA during the design phase. The Tornado toolset shall be available for ALMA use via this Ethernet interface.

3.5 Thermal control interface

Not relevant.

4.0 Software/Control Function Interface

4.1 Monitor and Control software interface

4.1.1 General

The CAN bus in use for monitor and control by ALMA consists of the CAN 2.0B variant and a non-standard higher level protocol defined in [10]. CAN 2.0B specifies the extended, or 29 bit, address range for the CAN frame [12]. The implications of the higher level protocol will be discussed further in this section.

Unless explicitly stated otherwise, all M&C values (integer, fixed or floating point) shall be transmitted in network byte order, or big endian fashion. Where specific bits in a byte are referenced in the following sections, bit 0 is the least significant bit.

In accordance with [10], the Contractor's ACU shall have a unique 64 bit serial number and a CAN node address in the range 0-63. The node address defines a range of CAN addresses within which all of the ACU specific CAN traffic will fall. As the ACU is a special node, ALMA defines the serial number and node address as follows:

Table 2: ACU Bus Constants

	Value (hexadecimal)
ACU Serial Number	*01 43 bc 12 00 00 00 86*
ACU Node Address	*0*

In the following sections, the prefix "0x" denotes that the number is hexadecimal.

This implies that the ACU will respond to the Identify Node broadcast message on CAN ID 0x00000000 as defined in the following table:

Table 3: ACU Bus Identify Response

ACU receives CAN ID (hex)	*ACU transmits CAN ID (hex)*	*With data bytes (hex)*
00 00 00 00	*00 04 00 00*	*01 43 bc 12 00 00 00 86*

Note that this transmission must begin within 200 milliseconds of receiving the Identify Node broadcast message.

The range of CAN IDs to which the ACU responds for M&C data will be restricted to ***0x00 04 00 01 to 0x00 07 FF FF.***

As defined in [10], each defined CAN ID represents a single monitor or control point. Control points require no explicit acknowledgement beyond the implicit CAN ACK bit. Monitor data is requested by a zero-length frame (not an RTR frame) and the ACU must respond with the

appropriate monitor data within 150 microseconds. If the values to be returned are not time critical, they may be returned from a local cache.

All commands (control points designated by a CMD suffix) must result in success, an error or a timeout. These error conditions shall be stored on a stack which may be polled with the GET_ACU_ERROR monitor point. This monitor request returns an error from the stack until none are left. All errors include a 1 byte code identifying the error condition or timeout and a 3 byte identification of the command which caused the error or timeout.

The Contractor's interface shall respond correctly if up to 50 messages per 50 millisecond timing period are addressed to it. An overall message rate on the CAN bus (including messages addressed to other nodes) that uses the full 1 Mbps raw data rate shall not cause any errors in the Contractor's interface.

The following tables summarise all M&C points for the ACU, with their CAN ID allocations, data size and typical access rates. Each M&C point is then described in more detail after Section 4.1.4 which details the data types used in the detailed descriptions.

Please note that this list of monitor and control points is expandable during the antenna design phase and will be frozen at the antenna CDR.

4.1.2 Summary of Monitor Points

Monitor data shall be polled by the ALMA bus master according to the protocol specified in [10]. A monitor request consists of a transmission of the appropriate CAN message with zero bytes of data. The ACU shall respond within 150 microseconds by transmitting the requested data in a message with the same CAN identification.

The "_RSP" suffix denotes a response message for which a corresponding "_CMD" control point exists. Most, but not all "GET_" monitor points have a corresponding "SET_" control point.

Table 4: Summary of Monitor Points

Name	*CAN ID (hex)**	*Data Size (bytes)*	*Typical Interval (secs)*
ACU_MODE_RSP	*00 04 00 22*	*2*	*5*
AZ_POSN_RSP	*00 04 00 12*	*8*	*0.05*
EL_POSN_RSP	*00 04 00 02*	*8*	*0.05*
GET_ACU_ERROR	*00 04 00 2F*	*0-5*	*0.05*
GET_AZ_BRAKE	*00 04 00 14*	*1*	*5*
GET_AZ_ENABLE_MOTOR1	*00 04 00 15*	*1*	*Rare*
GET_AZ_ENABLE_MOTOR2	*00 04 00 16*	*1*	*Rare*
GET_AZ_ENC	*00 04 00 17*	*4*	*0.05*
GET_AZ_ENC_STATUS	*00 04 00 18*	*4*	*1*
GET_AZ_MOTOR_CURRENTS	*00 04 00 19*	*4*	*5*

Name	CAN ID (hex)*	Data Size (bytes)	Typical Interval (secs)
GET_AZ_MOTOR_TEMPS	00 04 00 1A	4	5
GET_AZ_SERVO_COEFF_N	00 04 30 20 – 00 04 30 2N	8	Rare
GET_AZ_STATUS	00 04 00 1B	1	5
GET_CAN_ERROR	00 07 00 01	4	(debug)
GET_EL_BRAKE	00 04 00 04	1	5
GET_EL_ENABLE_MOTOR1	00 04 00 05	1	Rare
GET_EL_ENABLE_MOTOR2	00 04 00 06	1	Rare
GET_EL_ENC	00 04 00 07	8	0.05
GET_EL_ENC_STATUS	00 04 00 08	4	1
GET_EL_MOTOR_CURRENTS	00 04 00 09	4	5
GET_EL_MOTOR_TEMPS	00 04 00 0A	4	5
GET_EL_SERVO_COEFF_N	00 04 30 10 – 00 04 30 1N	8	Rare
GET_EL_STATUS	00 04 00 0B	1	5
GET_EMERG_STOP	00 04 00 21	1	5
GET_HW_ID	00 07 00 04	4	Rare
GET_IDLE_STOW_TIME	00 04 00 25	2	Rare
GET_IP_ADDRESS	00 04 00 2D	4	Rare
GET_NUM_TRANS	00 07 00 02	4	(debug)
GET_OTHER_STATUS	00 04 00 23	2	5
GET_PT_MODEL_COEFF_N	00 04 30 00 – 00 04 30 0N	8	Rare
GET_SERVO_PS_VOLTS	00 04 00 2B	8	5
GET_SHUTTER	00 04 00 2E	1	5
GET_SW_REV_LEVEL	00 07 00 00	3	(debug)

** The letter "N" is a hexadecimal digit in the range [0, F].*

4.1.3 Summary of Control Points

Control data shall be transmitted by the ALMA bus master according to the protocol specified in [10]. A control transaction consists of a transmission of the appropriate CAN message with data, if appropriate. The ACU shall acknowledge receipt of the control message by setting the acknowledge bits in the trailer of the CAN transmission. No further response is required.

Note that command failures and error conditions are polled in the monitor message ACU _ERROR.

The "_CMD" suffix denotes a command message which should result in the ACU adding error or timeout message on the error stack should the command fail. All of the "SET_" control points have a corresponding "GET_" monitor point.

Table 5: Summary of Control Points

Name	*CAN ID (hex)**	*Data Size (bytes)*	*Typical Interval (secs)*
ACU_MODE_CMD	*00 04 10 22*	*1*	*Rare*
AZ_TRAJ_CMD	*00 04 10 12*	*8*	*0.05*
EL_TRAJ_CMD	*00 04 10 02*	*8*	*0.05*
RESET_ACU_CMD	*00 04 10 2F*	*1*	*Rare*
SET_AZ_BRAKE	*00 04 10 14*	*1*	*Rare*
SET_AZ_ENABLE_MOTOR1	*00 04 10 15*	*1*	*Bootup*
SET_AZ_ENABLE_MOTOR2	*00 04 10 16*	*1*	*Bootup*
SET_AZ_SERVO_COEFF_N	*00 04 20 20 – 00 04 20 2N*	*8*	*Rare*
SET_AZ_SERVO_DEFAULT	*00 04 10 17*	*1*	*Rare*
SET_EL_BRAKE	*00 04 10 04*	*1*	*Rare*
SET_EL_ENABLE_MOTOR1	*00 04 10 05*	*1*	*Bootup*
SET_EL_ENABLE_MOTOR2	*00 04 10 06*	*1*	*Bootup*
SET_EL_SERVO_COEFF_N	*00 04 20 10 – 00 04 20 1N*	*8*	*Rare*
SET_EL_SERVO_DEFAULT	*00 04 10 07*	*1*	*Rare*
SET_IDLE_STOW_TIME	*00 04 10 25*	*2*	*Rare*
SET_IP_ADDRESS	*00 04 10 24*	*4*	*Rare*
SET_PT_MODEL_COEFF_N	*00 04 20 00 – 00 04 20 0N*	*8*	*Rare*
SET_SHUTTER	*00 04 10 2E*	*1*	*Rare*

** The letter "N" is a hexadecimal digit in the range [0, F].*

4.1.4 Data types

The following table indicates the data types used within CAN messages.

Data Type	***Description***
bit	*A single bit within a ubyte. Unused bits within ubytes are padded to fill the byte.*
ubyte	*An unsigned byte, usually used for bit fields.*
int8	*A signed 8 bit integer value.*
uint8	*An unsigned 8 bit integer value.*
int16	*A signed 16 bit integer value.*
uint16	*An unsigned 16 bit integer value.*
int32	*A signed 32 bit integer value.*
uint32	*An unsigned 32 bit integer value.*
float	*Single precision 32 bit IEEE floating point value.*
double	*Double precision 64 bit IEEE floating point value.*
string	*A string of single byte characters. Length is given by the DLC field in the CAN frame and the string is* ***not*** *null terminated.*

When multiple types are used in a single CAN message payload, there is no padding between values in a message.

All values appear in the CAN message payload in network byte order, or most significant byte first. Within a byte, bit 0 is the least significant bit.

4.1.5 Monitor Points in Detail

Name	*ACU_MODE_RSP*
CAN ID	*00 04 00 22*
Description	*Current operational and access mode information for ACU*
Typical Interval	*5 s*
Data	*2 Bytes:* *Byte 0 Mode: ubyte* *0x00 SHUTDOWN* *0x01 STANDBY* *0x02 ENCODER* *0x03 AUTONOMOUS* *0x04 STOW* *Byte 1 Access Mode: ubyte* *0x01 LOCAL* *0x02 REMOTE*

Name	*AZ_POSN_RSP*
CAN ID	*00 04 00 12*
Description	*Position of azimuth axis in turns at the last 20Hz pulse and 25ms before*
Typical Interval	*50 ms*
Data	*8 bytes:* *bytes 0-3: azimuth position at the last 20 Hz timing pulse* *bytes 4-7: azimuth position 25 ms before the last timing pulse* *Data format: signed, two's complement, fixed point binary number representing angle from –1 turn to* $+(1-2^{-31})$ *turn.*

Name	*EL_POSN_RSP*
CAN ID	*00 04 00 02*
Description	*Position of elevation axis in turns at the last 20Hz pulse and 25ms before*
Typical Interval	*50 ms*
Data	*8 bytes:* *bytes 0-3: elevation position at the last 20 Hz timing pulse* *bytes 4-7: elevation position 25 ms before the last timing pulse* *Data format: signed, two's complement, fixed point binary number representing angle from –1 turn to* $+(1-2^{-31})$*turn.*

Name	*GET_ACU_ERROR*
CAN ID	*00 04 00 2F*
Description	*Vendor defined ACU error conditions. This monitor point returns an error stack which includes an error code TBD and an identification of the command causing the error.*
Typical Interval	*50 ms*
Data	*0-5 Bytes:* *0 bytes means no current error conditions* *5 bytes indicates an error condition as follows:* *byte 0: ubyte Error code TBD* *bytes 1-4: Relative address of CAN message triggering error condition (uint32)*

Name	*GET_AZ_BRAKE*
CAN ID	*00 04 00 14*
Description	*Get azimuth brake status*
Typical Interval	*5 s*
Data	*1 byte (ubyte)* *0x00: brake released* *0x01: brake set*

Name	*GET_AZ_ ENABLE_MOTOR1*
CAN ID	*00 04 00 15*
Description	*Get azimuth axis motor 1 enable status*
Typical Interval	*Rare*
Data	*1 byte (ubyte)* *0x01: motor enabled* *0x00: motor disabled*

Name	*GET_AZ_ ENABLE_MOTOR2*
CAN ID	*00 04 00 16*
Description	*Get azimuth axis motor 2 enable status*
Typical Interval	*Rare*
Data	*1 byte (ubyte)* *0x01: motor enabled* *0x00: motor disabled*

Name	*GET_AZ_ENC*
CAN ID	*00 04 00 17*
Description	*Position in raw encoder bits at last 20Hz tick*
Typical Interval	*50 ms*
Data	*4 bytes (uint32): value of azimuth encoder. An uint32 containing the raw encoder value.*

Name	*GET_AZ_ENC_STATUS*
CAN ID	*00 04 00 18*
Description	*Status of azimuth encoder*
Typical Interval	*1 s*
Data	*TBD, but is expected to include the internal state of the encoder (initialised etc).*

Name	*GET_AZ_MOTOR_CURRENTS*
CAN ID	*00 04 00 19*
Description	*Motor currents in all azimuth axis drive motors*
Typical Interval	*5 s*
Data	*4 bytes:* *bytes 0-1 (uint16)* *value of motor 1 current in amps (range 0-??A)* *bytes 2-3 (uint16)* *value of motor 2 current in amps (range 0-??A)*

Name	*GET_AZ_MOTOR_TEMPS*
CAN ID	*00 04 00 1A*
Description	*Motor temperatures in all azimuth axis drive motors*
Typical Interval	*5 s*
Data	*4 bytes:* *bytes 0-1 (uint16)* *value of motor 1 temperature in deci-Kelvin (range 0-655.36)* *bytes 2-3 (uint16)* *value of motor 2 temperature in deci-Kelvin (range 0-655.36)*

Name	*GET_AZ_SERVO_COEFF_N*
CAN ID	*00 04 30 20 – 00 04 30 2N*
Description	*Azimuth servo coefficients*
Typical Interval	*Rare*
Data	*8 bytes. (double)* *Each message contains a different servo loop control parameter as defined by the Contractor's implementation.*

Name	*GET_AZ_STATUS*
CAN ID	*00 04 00 1B*
Description	*Status of azimuth axis*
Typical Interval	*5 s*
Data	*1 byte (ubyte)* *bit0: Limit 1, prelimit (set = in limit)* *bit1: Limit 2, final limit (set = in limit)* *bit2: Auto stow status (set = stowed)* *bit3: Stow pin 1 (set = engaged)* *bit4: Stow pin 2 (set = engaged)* *bit5: reserved* *bit6: reserved* *bit7: reserved*

Name	*GET_CAN_ERROR*
CAN ID	*00 07 00 01*
Description	*Number of CAN bus errors since power-up and error code of last error*
Typical Interval	*(debug)*
Data	*4 Bytes* *bytes 0-1 (uint16)* *count of CAN errors since power up.* *byte 2 (ubyte)* *(reserved)* *byte 3 (ubyte)* *Error code of last CAN error. Codes are those defined by Intel 82527 CAN Controller as follows:* *0x00: No error* *0x01: Stuff error* *0x02: Form error* *0x03: Ack error* *0x04: Bit1 error* *0x05: Bit 0 error* *0x06: CRC error*

Name	*GET_EL_BRAKE*
CAN ID	*00 04 00 04*
Description	*Get elevation brake status*
Typical Interval	*5 s*
Data	*1 byte (ubyte)* *0x00: brake released* *0x01: brake set*

Name	*GET_EL_ ENABLE_MOTOR1*
CAN ID	*00 04 00 05*
Description	*Get elevation axis motor 1 enable status*
Typical Interval	*Rare*
Data	*1 byte (ubyte)* *0x01: motor enabled* *0x00: motor disabled*

Name	*GET_EL_ ENABLE_MOTOR2*
CAN ID	*00 04 00 06*
Description	*Get elevation axis motor 2 enable status*
Typical Interval	*Rare*
Data	*1 byte (ubyte)* *0x01: motor enabled* *0x00: motor disabled*

Name	*GET_EL_ENC*
CAN ID	*00 04 00 07*
Description	*Position in raw encoder bits at last 20Hz tick*
Typical Interval	*50 ms*
Data	*8 bytes* *bytes 0-3 (uint32)* *value of elevation encoder 1 in raw encoder bits* *bytes 4-7 (uint32)* *value of elevation encoder 2 in raw encoder bits*

Name	*GET_EL_ENC_STATUS*
CAN ID	*00 04 00 08*
Description	*Status of elevation encoder*
Typical Interval	*1 s*
Data	*TBD, but is expected to include the internal state of the encoder (initialised etc).*

Name	*GET_EL_MOTOR_CURRENTS*
CAN ID	*00 04 00 09*
Description	*Motor currents in all elevation axis drive motors*
Typical Interval	*5 s*
Data	*4 bytes:* *bytes 0-1 (uint16)* *value of motor 1 current in amps (range 0-??A)* *bytes 2-3 (uint16)* *value of motor 2 current in amps (range 0-??A)*

Name	*GET_EL_MOTOR_TEMPS*
CAN ID	*00 04 00 0A*
Description	*Motor temperatures in all elevation axis drive motors*
Typical Interval	*5 s*
Data	*4 bytes:* *bytes 0-1 (uint16)* *value of motor 1 temperature in deci-Kelvin (range 0-655.36)* *bytes 2-3 (uint16)* *value of motor 2 temperature in deci-Kelvin (range 0-655.36)*

Name	*GET_EL_SERVO_COEFF_N*
CAN ID	*00 04 30 10 – 00 04 30 1N*
Description	*Azimuth servo coefficients*
Typical Interval	*Rare*
Data	*8 bytes. (double)* *Each message contains a different servo loop control parameter as defined by the Contractor's implementation.*

Name	*GET_EL_STATUS*
CAN ID	*00 04 00 0B*
Description	*Status of elevation axis*
Typical Interval	*5 s*
Data	*1 byte: (ubyte)* *bit0: Limit 1, prelimit (set = in limit)* *bit1: Limit 2, final limit (set = in limit)* *bit2: Auto stow status (set = stowed)* *bit3: Stow pin 1 (set = engaged)* *bit4: Stow pin 2 (set = engaged)* *bit5: reserved* *bit6: reserved* *bit7: reserved*

Name	*GET_EMERG_STOP*
CAN ID	*00 04 00 21*
Description	*Get state of antenna emergency stop*
Typical Interval	*5*
Data	*1 byte: (ubyte)* *0x01: Emergency stop applied* *0x00: Emergency stop clear*

Name	*GET_HW_ID*
CAN ID	*00 07 00 04*
Description	*Get ACU hardware identifier*
Typical Interval	*Rare*
Data	*4 bytes: Format TBD, uniquely specifies servo hardware connected to ACU*

Name	*GET_IDLE_STOW_TIME*
CAN ID	*00 04 00 25*
Description	*Currently set time for ACU to enter survival stow if no communications received on CAN bus or timing pulse has ceased.*
Typical Interval	*Rare*
Data	*2 bytes: (uint16)* *value representing seconds*

Name	*GET_IP_ADDRESS*
CAN ID	*00 04 00 2D*
Description	*ACU IP address*
Typical Interval	*(debug)*
Data	*4 Bytes (uint32)* *32 bit IP address7*

Name	*GET_NUM_TRANS*
CAN ID	*00 07 00 02*
Description	*Number of transactions handled by ACU since power up*
Typical Interval	*(debug)*
Data	*4 Bytes: (uint32)* *count of handled transactions*

Name	*GET_OTHER_STATUS*
CAN ID	*00 04 00 23*
Description	*State of miscellaneous related systems*
Typical Interval	*5 s*
Data	*2 bytes* *byte 0 (ubyte)* *circuit breaker status??* *Byte 1 (ubyte)* *Status of 8 emergency stop switches (set = engaged), allocations TBD*

Name	*GET_PT_MODEL_COEFF_N*
CAN ID	*00 04 30 00 – 00 04 30 0N*
Description	*Pointing model coefficients to be used in autonomous mode. This is a range of consecutive identifiers reserved for getting the current value of a variable number of coefficients.*
Typical Interval	*Rare*
Data	*8 bytes in each coefficient. (double)* *The actual mapping from each coefficient to terms in the pointing model is dependent on the vendors implementation.*

Name	*GET_SERVO_PS_VOLTS*
CAN ID	*00 04 00 2B*
Description	*Power supply voltages*
Typical Interval	*5 s*
Data	*8 bytes* *bytes 0-1 (uint16)* *Voltage 1, value in mV, range 0-10V??* *Bytes 2-3 (uint16)* *Voltage 2, value in mV, range 0-10V??* *Bytes 4-5 (uint16)* *Voltage 3, value in mV, range 0-10V??* *Bytes 6-7 (uint16)* *Voltage 4, value in mV, range 0-10V??*

Name	*GET_SHUTTER*
CAN ID	*00 04 00 2E*
Description	*Position of computer actuated shutter*
Typical Interval	*5 s*
Data	*1 byte: (ubyte)* *0x01 if shutter is open* *0x00 otherwise*

Name	*GET_SW_REV_LEVEL*
CAN ID	*00 07 00 00*
Description	*Revision level of vendor ACU code*
Typical Interval	*(debug)*
Data	*3 Bytes* *byte 0 (ubyte): major revision level* *byte 1 (ubyte): minor revision level* *byte 2 (ubyte): patch level* *ie. 0xXX 0xYY 0xZZ is interpreted as VXX.YY.ZZ*

4.1.6 Control Points in Detail

Name	*ACU_MODE_CMD*
CAN ID	*00 04 10 22*
Description	*Set current ACU operational and access modes*
Typical Interval	*Rare*
Data	*1 Byte:* *Byte 0 Mode: Defined in [6] (ubyte)* *0x00 SHUTDOWN* *0x01 STANDBY* *0x02 ENCODER* *0x03 AUTONOMOUS* *0x04 STOW*

Name	*AZ_TRAJ_CMD*
CAN ID	*00 04 10 12*
Description	*Position in turns and velocity in turns/sec to be applied at 20Hz tick subsequent to next. The values are treated differently depending on the ACU's operational mode. See Section 4.1.8.*
Typical Interval	*50 ms*
Data	*8 bytes.* *Bytes 0-3: Fixed point number as described in AZ_POSN_RSP representing turns.* *Bytes 4-7: Fixed point number representing "velocity" in turns/sec.*

Name	*EL_TRAJ_CMD*
CAN ID	*00 04 10 02*
Description	*Position in turns and velocity in turns/sec to be applied at 20Hz tick subsequent to next. The values are treated differently depending on the ACU's operational mode. See Section 4.1.8.*
Typical Interval	*50 ms*
Data	*8 bytes.* *Bytes 0-3: Fixed point number as described in EL_POSN_RSP representing turns.* *Bytes 4-7: Fixed point number representing "velocity" in turns/sec.*

Name	*RESET_ACU_CMD*
CAN ID	*00 04 10 2F*
Description	*Perform a soft reboot of the ACU*
Typical Interval	*Rare*
Data	*1 byte: (ubyte)* *0x01: Reboot*

Name	*SET_AZ_BRAKE*
CAN ID	*00 04 10 14*
Description	*Set azimuth brake*
Typical Interval	*Rare*
Data	*1 byte (ubyte)* *0x00: release brake* *0x01: set brake*

Name	*SET_AZ_ ENABLE_MOTOR1*
CAN ID	*00 04 10 15*
Description	*Enable or disable azimuth axis motor 1*
Typical Interval	*Rare*
Data	*1 byte (ubyte)* *0x01: enable* *0x00: disable*

Name	*SET_AZ_ ENABLE_MOTOR2*
CAN ID	*00 04 10 16*
Description	*Enable or disable azimuth axis motor 2*
Typical Interval	*Rare*
Data	*1 byte (ubyte)* *0x01: enable* *0x00: disable*

Name	*SET_AZ_SERVO_COEFF_N*
CAN ID	*00 04 20 20 – 00 04 20 2N*
Description	*Azimuth servo coefficients. These values should not be persistent and should default to static "safe" values when the ACU is rebooted.*
Typical Interval	*Rare*
Data	*8 bytes. (double)* *Each message contains a different servo loop control parameter as defined by the Contractor's implementation.*

Name	*SET_AZ_SERVO_DEFAULT*
CAN ID	*00 04 10 17*
Description	*Reset azimuth servo coefficients to default "safe" values*
Typical Interval	*Rare*
Data	*1 byte: (ubyte)* *0x01: Set servo coefficients to default values.*

Name	*SET_EL_BRAKE*
CAN ID	*00 04 10 04*
Description	*Apply or release elevation brake*
Typical Interval	*Rare*
Data	*1 byte (ubyte)* *0x00: release brake* *0x01: apply brake*

Name	*SET_EL_ ENABLE_MOTOR1*
CAN ID	*00 04 10 05*
Description	*Enable or disable elevation motor 1*
Typical Interval	*Rare*
Data	*1 byte (ubyte)* *0x01: enable motor* *0x00: disable motor*

Name	*SET_EL_ ENABLE_MOTOR2*
CAN ID	*00 04 10 06*
Description	*Enable or disable elevation motor 2*
Typical Interval	*Rare*
Data	*1 byte (ubyte)* *0x01: enable motor* *0x00: disable motor*

Name	*SET_EL_SERVO_COEFF_N*
CAN ID	*00 04 20 10 – 00 04 20 1N*
Description	*Elevation servo coefficients. These values should not be persistent and should default to static "safe" values when the ACU is rebooted.*
Typical Interval	*Rare*
Data	*8 bytes. (double)* *Each message contains a different servo loop control parameter as defined by the Contractor's implementation.*

Name	*SET_EL_SERVO_DEFAULT*
CAN ID	*00 04 10 07*
Description	*Reset elevation servo coefficients to default "safe" values*
Typical Interval	*Rare*
Data	*1 byte: (ubyte)* *0x01: Set servo coefficients to default values.*

Name	*SET_IDLE_STOW_TIME*
CAN ID	*00 04 10 25*
Description	*Time for ACU enter survival stow if no communications received on CAN bus or timing pulse has ceased.*
Typical Interval	*Rare*
Data	*2 bytes: (uint16)* *value representing seconds*

Name	*SET_PT_MODEL_COEFF_N*
CAN ID	*00 04 20 00 – 00 04 20 0N*
Description	*Pointing model coefficients to be used in autonomous mode. This is a range of consecutive identifiers reserved for setting a variable number of coefficients for the antenna. These values should not be persistent and should default to static "safe" values when the ACU is rebooted.*
Typical Interval	*Rare*
Data	*8 bytes in each coefficient. (double)* *The actual mapping from each coefficient to terms in the pointing model is dependent on the vendors implementation. Note that this is not intended to represent a classical pointing model; in autonomous mode the vendor should calculate the appropriate values using their metrology systems.*

Name	*SET_SHUTTER*
CAN ID	*00 04 10 2E*
Description	*Set position of computer actuated shutter*
Typical Interval	*Rare*
Data	*1 byte: (ubyte)* *0x01: open shutter* *0x00: close shutter*

4.1.7 Other signals which may be needed

The contractor shall provide details on the procedure for setting encoder zeros and any other encoder calibration required. Monitor and control messages required to support such procedures shall be negotiated between the Contractor and ALMA during the design phase.

4.1.8 ACU Modes of Operation

At any time, the ACU may be in one and only one of the following operating modes:

- *Shutdown: brakes set, no power to motors*
- *Standby: ready to drive, brakes set*
- *Velocity: rate loop driving of axes from local handset*
- *Encoder: drive so encoders equal commanded position*
- *Autonomous: drive so boresight equals commanded position*
- *Stow: drive to stow position*

Simultaneously, it may be in either of two access modes, Local or Remote. When remote access is selected, the controller responds to a set of commands via the CAN bus as defined in Section 4.1.3 above. When Local access is selected, commands received from the digital interface are ignored (but monitor requests are still accepted and processed) and the antenna may be controlled using the control panel described in [6] Section 3.5.6.2. Switching between Local and Remote access may be done only from the local control panel.

Upon changing access mode and at power-up and reset, the controller automatically enters the Shutdown operating mode. Not all operating modes may be entered from either access mode; see Table 6. In addition, Survival Stow mode or Shutdown may be entered automatically when the ACU detects certain fault conditions, regardless of the selected access mode. This is reflected in the Auto column of Table 6.

Table 6: Modes of Operation

	Mode Allowed?		
Operating Mode	***Local***	***Remote***	***Auto***
Shutdown	*Yes*	*Yes*	*Yes*
Standby	*Yes*	*Yes*	*No*
Active Modes			
Velocity	*Yes*	*No*	*No*
Encoder	*Yes*	*Yes*	*No*
Autonomous	*No*	*Yes*	*No*
Survival Stow	*Yes*	*Yes*	*Yes*

The following rules govern changes of mode:

- *From Shutdown mode, the only change permitted is to Standby mode, and then only if no fault conditions exist*
- *An active mode (Velocity, Encoder, Autonomous, Stow) may only be entered from Standby mode*
- *From Survival Stow mode, Standby mode is automatically entered upon reaching the stow position*

Any of the "SET_" control messages defined in Section 4.1.6 shall be accepted in any of the operating modes, provided the ACU is in remote mode. All monitor messages (Section 4.1.5)

shall be handled regardless of the current operating or access mode. The following table shows which "_CMD" control messages shall be applicable in which operating modes (Remote access mode only).

Table 7: Commands allowed by Operating Mode

Operating Mode	*Commands Accepted*
Shutdown	*ACU_MODE_CMD* *RESET_ACU_CMD*
Standby	*ACU_MODE_CMD* *RESET_ACU_CMD*
Velocity	*None*
Encoder	*ACU_MODE_CMD* *RESET_ACU_CMD* *AZ_TRAJ_CMD* *EL_TRAJ_CMD*
Autonomous	*ACU_MODE_CMD* *RESET_ACU_CMD* *AZ_TRAJ_CMD* *EL_TRAJ_CMD*
Survival Stow	*ACU_MODE_CMD* *RESET_ACU_CMD*

4.2 Reset Signal

The ACU shall initiate a software reset when a 1 ms 5V pulse is detected on the CAN bus reset pin (pin 9).

Note that this reset pulse is not a CAN standard.

The 28 volt remote signal noted in [6] shall also disconnect power to the ACU, causing a hard reboot.

4.3 Ethernet Interface

In addition to the monitor and control interface provided by the CAN bus, ALMA requires that the ACU also provide an Ethernet interface to facilitate debugging and testing of the vendor equipment.

In particular, is shall be possible via the Ethernet interface to

- *download new versions of the software*
- *use Tornado tools for debugging and profiling the ACU software*
- *issue a reset command to soft boot the ACU*

4.4 Static Parameters

The Contractor shall in general face the problem of replacement of units (like the ACU, motors etc) and shall propose a solution for downloading the correct set of parameters relevant to the replaced unit.

Other static parameters to which ALMA requires access:

- *Antenna hardware specific parameters (dependent on the Contractors specific implementation)*
- *Control loop parameters (generally those corresponding to the rare control points in Section 4.1.6 above, which are normally fixed at commissioning, but which may require alteration as components such as motors and encoders are replaced).*
- *Software parameters such as software version numbers, ACU serial number, antenna number and the CAN node number.*

ALMA requires the Contractor to provide access to these parameters and procedures for changing them remotely. It is permissible for such alterations to be made over the CAN bus or Ethernet interface. The exact list of static parameters and the methods for altering them are TBD during the design phase.

4.5 Non standard CAN behavior

The following behavior is required of the ACU but is not standard to the CAN specification:

- *Pin 9 of the CAN connector is used for a remote reset pulse. The presence of 5V on this pin for 1 millisecond should cause the ACU to reset.*
- *The bus will in a master/slave fashion under the control of ALMA's bus master. The Contractor's ACU shall not initiate transmissions on the CAN bus unless polled by ALMA's bus master.*

5.0 Safety Issues

ALMA's Monitor and Control system shall not address the safety condition of the antenna system and personnel. These details are covered in [8], along with other requirements TBD by the antenna manufacturer and ALMA safety personnel.

ALMA software shall, however, monitor and report situations which are approaching or reaching safety limits. In normal operation, ALMA software shall attempt to prevent the activation of hardware limits to provide a second level of safety margins and to reduce the possibility of reaching such hardware limits. Automatic hardware fail-safe mechanisms shall be applied when limits have been reached and ALMA software shall be able to monitor these.

The ACU shall monitor and display all of the following conditions, and should enter the Shutdown operational mode is any of these conditions are detected:

- *Excessive motor current*
- *Motor overheating*
- *Servo oscillation*
- *Limit switch actuation*
- *Critical sensor faults (especially encoders) or power failure*
- *Overspeed of azimuth or elevation axis*

The Contractor shall analyse all safety relevant situations and propose a strategy for a traceable shut-down in severe situations, like the ones indicated above. In other cases it might be appropriate to implement a retry-policy (to make the system robust) where such a retry is possible and safety-critical aspects are not directly involved.

APPENDIX A

Glossary

Access Mode	*Current mode of accessing the ACU. When in Local access mode, the ACU may only be commanded by a local handset; all commands via the CAN M&C interface are ignored except for monitor requests. When in Remote access mode, M&C commands are accepted. The ACI may not be switched from Local to Remote access mode over the CAN M&C interface.*
ACK	*Acknowledge. In a CAN transmission, this is a bit in a transmitted frames which is set by a successful receiver of the frame*
ALMA	*Atacama Large Millimetre Array*
AUI	*A type of Ethernet connector*
AZ	*Azimuth. Defined as zero to North when the antenna is in the northern hemisphere and zero to the south when in the southern hemisphere.*
Boresight	*The actual orientation of the axis of symmetry of the main reflector with respect to established local coordinates (zenith direction and nominal azimuth zero).*
CAN	*Controller Area Network*
CAN ID	*CAN message identification. A 29 bit identifier transmitted at the start of a CAN frame which also determines the frame's priority*
CDR	*Critical Design Review*
EL	*Elevation*
ICD	*Interface Control Document*
ISO	*International Standards Organisation*
M&C	*Monitor and Control*
Operational Mode	*The ACU state determining the availability of axis drive motors, and brakes. Also defines how the position commands are interpreted.*
PDR	*Preliminary Design Review*
PPC	*PowerPC, a Motorola processor*
RFP	*Request for Proposal*
RTR	*Remote Transmission Request. A type of CAN frame requesting transmission of a particular frame*
TBD	*To Be Determined*
Turns	*One turn of an antenna axis, or 360°*
VME	*VERSAbus Module European*

ALMA-US ICD No. 10

WBS 3.2.8.10 / 4.1.1

Antenna / Receiver Cabin Equipment Rack Interface

Authors: J. Kingsley / V.Gasho / D. Emerson / G. Moorey

Date: 2000-JAN-24

Version: A

Issued by: Antenna and Systems Groups

		Date:
Approved by: Peter Napier,	ALMA-US Division Head 1	2000-JAN-24
	Darrel Emerson, ALMA-US Division Head 2	2000-JAN-24
	Darrel Emerson, ALMA-US Systems Engineering	2000-JAN-24
Approved by: Torbin Andersen,	ALMA-EURO Team Leader 1	2000-JAN-24
	_____ ALMA-EURO Team Leader 2_____	
	_____ALMA-EURO System Engineering_____	

Revision Control

1. Revision Version #_____
   Date:
   Revised by:
   Reason for / items changed:

2. Revision Version #_____
   Date:
   Revised by:
   Reason for / items changed:

etc.

1.0 Description

To define the interface between the antenna and receiver cabin equipment racks.

2.0 Related Documents and Drawings

U.S. Prototype Antenna Purchase Order, Section 3.5.4 Receiver Cabin
U.S. Prototype Antenna Purchase Order, Section 3.6.5 Receiver Cabin Equipment Rack Interface
ALMA-US ICD No. 1 Antenna / Receiver Interface
ALMA-US ICD No. 3 Antenna / Site Electrical Power Interface

2.1 Related Interface Control Drawings

03031000M010A– Equipment View, Receiver Cabin, Revision a, 2000-JAN-24
03020810M005 - Equipment Rack Interface, 2000-JAN-24

3.0 Physical System Interfaces

3.1 Mechanical interface

The two receiver cabin equipment racks shall be mounted in the receiver cabin as shown in NRAO drawing number 03031000M010A (Equipment View, Receiver Cabin). The Contractor can propose an alternate layout but it must be approved by AUI. Any alternate layout must provide access to the front and back of the rack to service equipment in the racks and allow complete access all around the receiver.

The specified racks will be as described in ALMA drawing number 03020810M005 Equipment Rack Interface or will use a commercial Schroff equipment rack number 10114-417 along with plinth at the bottom. The HVAC system will supply an air duct inlet at the bottom of the equipment racks and an air duct outlet at the top of the equipment racks. The Contractor shall provide an installation mechanism for moving the racks from the ground to the location in the receiver cabin.

Provision will be made by the Contractor for cables to enter the racks from the bottom via cable trough in the receiver cabin as specified in U.S. Prototype Antenna Purchase Order Section 3.5.4 Receiver Cabin.

3.2 Mass, if relevant

The mass of each equipment rack is variable from 0 to 375 kg.

3.3 Electrical power

The electrical power is specified in ALMA ICD No. 3 Antenna / Site Electrical Power). Electrical power shall be provided by the contractor to each equipment rack in rigid metal conduit or flexible cable with connector capable of providing 3 kW of power at 230 VAC single phase. The entrance location shall be negotiated once the location of the rack is determined by Contractor.

3.4 Electronic interface, including computer hardware

Not relevant

3.5 Thermal control interface

The contractor shall provide a temperature controlled receiver cabin as specified in the RFP section 3.5.4 Receiver Cabin. The specification also requires output of the HVAC unit to provide cooling of the equipment racks. The cooling requirement for each equipment rack individually will be variable between 0 kW and 3 kW of heat load. This system shall provide forced air through the rack at a CFM to TBD prior to the PDR. The air temperature at the input to the racks shall be at a constant temperature +/- 1 C.

4.0 Software/Control Function Interface

4.1 Monitor and Control software interface

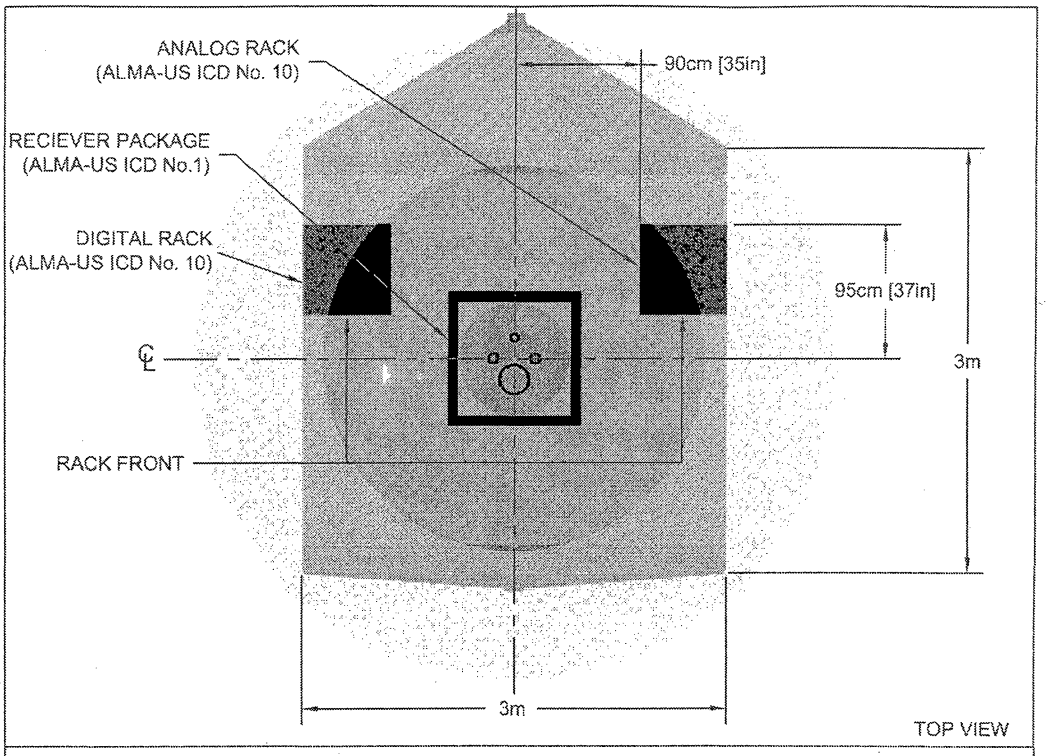
Not relevant

4.2 Other software or control interface

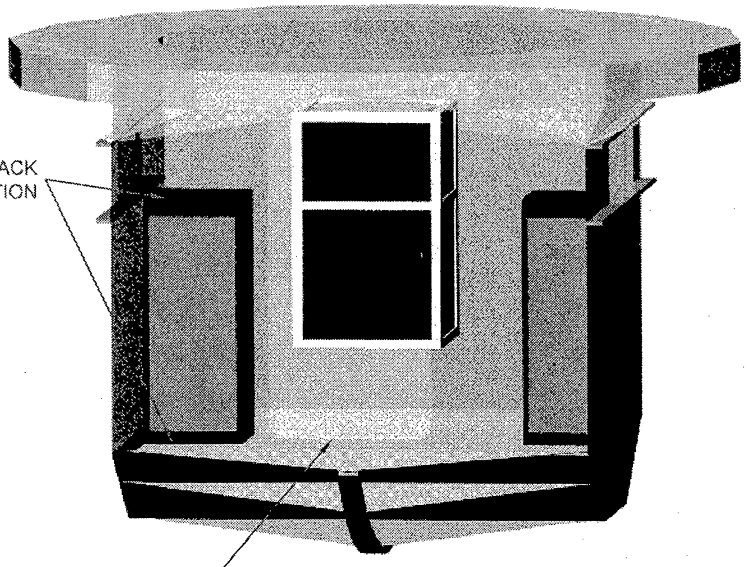
Not relevant

5.0 Safety Issues

Not aware of any.



TOP VIEW



FRONT OBLIQUE VIEW

METRIC

THIRD ANGLE PROJECTION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MILLIMETERS TOLERANCES ARE:

DECIMALS ANGLES
.X±0.8 ±0.5°
.XX±0.25

DO NOT SCALE DRAWING

TREATMENT

FINISH

SIMILAR TO | SPECIAL MARKING SYM

CONTRACT NO.

APPROVALS	DATE
DRAWN V.L. GASHO	2000-01-24
CHECKED J. CHENG	2000-01-24
ENGR. J. KINGSLEY	2000-01-24
SYSTEMS GROUP D. EMERSON	2000-01-24

MMA NRAO

NATIONAL RADIO ASTRONOMY OBSERVATORY

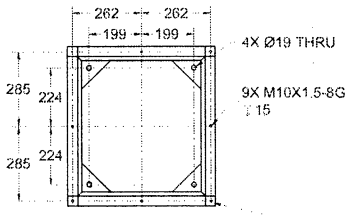
operated by ASSOCIATED UNIVERSITIES INC. in agreement with THE NATIONAL SCIENCE FOUNDATION

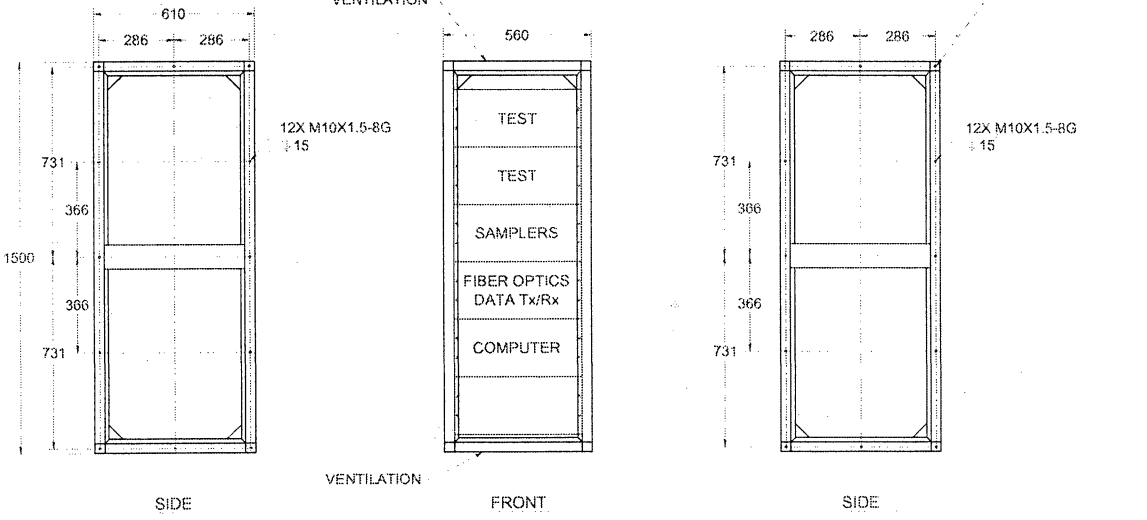
TITLE
EQUIPMENT VIEW
RECEIVER CABIN

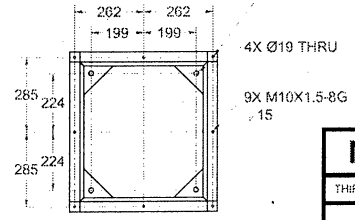
MMA-TUCSON
949 N. CHERRY AVE.
CAMPUS BLDG. 65
TUCSON, AZ 85721-0655

SIZE	CAGE CODE	DWG NO.	REV.
A		03031000N010B	B

SCALE NONE | CALC. WT | ACT. WT | SHEET 1/1







NOTE:
1. RACK CAN BE MOUNTED EITHER ON THE SIDES, TOP, AND/OR BOTTOM OF THE RACK.
2. HVAC RACK VENTILATION INLET IS ON THE BOTTOM AND THE OUTLET IS ON THE TOP.

METRIC

THIRD ANGLE PROJECTION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN MILLIMETERS
TOLERANCES ARE:
DECIMALS ANGLES
X±1 ±1°
.XX±0.1 ±0.5'
.XX±0.01
DO NOT SCALE DRAWING

TREATMENT

FINISH

SIMILAR TO

CONTRACT NO.

APPROVALS		DATE
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Basic Antenna Definitions

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Table of Contents

1 Scope

This specification shall unify definitions for the involved partners in the ALMA project, in particular the coordinate systems for the antennas will be defined. The sign and naming conventions in this document shall be used for future contracts, specifications and technical documents related to the ALMA project.

This document may also contain other definitions and naming conventions related to the ALMA project which are of a general nature and are not defined elsewhere. These definitions will be expanded in future issues of the document as required by the project.

2 Documents and Acronyms

2.1 Applicable Documents

The following documents are available and related to this specification:

- AD01: ESO-Call for Tenders (CFT) for Supply of one Prototype Antenna for the Atacama Large Millimeter Array (ALMA), Issue of 30th April 1999
- AD02: NRAO-Request for Proposal (RFP) for Supply of one Prototype Antenna for the Atacama Large Millimeter Array (ALMA), Issue of 30th March 1999

2.2 Acronyms

AD	Applicable Document
CFT	Call for Tenders (Europe)
ESO	European Southern Observatory
NRAO	National Radio Astronomy Observatory
RFP	Request for Proposals (USA)
TBD	to be determined

3 Arrangement of the Axes

This document defines some **basic coordinate systems** for different aspects of the ALMA project, cp. section 4. Additionally, **local coordinate systems** may be defined later according to the specified rules in this section.

All basic and local coordinate systems shall conform to the basic rules for the arrangement of axes, direction of rotation and labeling described in the following, and are referred to in this document as **standard coordinate systems**.

Other types of coordinate systems are referred to as **non-standard coordinate systems**. They shall be avoided as far as possible but they might be used when the basic rules cannot be used reasonably. However, data resulting from non-standard coordinate systems must be converted to standard coordinate systems for all ALMA technical documents and memoranda.

All Cartesian coordinate systems shall use a right-hand convention for the arrangement of axes as shown in Figure 1. All axis labels shall be assigned an alphabetic label with the cyclic alphabetic sequence corresponding to the right-hand axis sequence. Where required, the rotational directions shall be assigned a Greek letter with a cyclic alphabetic sequence corresponding to the axis sequence.

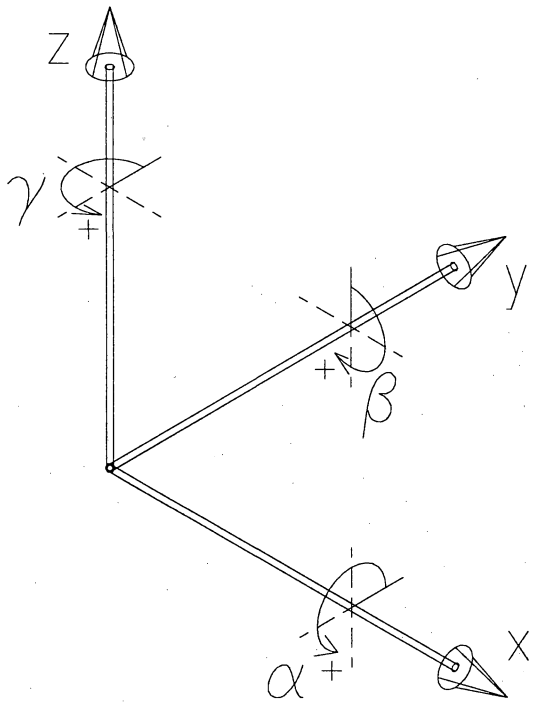

Figure 1: Arrangement of axes and rotations

The alphabetic labels for local coordinate systems may use letters between 'a' and 'q'. The letters r, s, t are reserved for the Site Coordinate System, the letters u, v are used in interferometry for the Fourier transform of the spatial coordinates and the letters x, y, z are used for the basic coordinate systems.

All coordinate systems defined here are related to the ideal, undeformed antenna. Antenna deformations can be taken into account using additional local coordinate systems.

The rotation angle is given by the right-hand convention. There is no general definition for the zero angle of the rotational axes. These will be defined individually for each coordinate system, when the definition of rotation angles is necessary. However, the zero angle shall lie in the direction of one of the other two axes.

4 Basic Coordinate Systems

This section defines four basic coordinate systems for the site, the antenna, the yoke and the reflector. For the definition of additional local coordinate systems, some rules are given in section 4.5.

4.1 Site Coordinate System

The global site coordinate system defines the position of each antenna foundation relative to a common origin and serves as the basis for the definition of all Antenna Coordinate Systems. The Site Coordinate System will also be used for the layout and dimensioning of infrastructure such as buildings or roads and for a definition of the ground level.

This coordinate system shall consider the curvature of Earth, for instance by giving the coordinates in longitude (coordinate s), latitude (t) and altitude (r) above sea level. The details are TBD.

4.2 Antenna Coordinate System

Each foundation has a fixed Antenna Coordinate System. According to Figure 2, the y-axis is aligned with the geographical south-north axis and the z-axis is aligned with local gravity and pointing upwards. The origin is at the intersection of the antenna azimuth axis with the ground level. Both the ground level and the position of the antenna coordinate´s origin on the site will be defined relative to the Site Coordinate System for each antenna foundation.

The Antenna Coordinate System shall be used for dimensioning of the foundation, the interfaces between foundation and antenna as well as all non-moving parts of the antenna. It also serves as the basis for the definition of the movable Yoke Coordinate System.

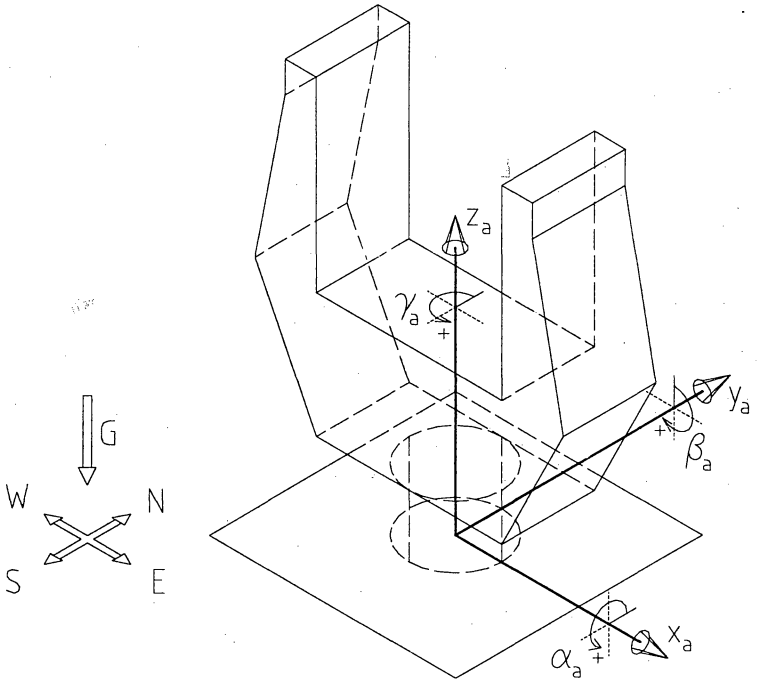

Figure 2: Antenna Coordinate System

The three axes will be labeled x, y and z. The x-axis is pointing towards the geographical east, the y-axis towards the north and the z-axis towards zenith. The rotational angles about the x-, y- and z-axes shall be designated α, β and γ respectively. The zero points for α and γ shall be in the direction of the y-axis. The zero point for β shall lie in the direction of the z-axis. In cases where confusion might arise between different coordinate system types, the antenna coordinates shall have the subscript "a" (i.e. x_a, y_a, z_a, α_a, β_a, γ_a).

In cases where confusion might arise between the coordinate systems for different antenna foundations, the antenna coordinates shall have a number as additional subscript according to the antenna foundation number.

The *azimuth angle* is counted clockwise around the z_a-axis with the zero angle in the north, i.e. the positive y_a-axis. As γ_a is counted counterclockwise around the z_a-axis according to the right-hand convention, the azimuth angle is given by $-\gamma_a$.

4.3 Yoke Coordinate System

Each antenna has a movable coordinate system for the yoke structure that rotates around the azimuth axis with respect to the Antenna Coordinate System (z_a-axis). The x-axis is aligned with the elevation axis and the z-axis is aligned with the

azimuth axis. The origin is at the intersection of the antenna azimuth axis and the elevation axis. Figure 3 shows the Yoke Coordinate System.

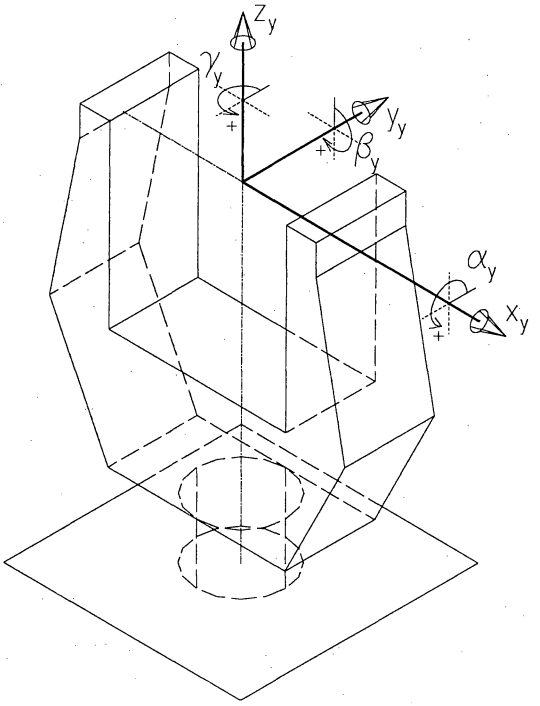

Figure 3: Yoke Coordinate System

This coordinate system shall be used for dimensioning of all antenna parts that are moving around the azimuth axis and it is the basis for the definition of the movable Reflector Coordinate System.

The three axes will be labeled x, y and z and the rotational angles about the x-, y- and z-axes shall be designated α, β and γ respectively. The zero points for α and γ shall be in the direction of the y-axis. The zero point for β shall lie in the direction of the z-axis. In cases where confusion might arise between different coordinate systems, the yoke coordinates shall have the subscript "y" (i.e. x_y, y_y, z_y, α_y, β_y, γ_y).

In cases where confusion might arise between the Yoke Coordinate Systems for different antennas, the yoke coordinates shall have a number as additional subscript according to the antenna number.

The *altitude angle* starts with 0° horizontal (y_y-axis) and has a value of 90° towards zenith (z_y-axis). The rotation angle α_y, however, is -90° when the reflector points horizontal (altitude angle 0°). That gives the relationship: altitude angle = $\alpha_y + 90°$.

4.4 Reflector Coordinate System

Each antenna has a movable coordinate system for the elevation part that rotates around the elevation axis (x_y-axis) with respect to the Yoke Coordinate System. This Reflector Coordinate System is shown in Figure 4 for $\alpha_y = -30°$. The x-axis is aligned with the elevation axis and the z-axis is aligned with the center line of reflector and subreflector. The origin is at the intersection of the antenna azimuth axis with the elevation axis. When the antenna is pointing at the zenith with the angle $\alpha_y = 0°$, the Reflector Coordinate System is coincident with the Yoke Coordinate System.

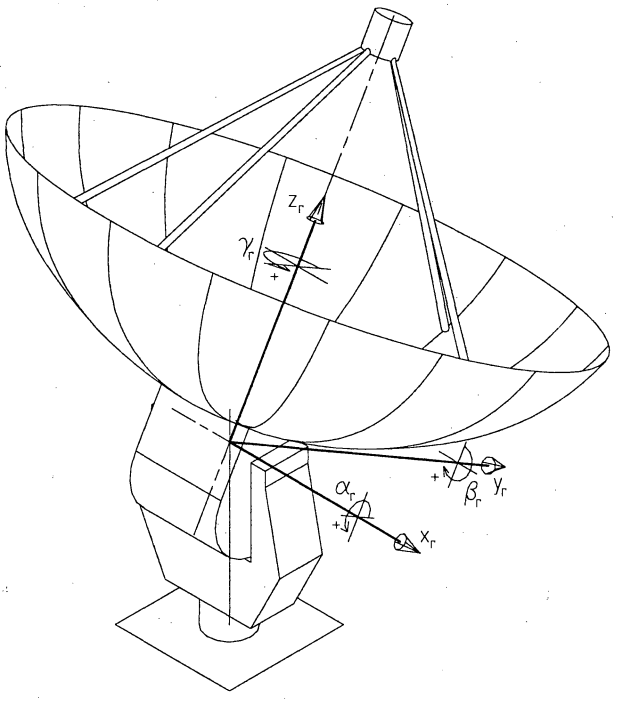

Figure 4: Reflector Coordinate System for $\alpha_y = -30°$

This coordinate system shall be used for dimensioning of the elevation structure, i.e. the reflector, the subreflector, the BUS and the receiver cabin.

The three axes will be labeled x, y and z and the rotational angles about the x-, y- and z-axes shall be designated α, β and γ respectively. The zero points for α and γ shall be in the direction of the y-axis. The zero point for β shall lie in the direction of the z-axis. In cases where confusion might arise between different coordinate systems, the reflector coordinates shall have the subscript "r" (i.e. x_r, y_r, z_r, α_r, β_r, γ_r).

In cases where confusion might arise between different reflector coordinate systems the reflector coordinates shall have a number as additional subscript according to the antenna number 4.5.

4.5 Local Coordinate Systems

Local coordinate systems can be defined for the design or analysis of individual sub-assemblies or components. They conform to the general rules, notations and conventions given in section 3.

A fixed or movable local coordinate system that is derived from either the antenna or the site coordinates may use the same labelling notation as the parent system, but with an appropriate subscript to indicate the subsystem to which it applies.

Other local coordinate systems, and those that are not derived from either the antenna or the site coordinates, shall use different sequences of alphabetic axis labels and greek rotational directions to avoid confusion.

5 Other Definitions

5.1 Units

All documents, contracts, reports, drawings and calculations belonging to the ALMA project shall use SI units or units that are based on the SI system.