RFP-VLBA-01
Revision 1A
October 25, 1984

SCHEDULE C

NRAO SPECIFICATION AND DESCRIPTION OF WORK

VLBA ANTENNA

[This schedule comprises a revision to Section 03, Specifications and Statement of Work, from RFP-VLBA-01 (dated March 9, 1984), and the referenced Appendices, based upon technical discussions prior to and during negotiations.]

03.1 Introduction

03.1.1 General Statement of Work

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 of antennas for the VLBA telescope system.

03.1.2 Objectives of the Program

The objectives of the effort under this subcontract are the following:

The design of an antenna that meets the operating parameters and requirements set forth in this specification.

The design for an antenna that is optimized for production of a quantity of ten (10) antennas, 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 antennas will be at ten widely separated sites geographically, antennas shall be designed for manufacture and shipping in such modules as will minimize shipping and assembly costs to the extent possible.

A design that takes into consideration ease of maintenance and the reliability of components to minimize maintenance.

The fabrication of antennas using the techniques specified in the design effort.

03.2 Design

03.2.1 Applicable Documents

The following documents may 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:

VLBA Antenna Memo No. 4 - Drive System Analysis

VLBA Antenna Memo No. 5 - Structural Data

Antenna Configuration Drawings D52502T001 Sheets 1 through 5.

Electronic Industries Association RS-222 - Structural Standards for Steel Transmitting Antennas and Supporting Steel Towers.

National Fire Protection Association - National Electrical Code - Latest Edition.

Bureau of Standards RP-1 (Federal Property Fire Protection).

American Institute of Steel Construction - Manual of Steel Construction - Latest Edition.

MIL.STD.461A - Electromagnetic Interference.

The first three items listed above are for use in describing a configuration and design that AUI has developed to describe a wheel and track antenna well fitted to perform the observations required and analyzed to assure an antenna which will meet the performance requirements set forth later in this specification. The antenna shall be of wheel and track design and shall meet the mechanical and operating parameters and conditions as set forth in section 03.2.2. Subcontractor is not required to adopt this configuration and design, but if the Subcontractor chooses to adopt another configuration and design, it must meet the operating parameters set forth in this specification as fully as the design described in the NRAO documents. Once under contract, if the Subcontractor elects to use the NRAO design, it will be the Subcontractor's responsibility to confirm and validate the NRAO design during the design stage of the subcontract, and to develop the detailed design, drawings, and component specifications necessary to accomplish a finished antenna design which meets the performance requirements set forth in this document.

03.2.2 Design and Performance Parameters

The antenna system for which this antenna is designed consists of ten (10) antennas with 25-meter (approximately 82 feet) diameter reflectors located at ten (10) sites, widely separated geographically. Design parameters are therefore set forth for climatic conditions which may not exist at each station.

The antenna shall be an elevation over azimuth configuration, with a 25-meter diameter solid surface, which is approximately a paraboloid of revolution, as the main reflector. The observing systems to be used shall be both Cassegrain and prime focus. The Cassegrain observing system shall be considered the normal mode of operation. The feed for prime focus operation will be permanently mounted in the center of the subreflector and will be used by moving the subreflector away from the main reflector to position the prime focus feed close to the prime focus. A clear opening of approximately 1.8 m (6 feet) in diameter will be required at the apex of the feed legs symmetrical about the reflector axis.

The antenna concept and design developed by NRAO and described in Section 03.2.1 above is one in which the gravity, thermal, and wind performance of the antenna structure is believed to be compatible with 86 GHz operation. It is NRAO's intent to preserve this structural performance capability so that a later upgrading of the antenna surface to operation at 86 GHz is not restricted by the structural capability of the antenna.

03.2.2.1 Mechanical Parameters

Diameter: 25 meters (82.02 feet)

Focal Length: 8.85 meters (29.035 feet)

f/D: 0.354

Sky Coverage: Elevation +0 deg to 125 deg; Azimuth ± 270 deg

Presently Planned Operational Frequencies: Cassegrain: 43 GHz, 22 GHz, 15 GHz, 10.7 GHz, 8.46 GHz, 6.1 GHz, 5.0 GHz, 2.3 GHz, 1.4-1.7 GHz.

Prime Focus: 611 MHz, 325 MHz.

Surface Accuracy: See Section 03.3.1 below.

Reflector Surface: The reflector surface shall be a surface of revolution which approximates a parabola but which is shaped to increase gain. The maximum deviation of any point on the shaped surface will not exceed 30 mm (1.2 inch) from the basic parabola; coordinates will be furnished later by AUI. Panels shall be individually adjustable, doubly curved, solid surface aluminum panels. The panels must withstand either a 20 lb/ft^2 uniform load or a concentrated "shoe" load of 250 lbs over designated step areas without suffering permanent deformation.

A circular area of approximately 3 m (11 ft.) in diameter in the center of the reflector will not be covered with reflector panels.

Panel gap: Spacing between panels shall be 2 mm (0.080 inches) ±0.75 mm (0.030 inches).

Axis Alignment: Azimuth axis tilt to plane perpendicular to gravity: maximum error of 15 arcseconds.

Total azimuth axis runout: 10 arcseconds maximum error.

Azimuth axis nonrepeatability: 4 arcseconds maximum.

Orthogonality elevation to azimuth: 15 arcseconds maximum error.

Offset of elevation axis from azimuth axis to a maximum tolerance of 0.25 cm (0.1 inches).

Orthogonality of collimation axis to elevation axis: 15 arcseconds maximum error.

Subreflector axis to collimation axis: the structure of the apex of the feed legs must locate the center of the opening coincident within 0.25 cm (0.1 inches) and the axis of the opening parallel within 30 arcseconds of the collimation axis of the reflector.

Counterbalancing: Shall be sufficient, at 0 deg elevation, to overbalance the antenna in the direction of the zenith by a minimum of 15,000 lb. ft. of net torque, with all instrumentation and the subreflector in place, but no wind, snow or ice loading.

Drive Requirement: Azimuth and elevation drives shall have a capability of driving the antenna at a velocity of 90 deg/minute in azimuth and 30 deg/minute in elevation, with the reflector in any attitude under the specified operating conditions. Azimuth and elevation drives shall drive the antenna at sidereal tracking rates with an accuracy as specified in paragraph 03.2.2.3. and 03.2.2.4. below.

Under the conditions described as Precision (Primary) and Normal (Secondary) operating conditions below, acceleration to full speed shall be accomplished in less than 2 seconds.

03.2.2.2 General Operating Parameters and Conditions

The antenna will be exposed to the elements at various sites and under various climatic conditions, with one site perhaps as high as 14,000 ft above mean sea level, and the remaining sites no higher than 7,000 ft above mean sea level. The antennas are to be designed for a life expectancy of 20 years. No damage to the operating components of the antennas must occur due to airborne sand or dust or accumulation of frozen or liquid water.

03.2.2.3 Precision (Primary) Operating Conditions

The antenna shall meet the required precision pointing and surface accuracies under the following conditions:

Temperature range: -18 deg C (0 deg F) to +32 deg C (90 deg F)

Rate of change of ambient air temperature is no greater than 2 deg C/hour.

No parts of the telescope structure differ in temperature more than 3.5 deg C (6.3 deg F).

The wind at 12 m above the foundation is no greater than 6 m/sec (13.4 mph), with gusts of ±1 m/sec (2.2 mph) super imposed. Wind from any direction with the reflector in any attitude.

No snow or ice load.

03.2.2.4 Normal (Secondary) Operating Conditions

The antennas must continue to operate under "normal" operating conditions but it is understood that the pointing, tracking and surface accuracies set forth under precision operation may not be achieved.

Normal operation must be possible under the following conditions:

Ambient air temperature: -30 deg C (-22 deg F) to +40 deg C (104 deg F).

Relative humidity: 0 to 99 %

Rain rate: up to 5 cm/hour (2 in/hour)

Ice and snow load: None

Wind velocity (measured at 12 m above the foundation) up to 18 m/sec (40 mph), with gusts of ±2.5 m/sec (5.6 mph) superimposed. Wind may be from any direction; reflector in any position. A special condition is to be provided which will allow the antenna to operate in winds to 25 m/sec (56 mph), but for which the acceleration time to full speed may be 4 seconds and maximum speed may be allowed to fall to 60 deg/min in azimuth for the worst case of wind direction and antenna attitude.

Requirements to be met in moving to stow and in the stowed position:

Slew to stow: The antenna shall be capable of being slewed to the stow position in elevation in winds of 27 m/sec (60 mph) with all exposed surfaces of the structure coated with 1 cm (0.4 inch) radial thickness of ice. The slew rate may then fall to 10 deg/minute.

Slew to dump snow: The antenna shall be capable of dumping snow by slewing at 30 deg/min to any position 5 deg above the horizon, with a wind of 11 m/sec (25 mph) from any direction and with an original snow load in the reflector of 4 lb/ft^2. No damage or overload shall occur to either structure, drives or brakes.

Survival: The antenna is to be designed to survive in the zenith position in winds of 50 m/sec (110 mph) with 1 cm (0.4 inch) of radial ice on all exposed surfaces. The antenna shall also be designed to survive in the zenith position with a surface load of 20 lb/ft^2 of snow. When loaded under these conditions, design stresses of materials shall not be exceeded and no permanent deformation shall occur. For survival wind loads (110 mph), combined with one cm of radial ice on all exposed surfaces, NRAO will allow the design stress increase set forth in the AISC specifications to be applied. Stow brakes shall be provided capable of holding the antenna in the zenith position when subjected to the design survival loading.

03.3 The Antenna Performance

03.3.1 Surface accuracy

With the installation of the selected 0.125 mm (0.005 inch) RMS panels, the installed RSS surface accuracy shall not exceed the total RSS surface accuracy as specified in the error budget below under the precision operating conditions specified in 03.2.2.3. It is further required that, under precision operating conditions, the distortions of the antenna structure caused by wind, gravity and temperature effects be consistent with with satisfactory antenna performance at 86 GHz as set forth in Sections 03.2.1, 03.2.2 and 03.5.2.2. (Part C of the following surface accuracy error budget will ensure compliance with this requirement.)

Surface Errors, Precision Operating Conditions.
(All table entries are RMS values.)

A. Surface Panels:			
	Manufacturing	0.125 mm	(0.005 inch)
	Gravity	0.075 mm	(0.003 inch)
	Temperature	0.050 mm	(0.002 inch)
	Wind	0.040 mm	(0.0016 inch)
	Subtotal RSS	0.160 mm	(0.0063 inch)
B. Measuring and Setting: 1)			
	Subtotal RSS	0.125 mm	(0.005 inch)
C. Reflector Structure:			
	Gravity 2)	0.140 mm	(0.0055 inch)
	Temperature 3)	0.125 mm	(0.005 inch)
	Wind	0.055 mm	(0.0022 inch)
	Subtotal RSS	0.196 mm	(0.0077 inch)
	Total Surface RSS	0.282 mm	(0.0111 inch)

Notes:

1) The setting and measurement errors of the assembled surface shall contribute no more to the error budget of the reflector than the panel manufacturing error (0.125 mm (0.005 inch)).

2) At any elevation angle over the range 0 to 90 deg with the surface set at 50 deg elevation.

3) For temperature differences of 3.5 deg C within the reflector structure.

The panel-setting RSS of the antenna surface may be calculated relative to a reference design surface that may be allowed to translate along the collimation axis and rotate about an axis parallel to the elevation axis as elevation angle changes. However, at no elevation angle shall such surface deviate from its "set" position at the surface setting elevation angle of 50 deg by more than 1.5 mm (0.06 in.) peak.

The term RSS where used in this document shall mean the "Root Sum Square" of the various error contributions from different types of contributor sources of error. Where the term RMS is used with respect to the manufacturing accuracy of the surface panels it shall mean the "Root Mean Square" of the departures from the design surface. The RMS value of measurements depends to some extent on the formulae used and shall be as defined in the proposal. In measuring the manufacturing accuracy of each panel a grid of points shall be chosen such that each measured point represents approximately 650 cm^2 (100 $inch^2$) of surface area.

03.3.2 <u>Pointing and Tracking Errors</u>

The pointing error is defined as the difference between the commanded position of the antenna and the position of the main beam of the reflector. Tracking error is a part of the pointing error and includes the effects of the servo update rate and axis velocity as determined by axis position. The repeatable pointing error is due to gravity deformation, axis alignment error, inductosyn offset, bearing runout, bearing alignment, and similar errors. The nonrepeatable pointing error is due to wind forces and gusts, acceleration forces, effects of temperature differences and temperature changes, inductosyn resolution, inductosyn error, data converter errors, servo and drive errors, position update rate, bearing nonrepeatability and random errors. The repeatable pointing error for this antenna shall not exceed 3 arcminutes. Of this pointing error budget the gravity deformation of the main reflector and feed legs shall not contribute more than 1 arcminute. In addition the translation of the vertex of the secondary reflector from the best fit collimation axis shall not exceed 2.5 mm (0.1 inch) nor shall the rotation of the apex exceed 4 arcminutes in the plane of the elevation motion, or 1 arcminute rotation about the collimation axis.

The non-repeatable pointing errors are of two types with different statistical behavior: (1) Random pointing errors with a time constant less than one minute and (2) random pointing errors with time constants longer than about one minute and up to several hours.

The first type, which averages out in observations lasting several minutes or more, shall not exceed 8 arcseconds RSS with the antenna in any position and operating at specified tracking rates. In some cases, such as pointing errors caused by wind on the reflector alidade and tower, only the peak error or "worst case" can be identified. In such cases, one half of the "worst case" error values should be used in the RSS error calculations.

The second type, which usually is caused by thermal effects, shall not exceed a peak of 14 arcseconds. Passive measures, such as antenna paint, sun shields and/or thermal insulation, aimed at reducing the temperature effects on the antenna structure, should be investigated during the design. The antenna design shall assure that temperature differentials which place the antenna outside the precision operating condition do not occur more than 5% of the time.

03.3.3 Slewing motion

Slewing motion is defined as the rapid movement of the antenna about either axis simultaneously or independently. The antenna shall be capable of driving at the rate of 30 deg/min of time about the elevation axis and 90 deg/min about the azimuth axis in winds to 18 m/sec (40 mph) with the reflector in any attitude. It shall be possible to slew either axis independently while the other axis is stationary or moving at the tracking rate, or to slew both axes simultaneously. The antenna shall be capable of accelerations of 0.25 deg/sec^2 about the elevation axis and 0.75 deg/sec^2 about the azimuth axis except for the special conditions set forth in 03.2.2.4. above.

03.3.4 Tracking motion

The antenna shall be capable of tracking a stellar source at the azimuth and elevation rates which correspond to the sidereal rate for the source position and maintaining the pointing accuracy as set forth in 03.2.2 above under precision operating conditions with a command update rate of 20 times/sec. The cone of avoidance near the zenith when in the tracking mode shall have a half-angle less than 2.5 deg.

03.4 General Requirements

03.4.1 Feed legs and apex

The feed leg supports shall be designed to support simultaneously an asymmetric subreflector of 3.2 m (10.5 ft) diameter and adjusting mechanism, weighing approximately 1300 lbs, and a prime focus feed of approximately 300 lbs. The feed legs shall also be designed to support a cable weight of 4 lb/ft on each leg. The apex structure shall be designed so that a clearance as shown on Drawing D52502T001 Sheet 1 exists between the bottom of the apex structure and the focal point of the main reflector. Its configuration shall be such that a clear opening of approximately 1.8 m (6 ft) diameter exists on the center line of symmetry for the location and attachment of the adjustment mechanism. The feed legs and apex, including a 3.2 m (10.5 ft) asymmetric subreflector, shall not cause RF blockage in excess of 6.5 % of the total 25 meter aperture area.

03.4.2 Vertex Equipment Room and Feed Mounts

An approximately circular room with a minimum of 18.6 m^2 (200 ft^2) area, having a height of 2.3 m (7.5 ft) for mounting of feeds and equipment, shall be provided. The floor of this room shall be parallel to the ground with the antenna pointed at zenith and shall be a minimum of 8 ft below the vertex of the antenna. This room shall be provided with the following features:

Mounting provisions for up to seven 0.6 m x 0.6 m x 2.1 m (2 ft x 2 ft x 7 ft) ceiling mounted racks, with a total weight of 2000 lbs.

An access door for access by personnel and for means of installing racks by use of a permanent hoist.

Thermal insulation, air conditioning, and duct heating to provide 18 ±1 deg C control of temperature measured at a central point in the vertex room with all equipment racks (see this Section, above) in place, an equipment heat input of up to 2 kW, and under "normal" operating conditions as described in 03.2.2.4. This control shall be accomplished with a temperature change no greater than 3 deg C between supply and return air. A proportional control modulated heating and cooling system is recommended. No specific humidity conditions are required.

The roof of the vertex equipment room shall contain a mounting ring for the mounting of a removable feed cone. Dimensions of this ring shall be determined in the design stage, but is anticipated that it will be approximately 3 m (10 ft) in diameter.

The weight of removable feed cone and the feed horns supported therein is estimated at 4400 pounds, with the center of gravity located approximately 33 inches above the interface of the feed cone with the projection of the vertex room.

The vertex room shall be electrically shielded in order to prevent the leakage of radio frequency interference out of the room. The room will be constructed to have an outside metal wall that is electrically continuous. All incoming power lines will be filtered and RFI gaskets will be provided around the vertex room door and around the interface between the vertex room and the feed cone. Manufacturer's data for any filters and gasket materials used must demonstrate at least 60 dB suppression or shielding over the frequency range 1 MHz to 44 GHz.

03.5 Statement of the Design Work

The objective of the design work shall be a design of an antenna which will meet the Design and Performance Parameters as set forth above. The design shall be for a wheel and track type antenna which will be used as primarily a Cassegrain antenna but which at lower frequencies will be used at prime focus. The antenna structure will be a fully steerable elevation over azimuth configuration supporting a 25 meter (approximately 82 feet) diameter reflector. It is anticipated that the main structure will be of steel with surface panels of aluminum.

The areas of design for which the antenna subcontractor will be responsible include the following:

Antenna Structure

Reflector Assembly

Primary reflector surface

Reflector back-up structure

Feed leg structure

Apex structure

Vertex equipment cabin

Elevation wheel

Reflector counterweight system

Azimuth Structure

Tower structure

Elevation bearing & supports

Elevation drive system (including motors, gears, operating and stow brakes, gear reducers and servo system)

Elevation and azimuth data system

Azimuth drive system (including motors, gears, operating and stow brakes and gear reducers and servo system)

Azimuth Base Structure (including alignment features)

Azimuth rail and attachment

Equipment room at base of tower

Pintle bearing and support

Cable loop system

Foundation (Reinforced Concrete - Typical type)

Interfaces

Foundation interface

Power cable interface

Secondary reflector mechanism interface

Servo/AUI control and data system interface

Maintenance and Repair Features

Procurement, Assembly and Alignment Plans

03.5.1 Design Analysis

A three-dimensional analysis of the reflector, back-up structure, pedestal and tower shall be conducted under varying conditions of pointing directions, wind force, and thermal gradients. A computer analysis shall be conducted using standard accepted programs to determine structural deflections, coordinates of the best fit paraboloid and the RMS deviation of the surface from this paraboloid. The computer analysis shall also determine the repeatable and non-repeatable pointing errors contributed by the various elements of the antenna for use in assuring that the error budget has been met. Results of these analyses shall be submitted to AUI along with the design drawings of the antenna structure as they are submitted for approval. Analysis of the dynamics of the antenna shall be conducted to determine the significant frequencies and the transfer functions applicable to the drive system and wind disturbance characteristics of the servo system. The total error analysis shall be made considering all factors which degrade the surface accuracy and the pointing and tracking capabilities of the antenna system. This analysis shall include: consideration of the error contributions of the antenna structure as developed in the structural analysis (under wind, thermal and gravity loads); the pointing and tracking error of the servo and drive system under required rates and wind conditions; antenna structural and mechanical alignment; the position indicating and data readout system errors and other system components contributing to pointing errors.

03.5.2 Design Requirements

The antenna shall perform as required in Section 03.3. under any combination of operational and environmental conditions as specified herein.

03.5.2.1 Mechanical Motion

Elevation 0 deg to +125 deg
Azimuth ± 270 deg

03.5.2.2 Operational Wavelength

In the NRAO design calculations for this antenna it will be noted that the gravity performance of the reflector backup structure, the stiffness of the tower, the resolution and accuracy of the position indicating system and the accuracy of the servo system are consistent with requirements for observing at 0.35 cm wavelength (86 GHz). It is AUI's goal to be able to achieve efficient 86 GHz operation at some later date by performing such improvements as installing more accurate panels, improved panel setting and azimuth track adjustment.

The subcontractor's final design shall maintain this objective.

03.6 Structural and Mechanical Features

03.6.1 Reflector Assembly

Surface - The reflecting surface shall be a surface of revolution comprised of approximately 200 individually adjustable, doubly curved, solid surface aluminum panels. The reflecting surface of the antenna shall be a shaped surface which approximates a paraboloid, but deviates to a minor extent in order to secure a higher gain. The exact shape of this surface will be specified to the Subcontractor during the design phase, but it is anticipated that the peak deviation from a parabola will not exceed 3 cm (1.2 inch). The spacing between panels shall be nominally 2.0 mm (0.08 inch) with a tolerance of ±0.75 mm (±0.03 inch). Flush panel surfaces are preferred. Projecting rivets, are acceptable provided the sum of the areas of all rivet heads on each panel surface is less than one-half of one percent of the panel surface area. An error budget shall be prepared during the design stage showing distribution and projected levels of each error contribution.

Panels shall be designed to withstand either a 20 lb/ft^2 uniform load or a concentrated load of 250 lb over a 6 inch square area located at specified step areas without exceeding the allowable design stresses for the material.

<u>Reflector Back-up Structure</u> - The reflector back-up structure shall provide the rigidity required to achieve the specified reflector tolerance and shall be designed so as to achieve the highest practical stiffness to weight ratio.

The reflector back-up structure shall be designed to support at the vertex of the reflector a removable feed cone assembly of approximately 3 m (10 ft) diameter (furnished by AUI, shown on Dwg. D52502T001 Sheet 1) and a fixed equipment room (Paragraph 03.4.2). It shall attach rigidly to the reflector support structure and shall support the feed cone assembly. Access shall be provided from inside the vertex room up into the feed cone assembly. Access shall be provided from the back of the reflector to the equipment room.

<u>Panel Supports</u> - Each surface panel shall be supported on four points by means which allow adjustment to the required surface accuracy. The panel supports shall be designed to allow a 250 lb man to walk on the panel without causing permanent deformation.

<u>Feed Systems Design</u> - The antenna feed system and Cassegrain reflector are not a part of this specification. The parameters and interface information for the antenna feed and Cassegrain subreflector will be specified to the successful antenna Subcontractor during the design phase.

03.6.2 <u>Azimuth Structure</u>

<u>Structure</u> - The azimuth structure shall be designed to provide the stiffness and strength required to meet the operating

and survival requirements and to provide the range of motion specified. Components of the azimuth structure shall be designed to facilitate field assembly to the required tolerances. Field assembly shall be by use of high strength bolting (the preferred method) or by welding. Flanged connections for tubular members shall be gasketed to provide a water-tight seal. Flanges shall have a center hole at least four (4) inches in diameter to provide for fluid flow. Adjustment provisions shall be provided for alignment of bearings, gear racks, gear reducers, azimuth drives and azimuth wheel assemblies. The antennas shall be so designed and assembled that the azimuth and elevation axis are orthogonal within the tolerances specified in Section 03.2.2.1. The axis of symmetry of the reflecting surface shall intersect the elevation axis within a tolerance of 0.25 cm (0.1 inch) and shall be orthogonal to the elevation axis within the tolerance specified in Section 03.2.2.1. The azimuth structure shall be a space frame with an equipment room located near the base. The base shall be rectangular in shape and shall interface with the azimuth rail and foundation at 4 points (the corners of the base rectangle). These 4 points consist of the wheel assembly, 2 of which shall be driven. An additional foundation interface shall exist at the center of the azimuth where the antenna is supported on the pintle bearing.

A joint use equipment room shall be located on the base of the azimuth structure, shall provide approximately 16.7 m^2 (180 ft^2) of area with a height of 2.4 m (8 ft), and shall be temperature controlled at 18.3 deg C $\pm$5 deg C (65 deg F $\pm$9 deg F) with a 5 kW interior heat input. A door and access provisions shall be included. This room shall provide adequate space for drive controls and cabinets, electrical circuit breaker cabinet, and a cabinet or rack for the antenna control unit and data converter.

<u>Drive Equipment</u> - Electrical drives using DC servo motors are the preferred drive system for each axis. The drive systems shall be supplied in pairs and torque biasing shall be provided so that paired gear trains oppose each other during operational function so as to minimize backlash. Motors selected shall have a base speed not to exceed 2500 rpm. The drive motors shall be able to withstand the following current load conditions:

100 % rated	continuous
150 % rated	2 minutes out of every 20 minutes
200 % rated	instantaneous, 0.5 seconds, repeated once every minute

Consideration shall be given to the use of identical drive motors on both elevation and azimuth axes. The NRAO analyses indicate that dual 15 hp DC drive motors are required for the azimuth axis and that while these are somewhat oversized for the elevation axis, commonality will simplify spare parts stocking.

The reducer ratio from motor to antenna axis shall be sized to deliver the torque required and to meet the speed requirement.

The aximuth drive configuration shall be such that the motor-reducer assembly does not carry antenna weight and may be decoupled and removed without removing the associated wheel from the alidade.

The NRAO analysis indicates that a common gear reducer can be used on both elevation and azimuth axes. The NRAO analysis used Philadelphia Gear Co. 10 HP 4 reducers similar to existing gear boxes on the VLA antenna elevation axis but with the reduction ratio changed from 541 to 1 to 400 to 1.

Brakes - Brakes that actuate with the power off shall be provided on each axis. Brakes on each axis shall have the capacity of three times rated motor torque. Brakes must have the capacity to hold the antenna in any position in winds to 27 m/s (60 mph) and to hold the antenna in the stow position in winds to 50 m/s (110 mph). Brakes may be provided in either of two configurations:

1. Operating brakes mounted on the motors and braking through the gear train plus stow brakes which act on the main section gear; or

2. Brakes which serve both as operating and stow brakes which operate through the gear train.

Remotely controlled stow locking devices, such as stow pins, shall not be used as an operating feature.

A manually operated stow pin shall be provided for the elevation axis for use in maintenance, and stow clamping devices shall be provided to lock the alidade in position when required.

Bearing and Gears - All main axis bearings and power train gearing shall be conservatively designed with a minimum 20 year expected life period. Running friction and breakaway friction for the drive system shall be held to levels which satisfy the non-repeatable pointing error budget.

Cable Wraps - Access shall be provided at the azimuth axis in the form of a cable wrap which will accommodate a minimum of 20 cables of 3.8 cm (1.5 inch) in diameter with connectors of 7.5 cm (3 inch) outside diameter. Arrangement shall be such that cables are neither stressed by twisting or damaged by pulling over edges of fixed structure. Cables may pass the elevation axis by means of a cable loop.

Lubrication - Provision shall be made in the design for proper lubrication of all components. Gear boxes, gear trains, couplings, bearings, motors and similar equipment provided by the Subcontractor shall have easily accessible lubrication fittings, drain fittings and be provided with vents where advisable. The design Subcontractor shall prepare a list of recommended lubricants and lubrication schedule. Lubricants shall be adequate to meet the performance and environmental requirements specified herein. The use of different types of lubricants shall be held to a minimum. Equipment shall not require lubrication more frequently than once every six months.

Lighting and Grounding - Adequate outside lighting shall be provided and installed on the structure for operation, safety and maintenance. All lighting shall be incandescent type.

The antenna requires safety and equipment grounds. A station ground will be provided by NRAO for the antenna structure. The Subcontractor shall ground the antenna structure, and its equipment, in accordance with National Electrical Code Specifications to this station ground. All elevation and azimuth bearings shall have a by-pass grounding connection as shall the wheel bearings at the azimuth wheel assemblies.

03.6.3 Additional Requirements

All operating components of the antennas, such as motors, bearings, drive units, brakes, gear boxes, switches, breakers, etc., shall to the extent possible be of standard design, and of proven operating life.

Access stairways, ladders, walkways and platforms shall be provided to afford access for service and maintenance to bearings, motors and drives, all equipment and equipment rooms. The access features shall be designed according to best antenna practice, shall meet the requirements of the Occupational Safety and Health Act and shall have sufficient strength to support at least a concentrated load of 400 lbs at any point. No ladders shall be used for access to the vertex equipment room.

An electric hoist of 1/2-ton capacity shall be provided to permit lifting of equipment to the platform adjacent to the access door of the vertex room when the antenna is in zenith position.

Safety devices shall be provided for protection of the antenna in the event of servo or mechanical failure. An auxiliary control shall be provided for 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 from a control such as a potentiometer located at the antenna. This auxiliary control shall also provide control of the brake mechanism.

Limit switches shall be provided for each axis of the antenna. Limit switches, cables, connectors used on telescope drives, brakes, motors, gear boxes, interlocks, etc., are to be weather-tight.

All machinery shall be covered or protected in such a way that working personnel are not subject to hazards.

Smoke detectors are required in both the base room and vertex room and shall be interlocked to remove all electrical power from the antenna. Either smoke detector shall energize a local alarm and have a contact or solid state switching for use by AUI. Emergency power for the smoke detectors and local alarm shall utilize "Gel-cells" with a reserve of 6 hours minimum.

Lightning rods shall be provided at the apex and the top edge of the main reflector.

Cable trays, for use by the Subcontractor and AUI shall be provided in the base room, from the base room to the vertex room and elevation cable loop, and to the apex.

03.7 Foundations

The Subcontractor shall provide the design of a typical foundation based upon subsurface information furnished by AUI during the design stage. Final design and detailing of all foundations and construction of these foundations will not be the responsibility of the Antenna Subcontractor but the Subcontractor must assure that the design of the typical foundation provides the stiffness and the pointing accuracy required by the error budget for the antenna. The Antenna Subcontractor shall be responsible for designing and specifying all azimuth rail attachment hardware, rail adjustment features and rail connection details and shall furnish all azimuth rail hardware except anchor bolts imbedded in the foundation concrete. The Antenna Subcontractor shall be responsible for installing the azimuth rail and hardware and adjusting the rail surface to the accuracy required by the error budget.

03.8 Servo and Controls

03.8.1 Servo System

The servo system shall provide the necessary control for drives as well as monitor the angular position of the antenna in both azimuth and elevation. The major subsystems of the servo system are (1) the drive units, (2) the control units, and (3) the position indicator system. The Antenna Subcontractor will be responsible for the design, furnishing, fabricating and installation of these systems. The servo control units interface with the drive units of the drive motors, brakes, clutches, limit switches and of the electrical circuit breaker cabinet. Cabling from these facilities to the servo control units shall be supplied and installed by the Antenna Subcontractor. The interface connection between the servo control units and the position indicator system shall be furnished by the Antenna Subcontractor.

03.8.1.1 Areas of Design

The areas of design for which the Subcontractor will be responsible include the following:

Azimuth and Elevation Drive System
- Power Amplifiers
- Current Loop
- Velocity Loop
- Position Loop
- Interlocks
- Monitoring

Azimuth and Elevation Control System
- Mode Switching
- Monitoring
- Servo Loops
- Auto Stowing
- Local Control
- Local Readouts
- Interface with the AUI Monitor and Control System

03.8.1.2 Total Tracking Error

The total tracking error (including the effects of friction, noise, dynamic lag at peak rates, wind gusts) shall be consistent with the following telescope performance while maintaining the stability specified above during performance in the precision operating condition:

Non-repeatable pointing error shall not exceed 8 arcseconds RSS as defined in section 03.3.2. The above accuracies shall be maintained at the azimuth and elevation velocities and accelerations required when tracking a source at the sidereal rate at any position of the source outside of the cone of avoidance. An acceleration rate shall be provided under this tracking mode which allows the antenna to reach the required velocity in less than one second of time. Angular errors refer to space angle errors.

03.8.2 <u>Wiring and Cables</u>

The subcontractor shall design, furnish and install all cables required for interconnection and interface with the equipment furnished under this contract including:

Drive Motors
Tachometers
Position System Data Converter
Synchros
Limit Switches
Stow Pin Switches
Other as required

Prime power connection between the motor amplifiers and the circuit breaker shall be wire and conduit.

03.8.3 <u>Servo Control System</u>

The Control System shall have the following modes of operation: (1) a non-operating mode in which the antenna brakes are applied and power is removed from the drive system, and (2) operating modes which shall cover all occasions in which brakes are released and power is applied to the drive and control system.

03.8.3.1 <u>Non-Operating Modes</u>

<u>Pre-standby Mode</u>
This mode shall be entered at all times when conditions exist such that all motors are inoperable and all brakes are engaged due to a fault within the system or an "emergency stop" engaged.

<u>Standby Mode</u>
This mode shall be entered when all faults and emergency stops allow the system to be ready for operation by either the local operator or the array operator (computer mode).

Local Mode/Computer Mode

This mode shall be determined by an alternate action switch located on the front panel of the Antenna Control Unit (ACU). A contact closure indicating local mode shall be available on an external connector for use by others.

03.8.3.2 Operating Modes

Manual Mode

This mode shall be entered only when the Local/Computer switch is in "Local". It shall allow operation of both axes simultaneously or independently, and the rate of each axis shall be variable from zero to maximum. In this mode it shall be possible to operate either axis on one motor.

Computer Mode

This mode shall be entered only when the Local/Computer switch is in "Computer". It shall be possible to operate either axis with the other axis in "Standby". Commanded axis position received shall be subtracted from the actual position of the encoders to provide slewing or tracking rates or position of the antenna axis. This mode shall allow operation of either axis with one motor if the wind is less than 30 mph or auto stow is engaged.

Auto Stow Mode

The elevation axis shall automatically be driven to the stow position of 88 deg to 92 deg (adjustable) if any of the following conditions exist:

Loss of updated commands for greater than 10 minutes.
Winds in excess of 55 MPH.
Ambient temperature less than -20 deg F.
Both azimuth drives are inoperable.
One axis drive is inoperable and wind is greater than 30 mph.
If commanded by the computer.
Encoder power supply interlock fault.

This mode shall cause the azimuth axis to revert to "Standby" and the elevation axis shall revert to "Standby" within 10 seconds after reaching the stow position.

03.8.3.3 Emergency Stop

An emergency off condition shall completely remove power from the antenna drive control, allow the brakes to set and be initiated by controls on the antenna structure or by command by the control console.

The subcontractor shall supply, wire and install emergency switches that can be padlocked in the emergency stop position. Emergency Stop condition shall completely remove power from the antenna drive control, allow the brakes to set and be initiated by switches on the antenna structure. These switches are to be located:

Vertex Room
Pedestal Room
Azimuth Rotating Stairway
Elevation Drive Platform
Each Azimuth Drive Motor

03.8.3.4 Position Loop

The position loop for each axis shall utilize System Type 2 loop only if the axis position error is less than 1 arcminute and both drives are operational. Other methods of inhibiting limit cycles may be suggested.

03.8.4 Control System Monitor

03.8.4.1 Local Monitor

The Antenna Control Unit shall monitor the following as a minimum:

Binary encoder position (LEDs)*
Binary commanded position (LEDs)*
Motor status (each) (LED)
Field status (each) (LED)
Motor over Temperature (each) (LED)
Emergency Stop (LED)
Stow Pins (LED)
Limit Switch Status (each) (LED)
Computer Mode Status (LED)
Each Motor Current (Analog)
Axis synchro position readouts
Each Tachometer (Pin Jacks)
Velocity commands, analog (Pin Jacks)
Position error, analog (Pin Jacks)
Circuit Breakers (each) (LED)

* LSB = 0.62 arcseconds and 22 bits includes the synthetic 360 deg (azimuth) bit.

03.8.4.2 Computer Monitor

The Antenna Control Unit shall transmit the following data in digital form as shown.

Actual Azimuth Position (22 bits)*
Commanded Azimuth Position (22 bits)
Actual Elevation Position (21 bits)*
Commanded Elevation Position (21 bits)
Motor Fault Status (each)
Emergency Stop
Limit Switch Status (each)
Computer Mode Status
Each Motor Current (Analog lines)
Velocity Command for each axis (Analog lines)
Auto Stow Status (Each type)
Stow Pin Status
Circuit Breaker Status (each)
All Control and Signal Power Supply Voltages (Analog lines)
Other error and fault status required and Spares

* See note above. 360 deg bit to be generated from the Azimuth 2:1 synchro output appropriately combined with the azimuth encoder output.

03.8.5 Computer Command System

The Antenna Control Unit must be capable of receiving the commands necessary to execute the proper modes and axis position commands necessary to track at the required tracking and slew rates. A typical list of commands is as follows:

Azimuth and Elevation mode (Computer, Standby, Stow, etc.)
Azimuth Commanded Position (22 bits)
Elevation Commanded Position (21 bits)
Motor Disable (each)
Spare Mode Commands (8 bits)

Other Commands

TTL logic level signals will be supplied by AUI to command:

Wind Auto Stow
Low Temperature Auto Stow
> 30 mph Wind (Single motor operation)
3 Spares

These logic signals shall be connected through opto-isolators in the Antenna Control Unit or by other approved isolation methods. Signal sense should be zero current to indicate that the condition is true.

03.8.6 Computer Command and Monitor Interface

A monitor and control interface card will be supplied by AUI and installed by the Subcontractor. This card supplies to the servo system a 16 bit bidirectional digital bus and 8 lines of analog monitoring capability. The card will be approximately 6 1/2 x 4 inch and will require connection to the servo system 5 V and ± 15 V power, and a four wire connection to a connector on the rear of the Antenna Control Unit (ACU).

Since the position commands, echo position commands, and actual positions are longer than 16 bits, they must be transmitted by two bus cycles. In order to ensure the compatibility of the high order and low order positions of the commands, AUI can provide an odd/even indication in each half of the command and comparision of the commanded and actual positions for axis position will be compared only when the bits are identical. Other schemes suggested by the subcontractor may be acceptable if approved by AUI. The exact format and electrical specifications of these signals must be approved by AUI before manufacture. Timing and connector specifications of the AUI supplied board will be provided to the Subcontractor upon request. Azimuth and Elevation commands will normally be provided at a 20 Hz rate. The system must include circuitry to detect missing commands and stow the antenna if no commands are received for longer than 10 minutes.

03.8.7 Limit Switch Interface

Limit switches shall have redundancy provided for each antenna limit and shall be arranged such that there are no common components, electrical or mechanical. A failure in the first limit system shall not render the second limit inoperative.

The servo system shall utilize the limit switch signals as follows:

03.8.7.1 Each Axis 1st Limit

Inhibit the velocity loop from driving further into the limit but allow opposite direction when the appropriate override is allowed in "Manual", "Computer" or "Auto Stow" mode. The override is to be automatic when in "Computer" or "Auto

Stow" mode, and the override shall be automatically cancelled when the axis is out of 1st limit. A velocity signal to drive further into the limit should cause brake release inhibit.

03.8.7.2 Each Axis 2nd Limit

Inhibit the current loop from driving further into the limit but allow opposite direction when a local override is utilized in "Manual Mode" only. This override is not to be readily accessible. The 2nd limit switch for each direction of each axis shall be wired in series with one of the axis brakes.

03.8.8 Prime Power - Servo

The drive system prime power shall be 120/208 V ± 10 %, 3 phase, 4 wire, 60 Hz connected to a 3 phase circuit breaker located in the pedestal room.

The Antenna Control Unit shall be connected to 120 V, 1 phase 60 Hz 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 V DC signal.

03.8.9 D.C. Power Supplies

All ACU and encoder power supplies shall be interlocked to cause the "Computer" mode to revert to Standby in the event of an ACU power supply failure or to go to "Auto Stow" mode in the event of an encoder power supply failure.

03.8.10 RFI & EMI

The control circuits, D.C. drive motors amplifiers, and switching devices shall be designed and contructed 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. All relay contacts and actuators should be properly bypassed, shielded and/or filtered. All amplifiers and oscillators should be mounted in shielded enclosures that will provide effective shielding of radio frequency energy. Silicon-controlled rectifier switching devices shall not be used unless they are designed so as not to cause radio frequency interference in the frequency range 1 MHz to 86 GHz in receivers mounted on the antenna. 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. The motor leads may be shielded instead of filtered, provided the shielding provides suppresssion at least equal to that achieved with the filters. The frequency range of interest extends from 10 MHz to 44 GHz. No verification measurements by the contractor will be required. All wires and cables within the vertex room shall have RFI suppression.

03.8.11 Azimuth and Elevation Position Angles

The azimuth and elevation postion angles shall be measured by position indicating devices directly coupled to the axes and shall use coarse and fine resolvers converted to azimuth (including an overlap bit) and elevation binary words by appropriate electronic equipment located in the pedestal equipment room. The position encoding system shall be a system making the measurement directly in binary form. The system provided shall provide 21 bits using an inductosyn for the fine transducer. The RMS error of the position indicating system, including couplings and electronics, shall not exceed 2 arcseconds.

Position indicating devices shall be accessible for servicing, shall be easily installed, shall be capable of later realignment, shall have provisions for mechanical indexing and shall be environmentally protected.

A separate synchro transmitter with accuracy of 0.5 deg shall be installed on each axis separate from the position angle transducers. These synchros will be used by the subcontractor for a local readout and the "auto-stow" feature. The elevation axis to synchro ratio shall be 1:1 and the azimuth axis synchro ratio shall be 2:1.

03.8.12 Electrical

03.8.12.1 Junction Boxes

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

03.8.12.2 Power

The Subcontractor shall supply a 50 kVA electric service entrance inside the pedestal equipment room for connection to the outside power source. The Subcontractor shall be responsible for all his antenna electrical wiring from this point. In addition he shall furnish for the later use of AUI, one 100 A 120/208 V, 3 phase, 4 wire disconnect switch or breaker.

The antenna Subcontractor shall supply a two bus system from a junction box (supplied by AUI) in the pintle bearing pit to two circuit breaker panels located in the lower equipment room (base room). One bus is the "critical bus" for servo, encoding system, cryogenic compressors, and a sub-panel in the vertex room. The other bus is the "non-critical bus" for lighting, air conditioning, a sub-panel in the vertex room, electronics and miscellaneous. Size and type of circuit breakers are to be determined later. Fuses shall not be used for equipment protection unless specifically authorized by AUI. Both buses shall have single phase and reverse phase protection interlocked with the smoke detectors specified in 03.6.3.

03.9 Materials and Fabrication

03.9.1 General

Material shall be in agreement with the general requirements as set down in these specifications. It shall be the responsibility of the Subcontractor to prepare specific material specifications for the various components of the antennas. 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 practice and shall be fabricated to proper size and tolerance as shown on the approved drawings. The approval cycle shall normally be 30 days.

03.9.2 Materials

The rail base structure, azimuth pedestal and reflector back-up structure 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 antenna structure shall be such that the low temperature embrittlement characteristics shall be acceptable to AUI. The nil-ductility transition temperature of the selected material shall not exceed -50 deg F. 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 propogation. A guide to meeting this requirement would be that the Charpy V-notch value of the metal chosen should be a minimum of 15 foot-pounds at a temperature of -37.2 deg C (-35 deg F).

All components which are designed for welded connections shall be of a weldable grade material. Bull gears and pinions shall be of a material having a minimum hardness of 255 BHN and may be surface hardened.

03.9.3 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 approval is obtained from AUI. Shop connections may be by either welding or bolting (as stated on 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 may be obtained.

03.9.4 Protective Coatings and Finishes

The reflector surface of the antenna shall receive a protective coating which will provide diffuse reflection of the solar rays. During the design (Phase I) effort, the Subcontractor may attempt to satisfy the above diffuse reflection requirement through an adaptation of their dry powder coating process. The Subcontractor shall demonstrate to NRAO's satisfaction that any such adaptation is as effective as the process set forth in National Radio Astronomy Observatory Process Specification, entitled "Application of Diffuse Reflecting Coating for Solid Faced Antenna Reflectors", attached hereto as Appendix D. Otherwise, the methods of Appendix D shall be employed.

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 the exception of the reflecting surface, shall be painted with a white solar reflecting paint. Material, preparation, application and quality control testing shall be as set forth in National Radio Astronomy Observatory Process Specification, entitled "Exterior Protective Coating for all Exposed Metallic Surfaces other than Reflector Surfaces", attached hereto as Appendix E.

Appendix E, Section IIA, Surface Preparation, is hereby modified to include sand blasting as an approved method of surface preparation. Sand blasting shall be to the condition of "Commercial Near-White" of the specifications of the Steel Structure Painting Council.

Appendix E, Section IIB, Primer, is modified to permit the application of the specified primer by spray painting when the surface is prepared by sand blasting to the "Near-White" condition, and the primer is applied within 48 hours of the completion of sand blasting.

The antenna to be provided for the Puerto Rico location shall have a prime coat differing from that specified in "Exterior Protective Coating for all Exposed Metallic Surfaces other than Reflector Surfaces," Appendix E. This prime coat shall be a zinc-enriched primer "Plasite 1000" as manufactured by Wisconsin Protective Coating Co., or ZRC Compound as manufactured by ZRC Chemical Products Co. applied according to manufacturers' instructions.

03.10 Reserved.

03.11 Drawings, Specifications and other Data

03.11.1 Design and Manufacturing Drawings

Design and manufacturing drawings shall be completed to the point at which shop and supplier detailing is all that is required for a complete description of the antenna.

Drawings shall be produced on standard size drawing forms whose size and format have been approved by AUI, shall conform to good commercial practice, and shall use symbols, conventions and notations endorsed by manufacturing and standards associations. At the start of the design phase, the Subcontractor shall submit a copy of his drafting standards to AUI for its review and approval.

Two print copies of all design and manufacturing drawings shall be submitted to AUI for its review and approval at the time of completion of the drawings.

One reproducible and five print copies shall be furnished to AUI after approval of drawings.

One reproducible of all drawings generated by the Subcontractor or any subsidiary will be supplied as part of this contract. Lower tier vendors will furnish sufficient drawings so that their equipment can be operated and maintained by NRAO. Specifically, sufficient information will be furnished so that assembly, disassembly, repair, and alignment can be performed to the extent covered by the O & M manuals.

03.11.2 Manufacturing and Procurement Specifications

Five copies of all manufacturing and procurement specifications, referenced on any drawing or prepared for procurement of purchased items, are to be submitted for AUI approval.

03.11.3 Shop Drawings

Detail drawings of all fabricated components and assemblies and any working drawing or sketches which the Subcontractor, or its subcontractors, may require to detail or illustrate any part of the work, supplementing the information in design or manufacturing drawings and specifications shall be furnished by the Subcontractor at no additional cost to AUI.

Such detail and/or working drawings shall be consistent with the purpose and intent of the design drawings and specifications and shall be subject to the approval of AUI.

Detail drawings and sketches prepared by the Subcontractor and for all purchased manufactured components shall be submitted to AUI for approval. One reproducible and five copies of all such drawings and sketches shall be submitted to AUI not later than four weeks prior to manufacture.

03.11.4 Design Calculations and Data

Three copies of all design calculations, design data, studies or other information prepared or utilized by the Subcontractor in the performance of the work shall be delivered to AUI.

One copy of all computer programs* and calculation runs and print-outs shall be furnished AUI for review. Magnetic tapes will be provided on all structural input data.

*(where computer program is not owned by the Subcontractor input and output data will be provided along with identification of the computer program.)

One copy of all purchase orders issued for this contract shall be delivered to AUI immediately upon issuance.

03.11.5 Assembly and Alignment Plans

The Subcontractor shall, at the completion of 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 proposed, assembly area, and facilities to be used, and schedule for completion of the work.

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

(c) Estimates of manpower requirements for each phase of assembly and alignment.

03.11.6 Testing and Acceptance Plans

The Subcontractor shall prepare a test plan acceptable to AUI that will qualify the mechanical, electrical and servo system performance in accordance with this specification after assembly and alignment are completed. Four copies of the test plan shall be submitted to AUI for its approval prior to commencement of acceptance testing of any antenna. Approval of a test plan shall not preclude AUI from requiring additional testing and shall not be deemed to be a waiver of the requirement to demonstrate the performance of the antenna in accordance with any or all performance specifications. *

AUI shall provide for this testing program a digital command input to Subcontractor's equipment connection at the equipment room of the antenna.

During this testing program, the Subcontractor shall demonstrate to AUI that the performance specifications set forth in this specification have been met.

03.11.7 Quality Assurance Plan and Inspection Procedures

The Subcontractor shall prepare and submit to AUI for review and approval, prior to the start of procurement and manufacturing, four copies each of a Quality Assurance Plan and Inspection Procedures to be utilized during the course of the work.

Quality assurance tests will be performed on materials, components and assemblies as specified in the Quality Assurance Plan.

AUI will be notified of such tests and may witness such tests.

All quality assurance test results recorded by either the Subcontractor or its subcontractors shall be signed and submitted to AUI in an approved documented form.

AUI may perform such inspections or tests as it considers necessary, on any component, or assembly, during or after fabrication at the site of fabrication or assembly.

Copies of results of tests normally performed by suppliers, such as certification of steel, bearings, etc., shall be supplied to AUI, in duplicate.

03.11.8 Spare Parts

Within sixty (60) days of approval of detailed design, the Subcontractor shall submit a recommended spare parts list to be based on the number of antennas supplied. Six copies of the list shall be furnished AUI. Each item listed shall be detailed as to identity, part number, drawing reference, manufacturer, model number, etc.

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

The Subcontractor shall maintain a capability to furnish to 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 so to do without limitation or liability to the Subcontractor and/or its lower tier subcontractor(s).

03.11.9 Operation and Maintenance Manuals

The antenna Subcontractor shall deliver at start of assembly of the first antenna four (4) copies of an Operation and Maintenance Manual. This Operation and Maintenance Manual shall contain the following information:

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

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

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

SCHEDULE C

APPENDIX A	-	Reserved.
APPENDIX B	-	Reserved.
APPENDIX C	-	Reserved.

SCHEDULE C

APPENDIX D

NATIONAL RADIO ASTRONOMY OBSERVATORY

PROCESS SPECIFICATION

APPLICATION OF DIFFUSE REFLECTING COATING FOR SOLID FACED ANTENNA REFLECTORS

March 1984

SCOPE

1.0 This specification establishes the procedure for material acceptance, preparation, application, and quality control testing of diffuse reflecting organic coating systems for solid face microwave antenna reflector surfaces.

MATERIALS

2.0 Solvants used as cleaners.

2.1 Naptha, Petroleum Aliphatic T-T-N-95.

2.2 Methyl Ethyl Ketons TT-M-261.

2.3 Toluene TT-T-548 or Jan-T-171 Grade A.

AQUEOUS CLEANERS

2.4 Vel - Colgate-Palmolive Company.

2.5 Kelite L-17 - Kelite Products Company.

THINNERS

2.6 Sol Cal No. 1 - Standard Oil Company.

2.7 Xylol - TT-X-916 Grade B.

TOP COAT

2.8 Hi-Reflectance Flat White No. 6 - Triangle Paint Co., 2222 Third Street, Berkeley 10, California.

2.9 Not used.

PRIMERS

2.10 Mil-C-8514 Coating Compound Metal Pretreatment.

2.11 Mil-P-8585 Primer Coating, Low Moisture Sensitivity.

PURCHASING

2.12 Purchase orders shall require that materials procured to Government Specifications conform to the applicable requirements. Purchase orders for proprietary materials shall require identification per Federal Test Standard 141 Method 1031.1. A copy of the supplier's record of batch production data and test results shall be required when ordering proprietary top coating. The supplier's record of batch production data shall be retained in file for a period of three years.

2.13 Materials shall be procured only from suppliers listed in current Qualified Products Lists. Substitutions of proprietary or commercial products or procurement from suppliers not listed in this specification is not allowed without Engineering approval. Finish coatings shall be purchased in 5 gallon or smaller containers.

RECEIVING

2.14 Receiving Inspection shall examine all incoming materials to insure conformance to Purchase Orders and applicable specifications.

2.15 Incoming acceptance testing of materials not covered by specification shall consist of any test by the Quality Control Laboratory which will assure maintenance of quality but shall at least consist of the following:

2.16 Federal Test Standard 141 Method 6101; Gardener 60 degree Specular Gloss Meter, specular gloss shall be two or less, specimens shall be prepared in accordance with paragraph 3.0. Wash primer may be omitted.

2.17 Federal Test Standard 141 Method 4041; volatile content. Volatile content shall be 33.5 percent ± 1.0 percent.

2.18 Weight per gallon as received shall be 11.6 lbs. ± 0.2 lbs.

STORAGE AND CONTROL

2.19 Paint type materials shall be stored under shelter at temperatures between 45 deg F and 80 deg F. Short periods above or below these limits shall not be cause for rejection. Paint subjected to prolonged periods outside the above temperature limits shall be inspected by Quality Control Laboratory for deterioration.

2.20 Issue of paint shall be on a first-in-first-out basis. Material shall be warmed to paint room temperature before use.

EQUIPMENT

2.21 Equipment, application technique, handling and mixing shall conform to Mil-F-18264 and as instructed by specific details in this specification.

2.22 Appropriate safety precautions applicable to handling of toxic and flammable materials shall be observed during all operations.

2.23 Cleanliness of spray guns and equipment is necessary to produce high quality coatings. Application of finish coatings shall be conducted in clean, dust-free spray booths.

PROCESS APPLICATION

3.0 The coating system shall consist of the following:

1 coat Mil-C-8514 Wash Primer - 0.1-0.3 mils thick dry.
1 coat Mil-P-8585 Primer - 0.3-0.7 mil thick dry.
2 coats Triangle No. 6 - 1.2-1.5 mils thick dry each.

Total dry film thickness shall be 3.1 to 4.0 mils unless otherwise specified on Engineering Drawing.

PREPARATION OF PRIMERS AND COATINGS

3.1 All paint shall be well mixed prior to use. Agitation for 15 to 30 minutes on a Red Devil paint shaker is recommended. Continuous mechanical agitation during use is mandatory.

3.2 Primers shall be thinned to spraying consistency by addition of thinner in ratios up to one to one.

3.3 Coating, Triangle No. 6, shall be thinned in the ratio of two parts paint to one or less parts thinner.

3.4 So Cal No. 1, Item 2.6, thinner shall be used to reduce Triangle No. 6 when spraying indoors. Xylol, Item 2.7, shall be used when application of coating is made in direct sunlight in the field or when ambient air temperatures are over 100 deg F. Xylol may also be used indoors.

SURFACE PREPARATION

3.5 All surfaces shall be clean and dry at the time of application of any organic coating.

3.6 After cleaning or surface treatment, parts must not be contaminated by handling or other means before painting.

3.7 Aluminum alloy assemblies containing faying surfaces which might retain liquids shall not be subjected to any acid or alkaline etching process.

3.8 Priming and painting shall be discontinued when the relative humidity of ambient air is greater than 75 percent or temperatures less than 50 deg F.

3.9 To insure that surfaces to be painted are free from dust and handling contamination, they shall be tack-ragged immediately before priming or painting. Tack-rags shall be prepared by dampening a piece of clean cheese cloth with toluene.

CLEANING OF ALUMINUM SURFACES

3.10 Reflecting surfaces of panels which have been manufactured by structural bonding require only degreasing prior to wash primer application.

3.11 Wipe surfaces to be painted with clean cheese cloth dampened with toluene. Wipe dry with second clean cloth before solvent evaporates. Repeat until second cloth shows no soil.

3.12 Aluminum surfaces fabricated by riveting or welding shall be cleaned as follows unless parts have been cleaned in detail prior to assembly.

3.13 Degrease by washing with any solvent listed in Item 2 using clean cheese cloth. Remove water soluble soil by sponging with detergent, Item 2.4, until clean.

3.14 Apply deoxidizer, Item 2.5, while surface is still wet from previous washing by sponging or mopping. Continue until surface appears clean and bright but no longer than 10 minutes. Remove deoxidizer with water wash and dry with clean rags.

3.15 One wet thin coat of wash primer, Item 2.10, shall be applied to all surfaces requiring paint. Dry for 30 minutes minimum before applying additional coats. When relative humidity is between 70-75 percent, drying time shall be extended to 2 hours and extreme care must be exercised that primer does not blush. If blushing should occur, primer shall be removed. If primer appearance is doubtful, test for adhesion by scraping surface with the sharp edge of a piece of 1/8" thick plexiglass. If primer can be removed to bare metal, the primer shall be removed and reapplied.

3.16 Apply one full box coat of zinc chromate primer, Item 2.11, and allow to dry for 1.5 hours to 24 hours. Air dry 2 to 24 hours if air temperature is less than 70 deg F. Primer may be force dried for 45 minutes at 140 deg to 160 deg F. Apply final top coating within 72 hours. If primer is older than 72 hours, reactivate the surface by sanding lightly with 320 mesh or finer wet or dry paper lubricated with toluene. Dry with clean cloth and apply top coat within four hours.

3.17 The dry film thickness of entire primer system shall be 0.4 to 1.0 mils.

APPLICATION OF TOP COAT

3.18 Surfaces to be top coated shall be free from dust, dirt, lint or other contaminates. Primer which is rough or grainy shall be sanded smooth with 280 abrasive paper or finer. Remove sanding dust and shop soil with tack rags per Item 3.9.

3.19 Apply two or more cross coats of Triangle No. 6 per Item 2.8 to form a dry film thickness of 1.2 to 1.5 mils. The paint film shall be uniform in appearance and thickness.

3.20 Dry a minimum of 6 hours at 72 deg F and relative humidity 80 percent or less. When ambient temperature is between 50 deg F and 60 deg F, dry for 12 hours before recoating.

3.21 Apply two or more cross coats to provide a finish coat 1.2 to 1.5 mils dry film thickness. Dry for a minimum of 6 hours before handling.

TOUCH UP AND REPAIR

3.22 Clean the entire area around the damaged portion with solvent cleaners per Item 2, followed by a thorough wash with detergent and water. Rinse well and dry with clean cheese cloth. Do not recoat for 30 minutes or until surface is completely dry.

3.23 Damaged coating may be repaired by fairing the edges of damaged areas into surrounding areas with 320 mesh paper or finer. Reapply primer system per Item 3.15 and Item 3.16 when damage extends to the bare metal.

3.24 If recoating is to be accomplished in hot sunlight or ambient temperatures higher than 100 deg F, top coating shall be thinned with Xylol. If coating appears too dry or grainy, add up to 50 percent mineral spirits to slow the evaporation rate.

QUALITY CONTROL

4.0 The Inspection Department shall determine that cleaning and surface preparation, mixing, application of coatings and film thickness is in compliance with this specification.

In addition, they shall insure that coatings are uniform in appearance and free from runs, sags, blisters, holes, cracks, dirt, orange peal or other defects.

4.1 Adhesion shall be determined by means of a tape test as follows:

Firmly press a 6-inch piece of 1-inch paper tape per UU-T-106 to the area to be tested. After loosening one end of the tape, remove it in one quick single jerk. If no paint is removed by the tape, adhesion is adequate. A slight whitening of the tape is not cause for rejection.

4.2 Total film thickness shall be measured on the concave face at each corner of the panel and over the surface, at intervals no greater than 2 feet. Film shall dry for 6 hours minimum prior to thickness measurements.

SCHEDULE C

APPENDIX E

NATIONAL RADIO ASTRONOMY OBSERVATORY

PROCESS SPECIFICATIONS

EXTERIOR PROTECTIVE COATING

FOR ALL EXPOSED METALLIC SURFACES OTHER THAN REFLECTOR SURFACES

March 1984

GENERAL CONDITIONS

1. All coating materials to be used, including solvents, thinners, etc., are specifically to be Sherwin-Williams products or (Wisconsin Protective Coating Corporation Products) as specified in the specifications made a part of this Scope of Work.

2. The work must be done in a manner and sequence such that no coated parts will be damaged by subsequent coating operations, that is, all coated areas or parts must be protected from damage by rigging or other operations required for coating later parts of the unit; similarly, parts to be coated later in sequence must be properly cleaned of any materials splashed or dropped from previous operations.

3. No painting is to be performed when the surface to be painted is wet, nor when the air temperature is less than 50 deg F, nor when the relative humidity exceeds 70 percent.

4. Wire brushing for the removal of all mill scale, rust, etc., must be performed on all steel surfaces to be painted--simple <u>spot</u> brushing is not sufficient. All steel surfaces must be prime painted the same day as the wire brushing is done.

I. ALUMINUM

A. <u>Surface Preparation</u>

Aluminum Oxide provides an excellent substrate for painting materials. Therefore, the general requirements of cleanliness and dryness only need apply. Aluminum surfaces should be steam cleaned or detergent washed followed by thorough rinsing and drying.

B. Primer

Spray a wet coat of Sherwin-Williams Zinc Chromate Primer, B50Y1, reduced up to 12-1/2 percent with mineral spirits. This material is very similar to Government Spec. MIL-P-8585. Primer should be applied to obtain a minimum dry film thickness of 1.5 mils and should dry 18 hours before recoating.

C. Second Coat (Intermediate)

Spray Sherwin-Williams Undercoat "B53W10" according to manufacturer's instructions, in a manner to obtain a minimum dry film thickness of 1.5 mils. This is a white rust inhibiting primer and is recommended to insure complete metal coverage. Holidays and metal peaks provide areas susceptible to early corrosion. This coat insures complete metal primer contact and provides an ideal surface for topcoating. Intermediate coat shall be tinted with lamp black or carbon black to a contrasting shade so that complete coverage by the final coat is readily determined. Minimum time before recoating is overnight.

As an alternate to Item I-C above, Subcontractor may apply an intermediate coat of "Plasite 2050 Primer" according to the manufacturer's instructions (Wisconsin Protective Coating Corporation). The minimum dry film thickness of the intermediate coat shall be 1.5 mils.

D. Third Coat

Spray Sherwin-Williams G&C White Enamel, B53WA3, reduced up to 12-1/2 percent with V.M.&P. Naphtha, in as heavy a wet coat as possible without running and sagging. Minimum dry film thickness shall be 2 mils.

As an alternate to Item I-D, Subcontractor may apply a top coat or coats of "Plasite 2050 Top Coat" Color White, according to the manufacturer's instructions. Minimum dry film thickness of top coat shall be 2 mils.

E. Minimum Thickness

A minimum of 5 mils of dry paint thickness is required for durability. The ability to achieve this thickness will vary because of many factors: application, thinners, surface, temperature, etc. Measurements must be made to insure proper film thickness and if this is not achieved in three coats, a fourth coat (second coat of G&C Enamel White, B53WA3, shall be applied.

II. STEEL

A. Surface Preparation

Surfaces should be as clean and dry as possible. Power wiring brushing is recommended to remove all loose rust and dirt. If oil and grease are present, these should be removed by solvent washing. On several areas of the steel mill scale may still be attached. Mill scale should not be left on the surface as it is not permanently adherent to the base steel. Specifications for surface preparation should include its removal. Any stratified rust or blisters shall be removed by power impact tools, rotary scalers, or by use of power grinding equipment.

B. Primer

In order to achieve intimate metal-primer contact, Sherwin-Williams E41N1 Kromik Primer should be applied full body by brush. Although spraying, under normal conditions, a full wet coat of a long oil primer will usually yield satisfactory results, actual application methods and conditions fall far short of the ideal and intimate metal-primer contact is not attained. Where it is not attained, the electrochemical properties are mostly lost and the physical barrier remains as the only corrosion deterrent.

1. Zinc Chromate Primer, B50Y1, may be used on the steel as well as on the aluminum surfaces, but the requirement of brushing would apply for the steel surfaces.

2. The antenna to be provided for the Puerto Rico location shall have a prime coat differing from that specified above. This prime coat shall be a zinc-enriched primer "Plasite 1000" as manufactured by Wisconsin Protective Coating Co. or ZRC Compound as manufactured by ZRC Chemical Products Co. applied according to manufacturers' instructions.

C. Second Coat

Same as aluminum second coat. See I-C.

D. Third Coat

Same as aluminum third coat. See I-D.

E. Minimum Thickness

The same comments apply as for aluminum in I-E.