Title: Primary Mirror Interface Specifications for the WIYN 3.5 Meter Telescope

Document number: WODC 01-12-08

Reviewed and approved:

/Matt Johns

Project Manager Date

/Dan Blanco

Lead Mechanical Engineer Date

/John Little

System Engineer Date

/Wayne Pollard

NOAO Manager of Engineering Date

## 1. General

The purpose of this document is to specify the mechanical, electrical and optical interfaces to the Primary Mirror Subsystem. Software interfaces are specified in a separate document.

The Primary Mirror Subsystem consists of the primary mirror, its cell and all associated supports and thermal controls including associated off-telescope electronic and thermal controls.

The Tertiary Mirror Subsystem, although attached to the primary mirror cell, is a separate subsystem and is not included.

## 2. Mechanical

This section describes the mechanical interfaces of the Primary Mirror Assembly, PMA.

### 2.1 Layout

NOAO drawing 3500.0003996E shows the mechanical layout of the Primary Mirror Assembly with control dimensions.

### 2.2 Coordinates

Primary Mirror Assembly coordinates are a cartesian coordinate system defined as follows: (a) the x-y plane is defined by the (mean) plane of the mounting pads for the primary flexions on the top surface of the cell weldment, (b) the y-axis is nominally perpendicular to the telescope elevation axis and positive in the upward direction when the telescope is pointed at the horizon, (c) the origin is located where the axis defined by the center of the tertiary assembly mounting ring passes through the x-y plane, and (d) the z-axis is positive towards the secondary mirror.

Elevation specifies the angle between the gravity vector and the y--axis defined above. Elevation is defined such that 0° occurs with the telescope pointing at horizon and 90° at zenith. Angles greater than 90° correspond to 'backward' tips past zenith of the OSS.

Tilt specifies the non-perpendicularly of the x-axis and the gravity vector.

### 2.3 Primary attachment

Flexion bars connect the Primary Mirror Assembly to the center section of the Optical Support Assembly. Threaded bolt holes on the top surface of the mirror cell weldment are provided for each of the four flexions. NOAO drawing 3500.0002073E sheet 1 shows details of the attachment points. The sheet metal plenum that covers the attachment points will have to be modified to accommodate the flexions. The flexion shall not intrude into the spaces for the blowers or primary mirror and shall preserve the integrity of the plenum in the final design.

The length of the flexions are chosen to place the paraxial vertex of the primary mirror 450 mm below the elevation axis.

### 2.4 Elevation drive disks braces

Each elevation drive disk will be braced by a pair of struts that attach to the primary mirror cell weldment and shown in drawing TBD. The purpose of the braces is stiffen the disks against out of plane bending. The geometry has been chosen to minimize lateral motion of the disks as the telescope moves in elevation.

The struts will be removed during primary mirror removal.

### 2.5 Tertiary Mirror Support Assembly interface

The tertiary assembly is cantilevered off the Primary Mirror Assembly. A machined land, NOAO drawing 3500.0002073E sheet 2, with twelve (12) 5/16-18 holes equally spaced on a 30.00" diameter bolt circle is provided in the mirror cell weldment for attaching the Tertiary Mirror Support Assembly. A flexible seal between the tertiary mirror support base and the primary mirror closes the air plenum behind the primary mirror. The only other connections between the Tertiary Mirror Support Assembly and other subsystems are flexible cables for the tertiary mirror control described in section TBD.

### 2.6 Lower mounting ring

A machined land with twelve (12) 5/16-18 holes equally spaced on a 30.00" diameter bolt circle is provided on the bottom plate of the cell weldment for attaching instruments. Details are shown in NOAO drawing 3500.0002073E sheet 2.

The mounting surface is TBD inches below the elevation axis.

### 2.7 Lifting points

Four reinforced pads are provided on the bottom of the cell weldment for lifting the Primary Mirror Assembly with jacks on the Primary Mirror Cart. Locator cups to receive the jack posts will be permanently mounted on these pads. Figure 3508.0004317E shows details of the Mirror Cart/cell interface.

### 2.8 Seals

In addition to the seal described in section 2.5, a flexible seal will be provided between the top of the primary mirror assembly and the inside diameter of the OSS center section as shown in drawing TBD. The purpose of this seal is to: (a) prevent dust and insects from reaching the primary mirror surface and (b) trap hot air below the mirror.

## 3. Physical

### 3.1 Weight and Center of Gravity

The Primary Mirror Assembly weight and CG includes the finished mirror, cell weldment, mirror supports, air blowers, radiators, nozzles, plumbing, cabling, sensors, control electronics, fluids, covers, plenums, safety clips, stops, seals, and all other associated hardware that constitutes the complete functioning assembly. The following are <u>not</u> included: (1) Tertiary Mirror Assembly consisting of support base, rotation mechanism, mirror cell and supports, and tertiary mirror, (2) Primary mirror baffle, (3) Cassegrain instrumentation, (4) primary flexions, (5) modifications to the existing structure to accommodate attachment of the flexions to the cell, or (6) balance weights. The CG is to be specified with the mirror in its normal operating position relative to the cell and fluid levels at operating capacity.

The CG is specified in the Primary Mirror coordinate system defined in section 1.2.

Primary Mirror Assembly:

| | |
|---|---|
| Weight: | 16,922 (+TBD, -TBD) pounds. |
| $CG_X$: | 0.0 (+TBD, -TBD) inches. |
| $CG_Y$: | 0.0 (+TBD, -TBD) inches. |
| $CG_Z$: | 10.624 (+TBD, -TBD) inches. |

A partial breakdown of the weights and CG's of the various parts of the Primary Mirror Assembly is given in appendix A.

### 3.2 Orientation

This section specifies the permitted elevation and tilt angles of the Primary Mirror Assembly during (1) operation in the telescope, (2) full range in the telescope, and (3) during handling while detached from the telescope.

#### 3.2.1 Observing Range

The Primary Mirror Assembly will function according to observing specifications if the following conditions are maintained:

Elevation: 15° to 89.6°

#### 3.2.2 In-telescope Mechanical range

Telescope motions through any combination of angles within the following ranges and operating accelerations specified in section 2.3 will cause no damage to any part of the Primary Mirror Assembly nor require readjustments of the mirror or supports other than those adjustments performed as a normal part of observing.

Elevation: 0° to 92°

#### 3.2.3 Handling range

The following tilt limit shall be observed when the Primary Mirror Assembly is removed from the telescope for service. Refer to WODC 01-30 for mirror cart requirements and handling procedure. During mirror assembly removal the following conditions shall be observed: (1) Accelerations shall be limited to the values specified in section 3.3, (2) TBD (safety clamps, mirror support adjustment, etc.).

Maximum tilt: 3°.

### 3.3 Accelerations

In normal operation the Primary Mirror Assembly will be subjected to the following maximum accelerations:

| | |
|---|---|
| Lateral: | $8 \times 10^{-3}$ g |
| Angular: | $1°/sec^2$ |

### 3.1 Emergency stops

The primary mirror will be subjected to maximum lateral accelerations of $8 \times 10^{-2}$ g per axis in the OSS x- and y- directions during emergency stops. The Primary Mirror Assembly will be able to withstand such accelerations without requiring a readjustment of the support system or mirror alignment.

### 3.2 Survival

The Primary Mirror Assembly will withstand accelerations of 0.3g along any axis without damage to the mirror or associated thermal controls and supports regardless of whether the Primary Mirror Assembly is installed in the telescope or removed for service.

### 3.4 Mirror Alignment specification

The mechanisms for adjusting the position of the primary mirror relative to the cell are the following:

A pair of tangent arms define the position of the primary mirror in the x-direction. Manually adjusting the length of the two tangent arms by opposite amounts in each causes the mirror to translate along x parallel to the elevation axis. Adjusting the tangent arms by the same amounts causes a rotation of the mirror about the z-axis.

The position of the mirror along the y-axis is determined by the fluid volume in the lateral supports. A motorized reservoir system allows the volume to be adjusted. The y position is measured by an LVDT sensor which provides feed-back to maintain the y position at its set point.

Piston, tip and tilt of the mirror are accomplished by adjusting the volume of hydraulic fluid in the three zones of the back supports. A reservoir and LVDT sensor similar to the unit in the lateral supports is provided for each zone. The axial motions are coupled so that, for example, a piston adjustment requires coordinated action by fluid level adjustment of all three zones. This also means that the range of any adjustment will be restricted when combined motions are necessary.

#### 3.4.1 Initial mechanical alignment

The mechanical position of the mirror will be defined with respect to its back plane and the ID of the center hole in the back surface. At installation, the primary mirror will be mechanically positioned in the cell with the following tolerances and adjustment range:

| | Nominal Position | Adjustment Range | Resolution | Units | Notes |
|---|---|---|---|---|---|
| Axial actuators: | 4.0 | +TBD, -TBD | TBD | inch | 1 |
| Maximum tip, tilt: | 0.0 | +TBD, -TBD | TBD | arcsec | 2 |
| x center: | 0.0 | +TBD, -TBD | TBD | inch | |
| y center: | 0.0 | +TBD, -TBD | TBD | inch | |
| Rotation: | 0.0 | +TBD, -TBD | TBD | TBD | 3 |

Notes:

1. See drawing TBD for actuator positions.
2. Tip and tilt adjustments may be restricted near the ends of actuator ranges.
3. Rotation angle should not be changed after initial adjustment.

### 3.4.2 Position Control During Operation

The primary mirror control system will hold the mirror in a nominally fixed position relative to defining points on the cell over the full observing range of elevation angle and tilt. The defining points for the axial positions (tip, tilt, piston) are the mounts for the three LVDT position sensor units located near the centers of the three zones of hydraulic support. The y defining point is the LVDT unit that senses the y position of the inside edge of the center hole in the primary. The x position and mirror rotation are referenced to the mounting pads of the tangent arms on the top surface of the cell weldment. Figure TBD shows the arrangement of defining units.

The position accuracy of the mirror relative to its cell depends on the resolution of the position sensors, long term drift due to aging, thermal drift and position variations within the deadbands of the actuator controllers. Deviations of the defining point locations due to structural deflection of the cell and primary flexion under changing gravity and thermal conditions are included in the telescope structural analysis and are compensated for by the pointing map.

| Sensor/actuator | Temperature drift inch/°F | Aging inch/year | Resolution inch | Deadband inch |
|---|---|---|---|---|
| Axial displacement | TBD | TBD | TBD | TBD |
| Lateral translation (y) | TBD | TBD | TBD | TBD |

The estimated collimation and alignment performance of the mirror supports in operation is:

| | Control Accuracy (1) | Short Term (2) | Long Term (3) | Units |
|---|---|---|---|---|
| Y positioning: | TBD. | TBD. | TBD. | inches |
| Piston (Z positioning): | TBD. | TBD. | TBD. | inches |
| Tip: | TBD. | TBD. | TBD. | arcsec |
| Tilt: | TBD. | TBD. | TBD. | arcsec |

Notes:
1. RMS/P-V.
2. Drift over 12 hours with a monatomic 5 °F temperature variation.

3. Drift over 12 months with no temperature difference start-end.

### 3.5 Optical Specifications and Tolerances

This section contains specifications for the primary mirror physical dimensions and optical figure.

#### 3.5.1 Optical Axis Alignment

The position of the primary mirror optical axis with respect to its mechanical center is specified as follows:

| | Nominal Position | Tolerance | Units | Notes |
|---|---|---|---|---|
| Vertex: | TBD | +TBD, -TBD | inch | 1 |
| Wedge angle: | 0.0 | +TBD, -TBD | arcsec | 2 |
| x center: | 0.0 | +TBD, -TBD | inch | 3 |
| y center: | 0.0 | +TBD, -TBD | inch | 3 |

Notes:

1. Height of the paraxial tangent sphere above the back surface.
2. Angle between the optical axis and the perpendicular defined by the back surface.
3. Distance of the optical axis from the mechanical axis at the front surface vertex.

#### 3.5.2 Radius of Curvature and Conic Constant

The optical figure of the primary mirror will be a hyperboloid described by the sag equation:

$$z = \frac{r^2}{\left(R_c + \sqrt{R_c^2 - (1+K)\, r^2}\right)}$$

where: $r^2 = x^2 + y^2$

The paraxial radius of curvature, $R_c$, and conic constant, K, are specified by:

$R_c$ = -12250 mm ± 96 mm.
K = -1.070833 ± 0.002

with the additional constraint that:

$$|\, 0.3878\, \Delta R_c + 18600 \text{ mm}\, \Delta K \,| < 19 \text{ mm}.$$

#### 3.5.3 Structure Function

The image error budget for the primary mirror is 0.2 arcseconds FWHM. Contributions to the primary mirror error budget are allocated as follows:

| | |
|---|---|
| Figuring: | 0.09 arcsecond. |
| Thermal effects: | 0.16 arcsecond. |
| Mirror support errors: | 0.09 arcsecond. |

Thermal effects include mirror seeing and distortion of the image due to thermal warping of the mirror blank.

The image error budget applies to the installed system with the active supports and thermal controls operating normally.

Structure functions are derived from these specifications that describe the allowable RMS mirror surface deviation as a function of the separation of measurement points on the surface. The method is described in WODC 02-01, "Optical design, tolerances, and alignment for the WIYN 3.5-meter telescope".

Figures 1-3 show the primary mirror structure functions.

### 3.5.4 Surface Smoothness

The desired surface smoothness is 25 A RMS or better.

## 4. Thermal Control System

The thermal control system maintains the primary mirror temperature near the temperature of the surrounding air. A complete description is contained in "Temperature Control of the 3.5-Meter WIYN Telescope Primary Mirror", WODC 02-13.

There are three cooling loops which act in series to move heat from the mirror to the rejection point. The first loop uses an enclosed volume of air within the mirror and cell structure to transfer heat out to the next loop. The air is circulated and conditioned with twelve sets of heat exchangers and blowers mounted in the cell. The second loop, using a coolant mix of 50-50 water and glycerol, moves the heat about 30 meters off the telescope to a liquid chiller. The temperature of the chilled fluid is the variable used for control. The chiller is housed at ground level in the control building. The third loop contains a water-glycol mixture. Its function is to reject the heat from the chiller to a convection heat exchanger down-wind from the observatory.

The control input is obtained from an array of thermocouples mounted around the front face of the mirror that measures the temperature difference between the glass and air. The thermocouple array is read by the Primary Mirror Controller over a serial line. The PMC controls the temperature of the coolant from the chiller to the mirror assembly to minimize the temperature difference.

### 4.1 Mirror cell thermal control

Figure 3 of WODC 02-13 schematically shows the closed air loop in the cell and mirror. Blowers force the air through the heat exchangers into a plenum that distributes the air into the mirror honeycomb structure. Air flowing out of the mirror returns to the blowers and is recirculated. The twelve heat exchangers share a common supply of chilled liquid located off the telescope.

### 4.1.1 Hose connections

The in-cell piping for the chilled liquid terminates at a pair of connectors on the outside of the primary mirror assembly as shown on drawing TBD. Connector fittings are:

| | |
|---|---|
| Supply: | 1.0" ID ball valves with [TBD sex] [TBD size] union. |
| Return: | 1.0" ID ball valves with [TBD sex] [TBD size] union. |

### 4.1.2 Power requirements

Commercial (Mountain) power is required for the blowers. A connector is provided on the outside of the primary mirror assembly as shown on drawing TBD.

| | |
|---|---|
| Service: | 110 VAC, 15 Amp. |
| Panel connector: | TBD. |
| Mating cable connector: | TBD. |

### 4.1.3 Control signals

The serial line for the temperature sensors terminates at a connector on the outside of the primary mirror assembly as shown on drawing TBD.

| | |
|---|---|
| Type: | RS485 + power. |
| Panel connector: | MS3120F-12-10P |
| Mating cable connector: | MS3126F-12-10S. |

## 4.2 Liquid Chiller Unit

The chiller unit provides conditioned liquid to the on-telescope heat exchangers. Waste heat removed by this loop is transferred to a second liquid loop and from there to a remote radiator and fan located outside the observatory. The chiller unit contains the pumps for the two loops, fluid reservoirs, and a thermoelectric liquid-liquid heat pump. Controls are provided for [TBD].

The chiller is housed in a double-wide wheeled instrument cabinet.

### 4.2.1 Physical Parameters

| | |
|---|---|
| Height: | 79 inches. (Lifting rings add 2.13 inches.) |
| Width: | 48 3/8 inches. |
| Depth: | |
| Basic: | 36 inches. |
| With optional table: | 48 inches. |
| Weight: | TBD pounds. |
| Front clearance: | 24 inches. |
| Left side clearance: | 1 inch. |
| Right side clearance: | 32 inches. |
| Top clearance: | 12 inches. |
| Back clearance: | 6 inches. |

| | |
|---|---|
| Power rating: | 14 KVA. |
| Heat production in room: | 2700 watts. |

#### 4.2.2 Mirror cell loop plumbing connection

Plumbing connections to the telescope loop are:

| | |
|---|---|
| Supply: | 1" ID ball valve with [TBD size] [TBD sex] union. |
| Return: | 1" ID ball valve with [TBD size] [TBD sex] union. |

| | |
|---|---|
| Maximum pressure: | 60 PSI limited by a relief valve. |

#### 4.2.3 Remote radiator plumbing connection

| | |
|---|---|
| Supply: | 1.5" ID sleeve. |
| Return: | 1.5" ID sleeve. |

| | |
|---|---|
| Maximum pressure: | 15 PSI limit by a relief valve. |

#### 4.2.4 Power

Electrical connections to the chiller unit are shown in figure TBD.

| | |
|---|---|
| Power: | 208 VAC/3 phase, 30 amp. |
| Connection: | Wired direct to disconnect. |

#### 4.2.5 Control Cables and Connectors

| | |
|---|---|
| Control: | RS485 + power. |
| Cable: | 9 conductor, 0.5" OD. |
| Rear panel connector: | MS3120F-12-10P |
| Mating cable connector: | MS3126F-12-10S. |

#### 4.2.6 Operating Conditions

| | |
|---|---|
| Location: | Weather protected area. |
| Temperature: | -5 °F to 95 °F |
| Relative humidity: | 95% non-condensing. |
| Altitude: | 6850 feet. |

### 4.3 Remote Liquid-air Heat Exchanger

The third cooling loop extracts heat generated in the thermoelectric chiller and ships it to the remote radiator. This loop runs continuously when the thermoelectric chiller is on.

The Primary Mirror Controller will read thermal sensors located at the remote radiator location over an RS 485 link using DGH analog input modules. The radiator fan will be controlled over the same communication link using a DGH output module to actuate a pilot relay. The pilot relay will switch the 110 VAC control signal from the motor starter to control the fan.

| | |
|---|---|
| Concrete pad: | 4.0' x 4.0' with J bolt anchors for radiator in 4 corners at 4" in from edges. |
| Electrical: | Two conduits from starter location to rain tight box. |
| Control: | Control conduit from mech. room along coolant pipe. Starter control in conduit from starter location to rain tight box. |
| Radiator: | TBD. |

### 4.4 Plumbing

#### 4.4.1 Telescope to Chiller

Two identical hoses carry the supply and return liquid between the primary mirror cell and chiller:

| | |
|---|---|
| Hose: | Boston BOSFLEX, 200 psi, 1.0" ID, 1.38" OD. |
| Length: | Approximately 110', adjust at assembly. |
| Connectors: | |
| Telescope end: | [TBD size] [TBD sex] union with 1" ID ball valve. |
| Chiller end: | [TBD size] [TBD sex] union with 1" ID ball valve. |
| Minimum operating head: | 35' |
| Insulation: | 0.5" wall foam pipe insulation, approx. 2.25" OD. |

Note: The last 10' of the hoses in the cable wrap to the Primary Mirror Assembly are not insulated.

#### 4.4.2 Chiller to Remote Exchanger Unit

The supply and return liquid to/from the remote radiator is carried by rigid 1.5" copper pipes that terminate within 10 feet of the chiller connectors. Short flexible hoses and hose clamps complete the connection to the chiller.

| | |
|---|---|
| Hose: | Boston BOSFLEX, 100 psi, 1.5" ID. |
| Hose length: | 10 feet, adjust at installation. |
| Pipe: | 1.5" ID copper, sweatted joints. |
| Pipe length (one way): | Approximately 140', determine at installation. |
| Minimum operating head: | 6' |
| Insulation: | None required. |

### 4.5 Fluid Capacities

| | |
|---|---|
| Primary loop: | |
| Coolant: | Ethylene Glycol/water 50/50. |
| Capacity: | 133 liters + 0.65 liters/ft hose. |

Secondary loop:

| | |
|---|---|
| Coolant: | Ethylene Glycol/water 50/50. |
| Capacity: | 19 liters + 0.95 liters/ft hose. |

## 5. Active Optics

The Primary Mirror System will dynamically adjust the support forces applied to the back of the primary mirror to bend the mirror and correct the wavefront errors from (a) thermal distortion of the primary mirror, (b) residual force errors in the passive components of the supports and (c) polishing errors in the primary, secondary and tertiary mirrors. The active controls will also maintain the position of the primary mirror relative to reference points fixed to the cell weldment as described in section 3.

The active optics system is not intended to compensate for (a) wavefront phase errors produced in the atmosphere, (b) guide errors or (c) distortions of the primary mirror caused by wind.

The supports consist of three components:

A. The 'passive' system carries the weight of the mirror and applies the appropriate forces through the back plate of the mirror to maintain the mirror figure as the telescope moves in elevation. The forces applied by the passive system are determined by the mechanical design of the interconnected hydraulic pistons and levers that comprise the supports. Both axial and lateral support units are provided.

B. The 'active' system applies corrective forces through the axial supports but carries little or none of the net weight. The magnitude of the desired force is determined in the Primary Mirror Computer and sent to a controller that moves an actuator in the axial support. The loop is closed around a load cell that reads the corrective force back.

C. The mirror position servos consist of a set of four motorized make-up cylinders that adjust the fluid levels in the hydraulics to maintain the mirror tip, tilt, piston, and translation perpendicular to the elevation axis direction.

Ref.: "Active optics system for a 3.5-meter structured mirror", Stepp, et. al., WODC 02-14-01.

### 5.1 Operation

In normal operation, the active system will continually update the support forces as the telescope tracks. Forces will be obtained from look-up tables in the Primary Mirror Computer with interpolation between tables for elevation angle. The elevation angle will be obtained from the Telescope Control System (TCS). Concurrently, the mirror position servos will maintain the mirror position relative to the reference points on the cell. The corrections will be applied in small increments so as not to produce pointing errors greater than 0.05 arcseconds over 30 seconds.

Except for supplying the elevation angle and accepting engineering data, this mode of operation will be transparent to the TCS.

During telescope repositioning, the active supports will be commanded to apply the appropriate corrective forces for the target position obtained from TCS. The mirror position servos will continue to operate as before.

### 5.1.1 Static correction.

In this mode, the corrective forces applied to the mirror are obtained from an array in the Primary Mirror Computer. This array will either be downloaded from the TCS or be the result of the reduction of the wavefront sensor image (see below). The corrective forces applied to the passive support forces only change when a new array is loaded.

The mirror position servos will still operate as above.

### 5.1.2 Generating force arrays.

Software routines in the Primary Mirror Computer will be provided for reducing wavefront sensor images and generating new force arrays. The results of the reduction (phase maps, zernike polynomials, correction force array) will be available to the control system over the observatory LAN.

### 5.1.3 Wavefront sensor.

The Instrument Adapter System will contain the wavefront sensor. Two sensor types are being evaluated: (a) wavefront curvature and (b) Shack-Hartmann. Sensor images will be passed to the Primary Mirror Computer in FITS format through shared memory or over the observatory LAN.

### 5.1.4 Secondary collimation/alignment.

The active optics system will not attempt to correct certain low order aberrations:

A. Pointing errors produce wavefront tilt that will be ignored.

B. Focus errors will be measured by separate hardware in the Instrument Adapter System. Focus terms in the wavefront reduction will be ignored.

C. Collimation errors between the primary and secondary produce coma in the image. These terms will be separated out of the reduction and sent to the control system. The operator will have the option of adjusting the secondary mirror to eliminate the coma.

## 5.2 Actuators

| | | Units | Notes |
|---|---|---|---|
| Position drift: | +TBD,-TBD | inches | |
| Update rate: | | | |
| 80° elevation: | TBD | | |

| | | |
|---|---|---|
| Settling Time: | | |
| Operating: | TBD | seconds |
| Telescope reposition: | TBD | seconds |
| Image motion: | | |
| Tracking: | TBD | Arcseconds |
| Telescope reposition: | TBD | Arcseconds |

### 5.3 Power

UPS backed up power for the active controls is supplied by the Primary Mirror Controller. An input power connector is provided on the outside of the Primary Mirror Assembly as shown in drawing TBD.

| | |
|---|---|
| Control Power: | +8 VDC, TBD amps.<br>±15 VDC,TBD amps.<br>+48 VDC, TBD amps. |
| Panel connector: | Burndy G0A18-22-PNE |
| Mating cable connector: | Burndy G6A18-22-SNE. |

### 5.4 Control signals

Control signals for the active supports come from the Primary Mirror Controller. A connector is provided on the outside of the Primary Mirror Assembly as shown on drawing TBD.

| | |
|---|---|
| Type: | RS485, 9 twisted pair |
| Panel connector: | MS3120F-14-19P |
| Mating cable connector: | MS3126F-14-19S. |

## 6. Primary Mirror Controller

The Primary Mirror Controller monitors and controls the operation of the active supports and thermal control system. It is the interface point to the telescope Control System and also reduces images from the wavefront sensor. The Primary Mirror Controller performs the following functions:

a. Read the load cells and command the actuators to maintain the correct support forces on the axial supports.

b. Read the position sensors and command the four fluid make-up units to maintain the correct position of the primary mirror with respect to its cell.

c. Receive and reduce images from the wavefront curvature analyzer to obtain correction terms for the mirror figure and system collimation/alignment.

d. Update the support force tables using the results from the wavefront analysis.

e. Send collimation/alignment terms back to the Telescope Control System.

f. Read the thermal sensors in the cell and implement the thermal control loop.

g. Send engineering data, including thermal control and support information, to the Telescope Control System.

h. Accept control commands from the Telescope Control System.

i. Download support force tables to the actuators.

## 6.1 Hardware

The target controller for the Primary Mirror Assembly is the Heurikon HK68/V3D single board computer (SBC) with a 68EC030 cpu operating at a clock frequency of 33 MHz in a VME backplane. The SBC provides sockets for up to 16 Mbytes of DRAM and will be configured with the optional 68882 math coprocessor and 84596 ethernet interface. It also includes two RS232 ports and may be ordered with an optional SCSI interface. The controller will be operated as a diskless node on the Observatory LAN.

Depending on the requirements for the thermal control subsystem, an additional serial interface card may be required.

At the time of purchase, newest technology will be considered, and the HK68/V3D SBC may be upgraded to a faster model if available.

Supporting hardware is (a) TBD VME bus card cage, (b) power supply and (c) rack, some of which may be shared with other telescope subsystems.

## 6.2 Software

The operating system for the primary mirror controller will be VxWorks, a real-time UNIX-like operating system from Wind River Systems currently in use in the newer control systems on Kitt Peak. Heurikon supports VxWorks for their systems.

The TCP/IP communication layer serves as a link to the UNIX host environment. Sockets are included in VxWorks to link software modules across the network.

Procedures will be coded in C.

## 6.3 Interfaces

### 6.3.1 Observatory LAN

Commands and engineering data will be transmitted to and from the primary mirror controller over the Observatory LAN using the ethernet connection and TCP/IP protocols. The format for commands shall be remote procedure calls (RPCs). Engineering data will be sent as TBD. Images from the wavefront analysis will also be sent across the observatory LAN for diagnostic and archival recording in FITS format.

### 6.3.2 Actuator Controllers

The primary mirror controller will communicate with the actuator controllers on the primary mirror through an RS232 ports. The RS 232 will be converted to RS 485 by electronics in the Primary Mirror Computer for multidrop service to the axial support actuators and fluid make-up units.

### 6.3.3 Temperature Sensors

The output mirror temperature sensor array will be digitized by an instrumentation module in the Primary Mirror Assembly and read by the Primary Mirror Controller over an RS485 line.

### 6.3.4 Thermal Control Subsystem

The Primary Mirror Controller will control the set-point for the chilled liquid supply, monitor temperatures at the chiller and remote fan unit, and provide a control signal for the fan using instrumentation modules. The Primary Mirror Controller will communicate with the instrumentation modules over a multiple drop RS485 link.

### 6.3.5 Wavefront Analyzer

Wavefront images (raw and reduced phase maps) will be transmitted in FITS format. The header format is specified in the software control document. Zernike coefficients will be transmitted as engineering data.

## 6.4 Power & Environmental

| | |
|---|---|
| Location: | Protected from weather. |
| Temperature: | TBD to TBD. |
| Relative Humidity: | 98% non-condensing. |
| Altitude: | 6858. |
| Power: | 110 VAC UPS, TBD amps. |

# 7. Cable routing

## 7.1 General

Utilities will be provided via flexible cables and piping from off the telescope. Cable routing and the location of utility disconnects is shown in Appendix B of WODC 03-03. Cables and utilities will be provided with strain reliefs where they connect to the center section of the OSS and drape to the Primary Mirror Assembly.

## 7.2 Tertiary Mirror Assembly control cables

Cabling for the Tertiary Mirror Assembly is routed through the interior of the mirror cell weldment. Cables terminate on one end at panel connectors on the outside of the Primary Mirror Assembly as shown in drawing TBD. The cables exit through the cell wall on the inside center hole. There they terminate at connectors attached to the Primary Mirror Assembly. This routing leaves the Cassegrain instrument mounting surface unobstructed and allows the tertiary and primary mirrors to be removed without pulling cables.

The number of cables and connector types is TBD.

### 7.3 Instrument cables.

Cabling for instruments attached to the lower mounting ring will be routed across the surface of the Primary Mirror Assembly. Cable ties and hold-downs will be provided to prevent tangling and snagging.

## 8. Service Requirements

This section contains the interface requirements for mirror assembly servicing.

### 8.1 Blowers

Blowers are accessed through panels in the upper plenum. These panels should be accessible with sufficient space for panel removal, blower inspection and service including blower replacement without requiring removal of the Primary Mirror Assembly from the telescope. Blower access panels are shown on drawing 3500.0003996E.

### 8.2 Heat Exchangers

Heat exchangers are accessed through panels in the cell weldment. These panels should be accessible with sufficient space for panel removal, heat exchanger inspection and service including heat exchanger replacement without requiring removal of the Primary Mirror Assembly from the telescope. Removal of the heat exchanger without disconnection of the coolant hoses allows inspect of the mechanisms in the lower plenum. Sufficient head room should be maintained to allow this operation on the telescope. Drawing 3500.0003996E shows the location of the heat exchanger panels.

### 8.3 Handling clips

Safety clips are engaged to restrain mirror motion before the Primary Mirror Assembly is removed from the telescope. Access to the safety clips is through panels in the upper plenum and must not be blocked when the Primary Mirror Assembly is installed in the telescope. Location of panels is shown on drawing 3500.0003996E.

### 8.4 Axial Supports

The axial support units and make-up units are serviced by removing the sheet metal cans that cover each unit. No part of the telescope structure shall restrict access for cover removal or servicing a unit. Approximately 20 inches below the units are required for cover removal.

### 8.5 Mirror Wash

TBD.

### 8.6 Utility Disconnects

Utility disconnects and strain reliefs shall remain accessible when the Primary Mirror Assembly is installed in the telescope.

## 8.7 Mirror Removal

The Primary Mirror Assembly (mirror, cell, primary flexions, and tertiary mirror support) will be removed with the telescope zenith pointing using the Primary Mirror Cart, drawing 3508.0003995E. The tertiary mirror will first be removed at location TBD such that no part of the remaining tertiary support assembly extends above TBD inches. The complete procedure is specified in WODC 01-30.

No part of the telescope structure shall restrict the mirror removal operation which involves (a) rolling the cart under the Primary Mirror Assembly, (b) raising the jacks until they contact the cell, (c) disengaging the Primary Mirror Assembly from the rest of the OSS at the upper end of the primary flexions, (d) lowering it to the travel position, and (e) rolling the cart and Primary Mirror Assembly out from under the OSS. In particular, access must be provided to the bolts at the upper end of the primary flexions which attach the Primary Mirror Assembly to the center section of the OSS.

Once out from under the OSS, the Primary Mirror Assembly will be raised up by the cart and jack stands installed to support the Primary Mirror Assembly on the observing floor. Drawing 3508.0004332E shows the building interface.

Figure 1

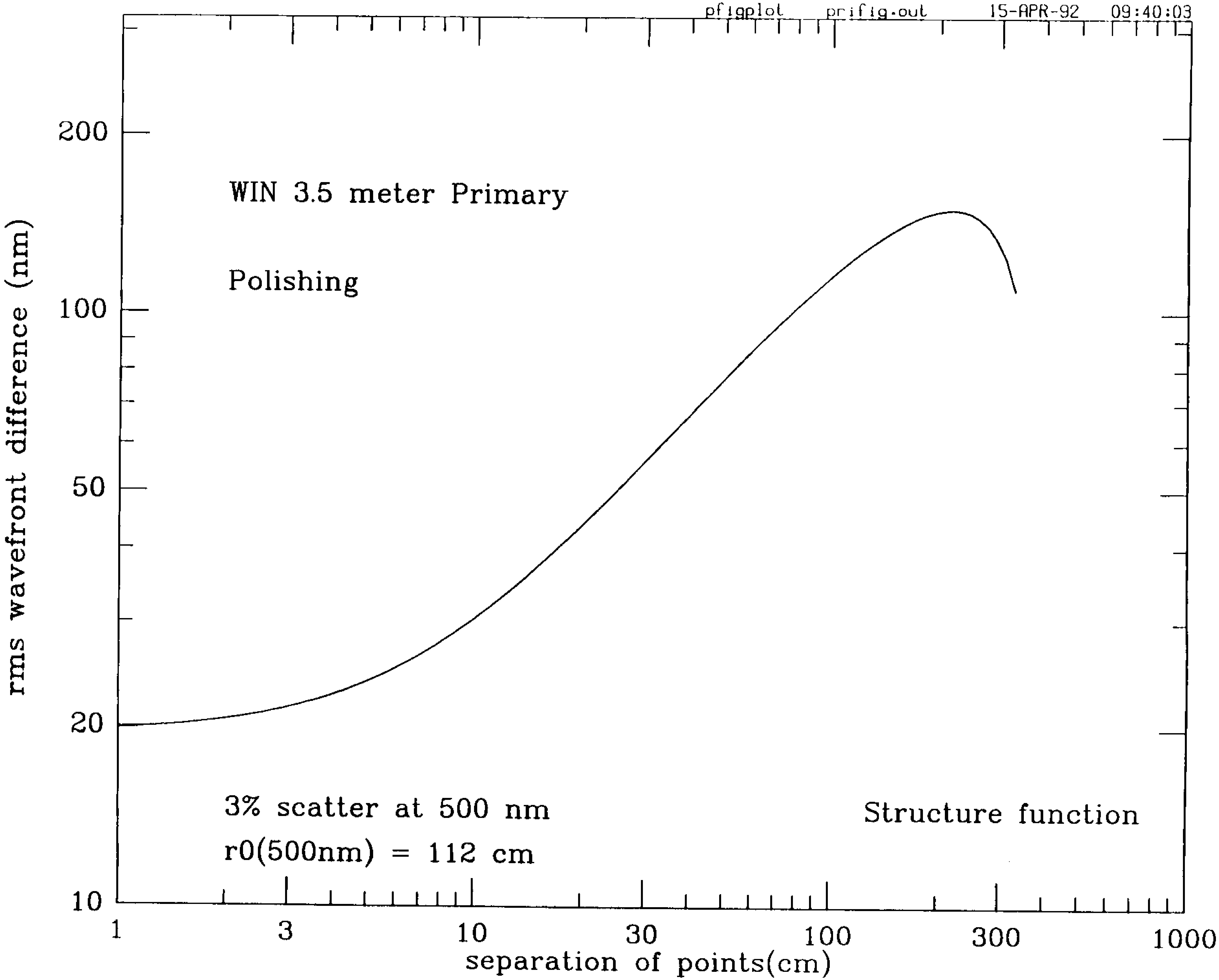
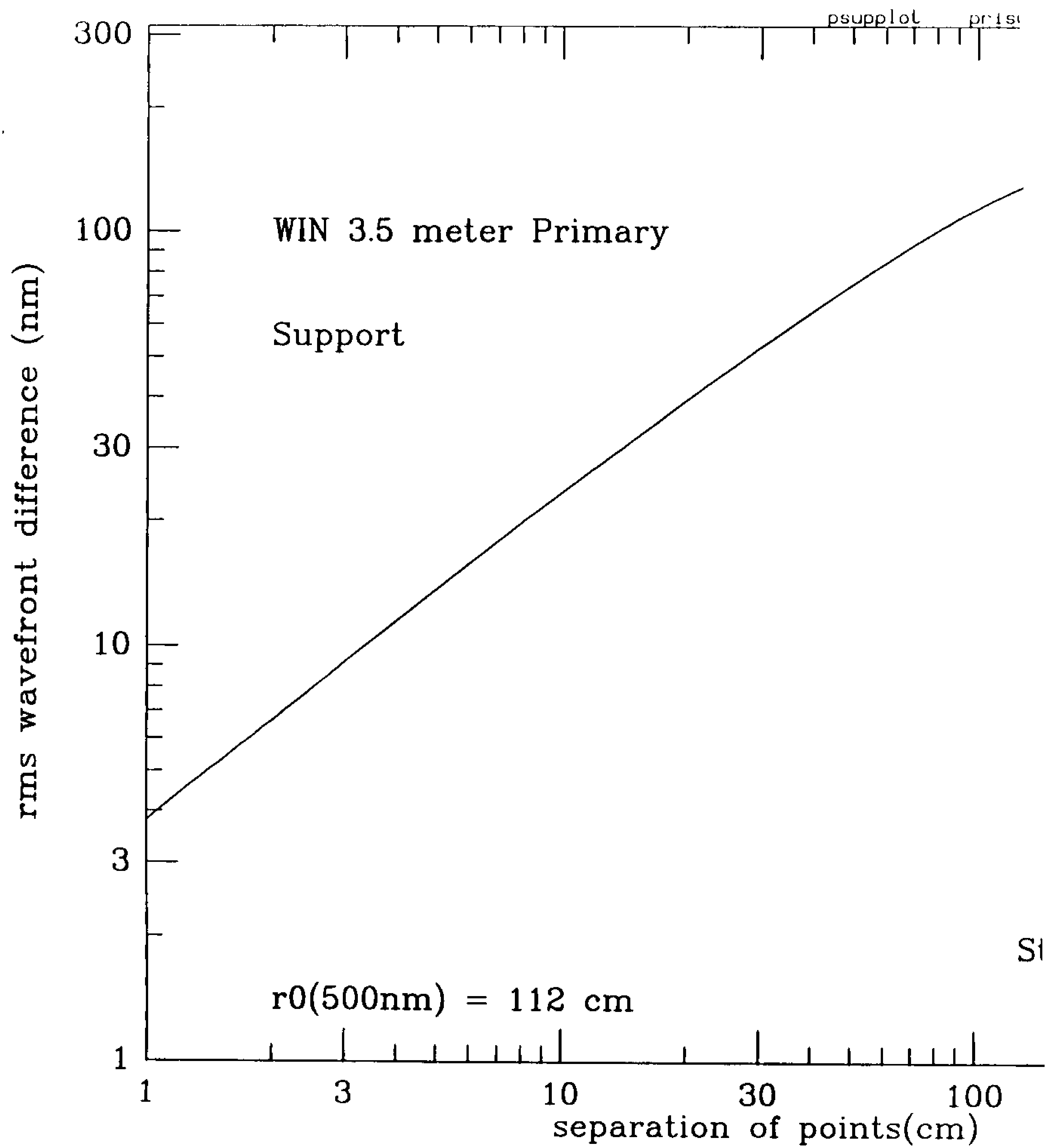

pfigplot prifig.out 15-APR-92 09:40:03
WIN 3.5 meter Primary
Polishing
3% scatter at 500 nm
r0(500nm) = 112 cm
Structure function
rms wavefront difference (nm)
200
100
50
20
10
1
3
10
30
100
300
1000
separation of points(cm)

Figure 2



psupplot
WIN 3.5 meter Primary
Support
r0(500nm) = 112 cm
rms wavefront difference (nm)
separation of points(cm)
300
100
30
10
3
1
1
3
10
30
100