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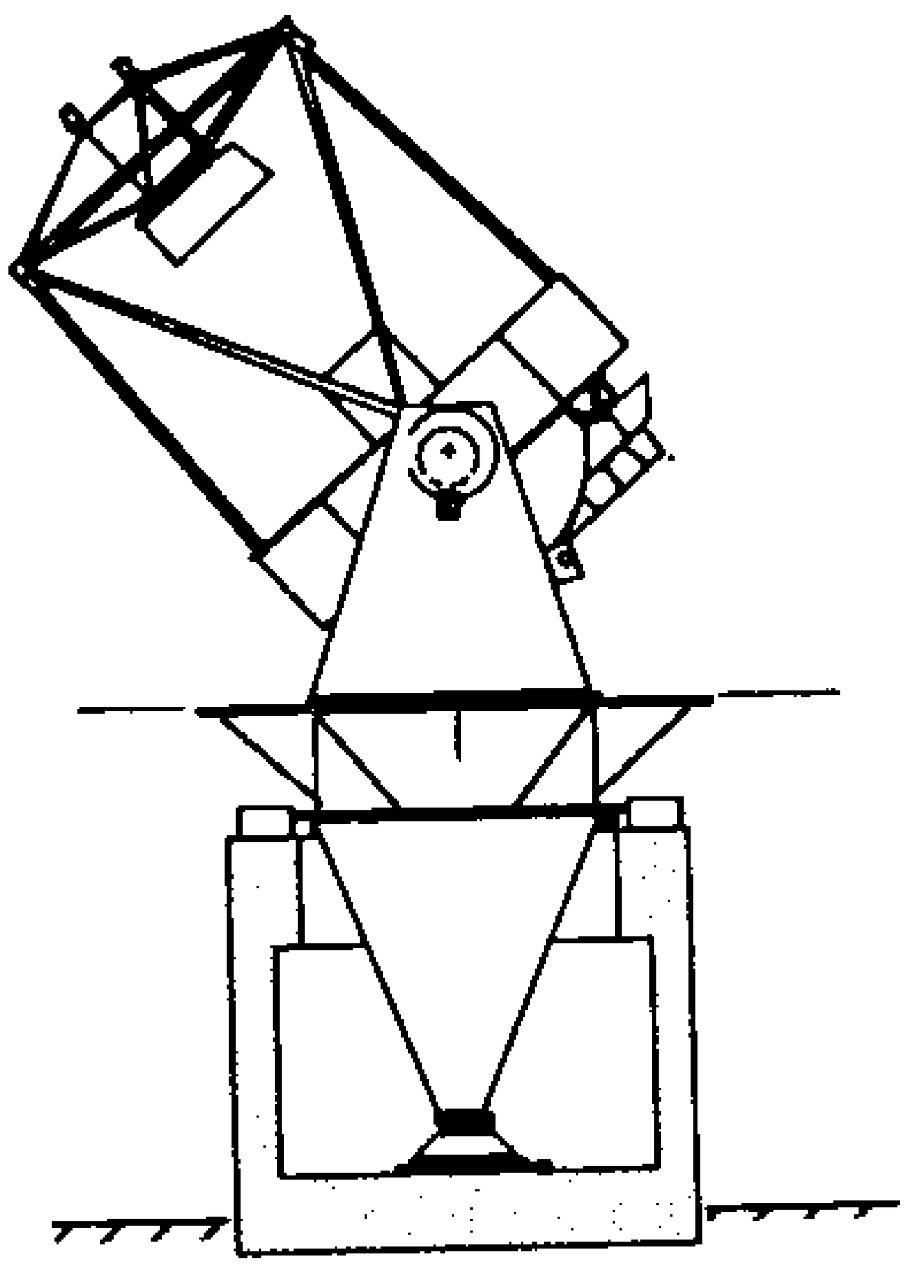

3.5 Meter Telescope

Telescope Mount

Technical Specifications for the WIYN 3.5 Meter Telescope

WODC 01-10-11

8/7/91

Title: Telescope Mount Technical Specifications for the WIYN 3.5 Meter Telescope

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1. General Information

The purpose of the work is to design, construct and test an astronomical telescope structure to utilize a 3.5 meter diameter primary mirror.

1.1 Technical Specifications

The following specifications include those which WIYN and the Contractor have established during the preliminary design phase. In some cases a best effort is specified to meet a specific goal. A "best effort" shall be meant to be a purposeful attempt by the Contractor, as determined by WIYN, to apply the best design and fabrication techniques, previous experience, known examples, and other expertise and practices to a problem in order to achieve the best possible engineering solution within the existing constraints of function, budget, and schedule. The spirit of this effort shall include an attempt to advance the state of the art for optical telescope structures, if only slightly, wherever an opportunity permits.

WIYN and Contractor agree to work together and consider changes in specifications that provide more cost effective, higher performance solutions for the telescope structure. Any changes to these specifications shall be made in writing in accordance with the change order process defined elsewhere.

References to additional WIYN technical documents will be by document number, WODC nn-nn-rr, where nn-nn denotes the document reference number and -rr the revision number. Revision numbers will be omitted in most cases. Referenced documents are incorporated in these specifications and will be supplied to the Contractor as supplements.

1.2 Preliminary Design

WIYN and the Contractor have developed a partially engineered design for a 3.5 meter alt-azimuth telescope shown in L&F drawing E305030. Engineering studies have been performed to determine the layout of the telescope and associated subassemblies, select bearings for the azimuth and elevation axes, and optimize the structure stiffness and modal performance. The results of these studies are summarized in the report "Preliminary Design of the WIYN 3.5 Meter Telescope", WODC 02-07, and layout drawings referenced therein.

1.3 Exact Dimensions

Except as otherwise provided in these specifications, exact dimensions are to be determined by the Contractor to the extent that they represent reasonable cost/performance optimization and are consistent with the functionality and performance requirements of the telescope.

1.4 Coordinate Systems

The coordinate systems to be used in the design of the telescope are defined in WODC 01-01. They are distinguished in use by their subscripts and listed here for reference:

- WORLD Referenced to the local gravity vector and true north. Subscript: w.

- •FORK Fixed to the rotating fork assembly and referenced to the azimuth and elevation rotation axes. Subscript: f.
- •TUBE Fixed to the rotating Optics Support Structure (OSS) and referenced to the elevation axis and folded Cassegrain instrument port. Subscript: t.
- •NIR(2) Fixed to the rotating Nasmyth Instrument Rotators and referenced to the rotator axes of rotation and instrument mounting surfaces. The two coordinate systems are distinguished by their use in context. Subscript: n.
- •OPTICAL Fixed to the primary mirror and referenced to the mirror optical axis and vertex. Subscript: o.

The Contractor may define additional coordinate systems referenced to these primary coordinate systems as needed for his design.

2. Interfaces

This section sets forth dimensions and properties of items not included in this contract which place constraints on the dimensions and configuration of the final telescope design.

2.1 Primary Mirror and Cell

The primary mirror will be a 3.5 meter diameter, lightweight structured casting of borosilicate glass with approximately 1.18 inch (30 mm) thick face and back plates. It will be supported in a cell with 66-axial and 24-lateral hydraulic supports acting in the z_t-direction and y_t-direction respectively. Additional force actuators incorporated into the axial supports will provide active mirror figure correction.

There will be a ventilation system for circulating air through the mirror's interior to maintain the glass at a uniform temperature close to the dome air temperature. The air will be conditioned by passing it through on-board heat exchangers supplied with chilled glycerol from off the telescope.

The Primary Mirror Assembly including mirror, its cell, supports and ventilation system are being fabricated and tested by NOAO. Specifications for this system including weights, a configuration drawing, cell details, cabling and plumbing requirements will be made available to the Contractor prior to the first design review so that telescope structure interfacing can be designed. Interface specifications for the Primary Mirror Assembly are contained in WODC 01-12.

Interface requirements are:

- The primary mirror cell shall be attached to the telescope by the primary trusses.
- Clearance shall be provided for the mirror and cell assembly including supports and associated plenums, boxes, etc. for all permitted orientations of the OSS. A best effort attempt will be made to safeguard potential pinch-points between the primary mirror assembly and telescope structure.

- Clearance shall be provided for removing the mirror and cell assembly from the telescope (see Mirror Removal, section 2.6, below).

- The Tertiary Mirror Support Assembly shall be attached to the cell.

- Clearance shall be provided between the tertiary mirror assembly and the primary mirror.

- A flexible seal shall be provided between the tertiary mirror assembly and the primary mirror.

- Routing shall be provided for drapes, conduits, cabling and plumbing for the primary mirror assembly and the tertiary mirror assembly.

Contractor will be required to simulate part or all of the mass and c.g. of the Primary Mirror Assembly/Tertiary Mirror Support Assembly/Tertiary Mirror Assembly during shop testing.

2.2 Secondary Mirror and Cell

The telescope is being designed for a single secondary mirror. The principal telescope configuration shall be f/6.3 Ritchey-Chrétien. An f/13-f/15 focus will be provided below the primary mirror by inserting focal reducing optics in the f/6.3 beam. All foci will be confocal.

Manual adjustments of the mirror position will be required for initial set-up. During operation, automatic focus and tip/tilt adjustments will be required to accommodate variations in the placement of the instrument focal planes and deflections of the OSS.

The Secondary Mirror Assembly consisting of the mirror, its cell, supports and fine position actuators will be supplied by WIYN. Specifications for the secondary mirror assembly including a configuration drawing, weights, cabling requirements and motion specifications shall be provided to Contractor prior to the first design review so that telescope structure interfacing can be designed. Reference may be made to "Secondary Mirror Subassembly", WODC 01-13 and WIYN drawing 3501.0003994E

The Secondary Mirror Assembly will mount on the secondary cage supplied by Contractor. Interface requirements are:

- Mechanical mounting of the secondary assembly to the cage.

- Clearance shall be provided around the cage and baffle to accommodate motions of the secondary.

- Routing shall be provided for hoses and control cables.

- Balance changes due to Secondary Mirror Assembly motions along the tube axis shall be compensated by counterweights on the OSS.

Contractor will be required to simulate the mass of the secondary assembly during shop testing and provide a target for aligning the secondary cage.

2.3 Tertiary Mirror and Cell

In its normal (folded-down) configuration, the tertiary mirror intercepts the beam coming from the secondary mirror and directs it to either of the Nasmyth foci or the Folded-Cassegrain focus. Switching is accomplished by rotating the tertiary about the z_t axis. With the mirror folded-up, the beam bypasses the tertiary to reach the Modified-Cass focus.

The tertiary mirror will be provided in a cell with supports and mounting points for attaching it to the Tertiary Mirror Support Assembly. Motorized collimation/alignment actuators supplied by WIYN will be incorporated into the supports or the Support Assembly. The determination of whether to put the actuators on the cell or support assembly will be made during detail design. Contractor shall provide mounting pads for the actuators if required.

The Tertiary Mirror Assembly including the mirror, its cell and supports will be supplied by WIYN. Specifications for the Tertiary Mirror Assembly including a configuration drawing, weights, cabling requirements and motion specifications shall be provided to Contractor prior to the first design review so that telescope structure interfacing can be designed. Design specifications for the Tertiary Mirror Assembly are contained in WODC 01-14.

Interface requirements include:

- The Tertiary Mirror Assembly shall attach to the Tertiary Mirror Support Assembly.
- Clearance shall be provided between Tertiary Mirror Assembly and the primary mirror.
- Provision shall be made for removing/installing the tertiary mirror with the primary mirror assembly in the telescope.
- Clearance will be provided within the tertiary mirror baffle to allow motions of the tertiary mirror including alignment/collimation, rotation and fold-up motions.
- A best effort will be made to maximize air circulation around the tertiary mirror to promote rapid thermal relaxation of the mirror within the constraints imposed by optical baffling.
- Cabling shall be provided for the alignment/collimation actuators by others. Contractor shall provide cable routing to be incorporated with cable routing associated with the Tertiary Support Assembly.

2.4 Optical Design

The telescope mount is required to position the major optics (primary mirror, secondary mirror, tertiary mirror, and correctors) according to the optical design described in the System Definition and Configuration, WODC 01-01. The following nominal relations will be used for designing the mount:

- The optical axis of the primary mirror (the z_o axis) will be co-linear with the z_t axis.

- The optical axis of the Nasmyth beams will be co-linear with the elevation (x_t) axis.

- The distance from the elevation axis to the primary mirror vertex will be 450 mm (17.72 inches).

- The separation of the primary mirror vertex and the secondary mirror vertex will be 4,200 mm (165.35 inches).

- The intersection of the z_t axis and the front surface of the tertiary mirror will be at the elevation axis.

- No obstructions to the entering beam shall exist other than the secondary support vanes, telescope optics and optical baffles. An optical design layout showing marginal rays for a 1 degree field is included in WODC 01-01.

- A clear path for a 6 arcminute field is required for the Modified-Cassegrain configuration. When folded up the Tertiary Mirror Assembly is allowed to protrude 3.0 inch beyond the edge of the cone of minimum obscuration.

Contractor's mount design shall accommodate variations in the final (as-built) spacings of the telescope optics. WIYN shall provide Contractor with WIYN's best estimate of the final spacings during primary mirror and secondary mirror fabrication. Contractor shall notify WIYN of any anticipated difficulties in accommodating these spacings. Except as provided for in the design, Contractor shall not be required to modify a structural component to accommodate spacing changes once the component has been released for fabrication.

2.5 Enclosure and Pier

WIYN will monitor the telescope structure design and approve all features and dimensions which may drive enclosure design. Enclosure specifications that may be particularly sensitive to the outcome of the telescope design include but are not limited to:

- Observing floor clearance around the telescope.
- Clearance between the telescope and the dome structure.
- Height of the elevation axis above grade and above the observing floor.
- Shutter width requirements to accommodate telescope installation.
- Concrete foundation (pier)/telescope interface specifications.
- Air baffles and seals between the telescope and observing floor and telescope and pier.
- Ventilation system design.
- Cable routing.

The basic geometrical relations determined in the preliminary design are shown on the configuration drawing L&F E305030. Changes to the dimensions that may effect the design of other systems (enclosure, mirror handling cart, instrument lift, etc.) shall require the written approval of the WIYN project manager.

Other interface requirements related to the enclosure but provided by others include handling of scientific instruments and mirrors.

2.6 Mirror Removal

The primary mirror will be removed from the telescope with the telescope pointing at the zenith. A Mirror Changer Cart has been designed to lower the Primary Mirror Assembly and truss until it clears the structure of the telescope and roll it out onto the observing floor of the dome. The cart will roll on rails that bridge across from the throat of the fork to the observing floor. The section of rails on the telescope fork will be permanently in place. The estimated combined weight for the Primary Mirror Assembly and mirror cart is 20,000 lbs. WODC 01-30 contains the specifications for the cart which is shown in drawing 3508.0003995E.

Telescope structure interface requirements are:

- A mounting surface shall be provided for the rails with sufficient capacity and continuous bearing surface to support the loaded rail during mirror lowering and roll-off.
- A stay-bar shall be provided to prevent rotation of the OSS about the elevation axis in the presence of (possibly) large unbalanced moments.
- A minimum clearance of 0.39 inch (10 mm) shall be maintained between the Primary Mirror Assembly/Mirror Cart Assembly (except at the rails) and the telescope structure, drive components, brakes, etc. during lowering and roll-out. A best effort shall be made to provide more clearance where possible without impacting the telescope performance.
- A best effort shall be made to minimize the number of components that must be disassembled, uncabled or removed from the telescope for mirror removal.
- Mirror removal shall not require that assemblies with critical alignments such as drives, encoders, etc. be removed.

Installation of the primary mirror is the reverse procedure of removal.

2.7 Telescope Controls

The Telescope Control System provides the signals for driving motors, brakes, stow pins, lamps, etc. and reads encoders, limit switches, index marks, temperature sensors, etc. Power sources which are not supplied as an integral part of a component will also be provided by the control system. The Control System shall also provide the high-level control functions associated with observing such as pointing and tracking the telescope, master control over the various telescope subsystems, and the user interface. Design requirements for the control system are contained in WODC 01-20.

Interface of actuators and transducers to their controller electronics is via electrical connectors. Connector types and locations are to be determined by Contractor and approved by WIYN. Cabling from component connectors to controllers and off-telescope cabling will be provided by the control system task. A full description of telescope cabling, etc. will be determined during the design and made available to the Contractor prior to the first design review.

Interface requirements are:

- Contractor shall coordinate with WIYN and the WIYN controls group in the selection of motors, encoders, transducers, connectors, etc..
- Contractor shall coordinate with WIYN and the WIYN controls group in designing utilities routing and locating electronic boxes.
- Contractor shall provide mounts for controller boxes as required.
- Contractor shall provide ports into the mount ventilation plenum for electronics boxes mounted on the telescope.
- Contractor shall provide conduits, cableways, drapes, wraps, etc. for control system cabling.

2.8 User Instrumentation

Science instruments may be attached to the telescope at four places:

- The Nasmyth Instrument Rotators (2).
- Primary Mirror Assembly (modified Cassegrain).
- Center Section folded-Cassegrain port.

General instrument interface requirements are contained in the "Scientific and Technical Requirements", WODC 00-01.

3. General Specifications

3.1 Vibrational Modes

Contractor shall make a best effort during design and fabrication to produce a telescope with all structure ("locked encoder") vibrational modes above 8 Hz.

3.2 Axis Motion Ranges

The mechanical range of the elevation axis shall allow the OSS to point anywhere in the quadrant from horizon (elevation = 0°) to zenith (elevation = 90°) plus an additional 2° beyond the zenith. The observing range for the telescope will be from 15° to 89.6° elevation.

The mechanical range of the azimuth axis shall allow rotation limited only by cable wrap-up. In operation, rotation shall be limited to ±270° from 90° true azimuth.

3.3 Motion Rates

Slew rates of the azimuth and elevation axes will be limited by the control system to ±5 degrees/second. The drives, encoders, etc. shall operate within specifications in this range plus 10%. The telescope structure will permit overspeed rates of 20 degrees/second on either axis without damage to bearings, drives, encoders, or other parts of the structure.

3.4 Repeatability of Distortions

Contractor shall make a best effort in design, fabrication and assembly to minimize structural deflections and drive inaccuracies which contribute to pointing and tracking errors and optical misalignment. Hysteresis in the telescope structure shall be minimized so as to allow for the compensation of deflections by computer control.

Stress-relieved welds are preferred over bolted joints. When detachable joints are necessary, they will be designed to minimize hysteresis.

3.5 Materials and Fasteners

All major components are to be fabricated from suitable grades of high quality steel capable of being welded, stress-relieved and machined as appropriate. No materials shall be used that become brittle or otherwise deteriorate over the range of specified survival conditions.

Components that wear and are expected to require replacement over the life of the telescope shall be accessible for inspection and replacement.

Details of the structure, size and thickness of plates, structural tubing, etc. and the location of gussets, etc., are described in the Preliminary Design Report, WODC 02-07.

All fasteners shall be stainless, zinc- or cadmium-plated steel.

Final choice of materials, components, connectors, fasteners, etc., shall be approved by WIYN.

3.6 Thermal control

Contractor will make a best effort to optimize the thermal performance of the telescope structure. In general, this will involve:

- Minimizing the mass of the structure to reduce stored heat.
- Minimizing plate thickness to promote rapid cooling of the structure above the observing floor. As a rule-of-thumb, steel plate up to 0.5 inch thickness ventilated from one side is acceptable. Plates ventilated from both sides may be up to twice as thick.
- Providing plenums to exhaust air from the interior of the structure.
- Providing enclosures and ducts to trap heat from active sources (motors, encoders, electronic boxes, etc.) and exhaust it out of the telescope chamber.
- Utilizing special coatings approved by WIYN on the exposed parts of the telescope structure to control over cooling by radiation to the night sky.
- Insulating the skirt to prevent a thermal bridge to the level below the observing floor.

The goal shall be that the telescope will track the ambient air temperature to within 0.5°C when the air temperature is changing at 0.25°C/hour.

4. Pier

The pier shall be composed of a non-precision monolithic concrete foundation poured in place at the site (by others) with embedments for attaching the telescope to it. Contractor shall be responsible for embedments and all temporary fixtures for holding the embedments in position during the pour.

The function of the pier structure is to couple the telescope solidly to the earth and to concentrate the mass of the telescope/pier combination near the ground to achieve optimal stability. During operation, no physical contact (other than through cable drapes and via earth coupling of the building and telescope foundation) shall exist between the enclosure and any part of the telescope/pier combination.

The height of the pier structure shall be such that the elevation axis of the the telescope lies nominally 30' above ground level. The exact dimensions of the pier will be determined during the detail design. The plan cross section of the pier above grade is square. The width between flats shall be 190" (+0", -3").

Pier design shall include provisions for routing cables and other utilities between the moving axis and stationary building and room for additional cabling.

A liquid-contact moat seal will be provided between the pier and telescope axis as part of the telescope ventilation system described in section 12.

Relative motion between the upper surface of the pier and the azimuth drive disk due to the differential expansion of steel and concrete will be accommodated in the design of the upper azimuth support frame. This provision is intended to prevent relative force buildup (1) in the vertical direction across the contact boundary with the friction drive capstan which could result in sudden release when this force overcomes static friction and (2) in the loading of the rollers due to differential expansion in the horizontal plane.

Contractor shall provide:

- Design and fabrication of parts necessary to support the telescope for shop assembly and test. It is not a requirement nor intended that the support of the telescope in the shop duplicate the mass stiffness of the pier.
- Embedments and associated installation fixtures for attaching the telescope to the pier.
- Complete documentation including procedures and specifications necessary for the correct interfacing of the concrete pier foundation design to the telescope.
- Supervision during embedment installation at the time concrete pier foundation is poured if required by WIYN.

5. Azimuth Fork Assembly

The fork assembly carries the Optics Support Structure and rotates about its vertical axis to point the telescope in azimuth.

5.1 Pedestal and Lower Bearing

The pedestal functions as a base for the telescope and transfers the weight of the structure to the ground through the pier. The pedestal bolts to an embedment (supplied by Contractor) in the poured concrete pier. A provision for leveling and grouting of the pedestal will be part of the design.

The lower azimuth bearing is incorporated in the pedestal. Either an SKF 29292 or FAG 29292E.MB spherical roller thrust bearing has tentatively been selected. The bearing and an earlier-considered alternate concept self-aligning ball bearing are shown on L&F drawing D305003. Bearing retainers and a labyrinth grease-filled seal shall be provided. Contractor shall make a best effort attempt to achieve the goals for bearing runout:

Maximum radial runout:	0.004 inches.
Max. Non-circular runout:	370 microinches.
Max. RMS non-repeatable radial jitter:	74 microinches.

Telescope and instrument cabling will pass through the central hole in the pedestal. A minimum 15 inch clear diameter is required and no part of the pedestal, bearing, or embedment may encroach in this space. The embedment shall be designed to allow cable conduits to pass down through the pier.

Mounting pads shall be provided near the bearing for two proximity sensors (supplied by WIYN) spaced 180° around the pedestal.

5.2 Axle

The azimuth axle is an inverted cone that rotates on the lower azimuth bearing in the pedestal. A journal on the bottom of the cone and retainers shall be provided for the bearing. Bearing seals shall be provided as required.

A track shall be provided near the bearing and concentric with the bearing axis for measuring bearing runout with the proximity sensors.

Ventilation holes shall be provided in the cone surface as part of the telescope ventilation system. The number and size of holes will be determined in the design phase.

Holes for threading fiber optic cables shall be provided in the cone. The size, number and placement shall be specified by WIYN prior to the first design review.

Mounting brackets shall be provided for the moat seal described in section 5.6.

A thickened ring with threaded mounting holes shall be provided at the top of the cone for attaching the azimuth drive disk and fork base. The top surface and outside diameter of the ring shall be accurately machined to provide registration for the axle to the disk.

A ladder shall be provided inside the axle for personnel access from above.

5.3 Azimuth Drive Disk

The azimuth drive disk consists of a 2.5" thick circular steel disk with an 140" outside diameter. Machined lands will be provided on the top and bottom surfaces of the disk for registering the fork and axle respectively. The fork land will define the nominal center of the drive disk. Bolted connections will be used to attach the fork base, disk and axle together.

A hole through the center of the disk will provide personnel access to the interior of the axle and routing for cables and utilities.

The top and bottom faces of the drive disk will be machined parallel. The drive and idler guide rollers will contact these surfaces near the outer edge of the disk.

The outside cylindrical rim of the drive disk is a critical surface for the pointing and tracking performance of the telescope. It will be continuous and unbroken around the circumference and extend across the full width of the disk except for chamfers at the edge. The two drive boxes and two idler boxes rolling on this surface define the upper azimuth axis. A track for the friction coupled encoders is also part of this surface.

Contractor will make a best effort to meet the following drive surface specifications:

Maximum runout w.r.t. nominal center:	0.010 inch.
Maximum departure from mean center:	800 microinches.
Maximum RMS surface roughness:	50 microinches.
Surface hardness:	Rockwell 55.

Measurements of these parameters shall be made available to WIYN during the fabrication of the drive disk.

Holes for mounting index sensor magnets will be provided in the top surface of the disk. The location and number of magnets will be determined in the design phase. The number shall not exceed 24.

5.4 Upper Support Frame and Rollers

The top end of the azimuth axis will be constrained by four wheel assemblies that roll on the edge of the azimuth drive disk. Two of the wheel assemblies will be driven and the other two will be idlers. The wheels will be located in the corners of a square frame as shown in L&F drawing E305008. The frame will be attached to the pier at the midpoints of the square sides. Mounting blocks will bolt to embedments (supplied by Contractor) in the pier and transmit the upper support lateral forces to the pier. The corners of the frame where the roller assemblies attach will have compliance in the horizontal direction to accommodate differential expansion of the pier and frame.

The drive and idler units will be preloaded against the drive disk by push rods mounted in the corner of the frame. Overload springs in the push rods will limit the roller contact force to a safe value in the event of seismic disturbance or misadjustment. Flexures in the push rods shall accommodate differential expansion in the vertical direction between the pier and telescope.

Tangent arms from the roller units to the mounting blocks will constrain the units azimuthally and transmit drive reaction forces to the pier.

Bumpers attached to the mounting blocks shall be provided to limit the displacement of the drive disk in the event of earthquake or other shock loads. The contact surface of the bumpers shall be a shock absorbing, non-scratch, material. The gap between the bumpers and disk shall be adjustable over the range ±0.25 inch from the nominal separation of 0.12 inch.

Encoder mounting pads shall be provided on each of the two mounting blocks that connect to the idler wheel assemblies.

Mounting pads for proximity sensors shall be provided on each of the four mounting blocks.

5.5 Fork

The fork consists of a pair of tines that support the elevation journal blocks and a base section that connects the tines. The base and tines will be a single weldment.

The bottom plate of the fork shall be machined to register in the land provided in the azimuth drive disk. The fork will be bolted to the drive disk and axle.

The elevation journal blocks mount on the top surfaces of the fork tines. These surfaces nominally lie in a plane parallel to the mounting surface of the bottom plate but may be scraped during assembly to achieve the alignment requirement for the elevation and azimuth axes.

The primary mirror and cell will be installed with a cart that rolls from the observing floor onto the throat of the fork (see section 2.6). The fork structure must be capable of supporting the weight of the fully loaded cart as it moves on and off the telescope. Mounting surfaces for the rails shall be provided.

Holes shall be provided in the internal plates of the fork to provide continuity of the telescope ventilation system. Holes to the outside will be provided with blank-off plates or otherwise sealed except where required to connect external equipment or other parts of the structure to the ventilation system. Openings in the top of the fork tines shall align with openings in the base of the elevation journal blocks to provide ventilation for the blocks and OSS.

Hatches in the throat of the fork shall provide access for personnel and routing for cables and utilities.

Conduits and panels for cabling and utilities shall be provided as specified in sections 14 and 15.

Two horizontal rows of threaded mounting holes shall be provided on the outside surface of each tine for attaching equipment. The location of holes is shown schematically in L&F drawing E305007. The maximum equipment weight and moment that will be attached to these mounts will be supplied to Contractor at the first design meeting.

5.6 Moat Seal

The interior of the pier acts as a plenum for the telescope ventilation system. A non-contacting liquid seal shall be provided between the upper end of the azimuth axis and the pier to seal the plenum and prevent inflow of air around the azimuth drive disk.

The moat shall be designed for a differential pressure of approximately 1" H_2O.

Drain and fill connections shall be provided as deemed necessary.

5.7 Skirt

A skirt shall be provided around the fork to fill in the circular detail between the telescope and observing floor. The skirt will be level with the throat of the fork and approximately level with the observing floor. The exact height will be determined during the detail design.

The skirt shall provide a mounting surface for the primary mirror cart rails. Bracing under the skirt shall be capable of supporting the weight of the fully loaded cart as it moves on and off the telescope.

The skirt shall be insulated to prevent a thermal bridge between the second level and the telescope chamber.

5.8 Elevation Journal Blocks and Bearings

The elevation axles will be mounted in journal blocks that bolt to the top of the fork tines. Duplex pairs of moment-carrying angular contact ball bearings will mount on the ends of the axles and in the center section of the OSS as shown in L&F drawing E305007. The bearings will be Kaydon KG250AR()BR2Z selected for 0.0008 inch runout. Each duplex pair shall be individually preloaded sufficient to keep all clearance out of the bearing under full load and range of elevation angle. The axles will be pre-cocked to achieve a nominally zero moment on each bearing pair with the telescope fully assembled and over the full range of elevation angle.

The elevation axis, defined at its ends by the centers of rotation of the the elevation bearings, shall be perpendicular to the azimuth axis of rotation to within 20 arcseconds.

Bearing retainers and seals shall be provided as deemed necessary. Provision shall be made for lubricating the bearing without disassembly or removal of the bearing assembly. Seals shall prevent lubricant from migrating to other parts of the telescope.

Clearance shall be provided through the elevation axle for the 1° FOV beam plus allowance for mounting the wide-field corrector. The optical diagram in WODC 01-01 shows the marginal rays.

The instrument rotator will be an integral part of the elevation journal block as described in section 13.

6. Optics Support Structure

The Optics Support Structure (OSS) carries the major optics of the telescope (primary, secondary and tertiary mirrors) and is mounted on bearings to allow the telescope to point in elevation.

6.1 Center Section

The box girder that forms the gimbal ring for the elevation axis is referred to as the "center section". The other portions of the OSS (primary mirror assembly and truss, secondary mirror assembly and truss, etc.) are connected to the center section. The center section is supported by the fork assembly via bearings on the elevation axles (section 5.8). The bearings mount in journals in the walls of the ring.

The central hole through the ring shall provide clearance for the 1° FOV beam plus allowance for ventilation plenums around the primary mirror (section 6.3). The central hole is nominally centered on the z_t axis. A machined reference surface or pads mutually acceptable to Contractor and WIYN will be provided on the center section as reference points to establish the tube coordinate system during assembly and testing.

An instrument mounting ring ("folded Cassegrain port") shall be provided on the outside of the center section at 90° to the elevation axis on the $+y_t$ axis. The bolt pattern and distance from the z_t axis will be determined in the detail design.

Clearance shall be provided through the walls of the ring at the elevation axes and folded Cassegrain focus for the 1° FOV beam.

Mounting pads for the primary truss shall be provided on the bottom side (telescope zenith pointing) of the center section. The pads shall define a plane nominally parallel to the x_t-y_t plane and concentric with the z_t axis.

Mounting surfaces for the two elevation drive sectors will be provided on the bottom side of the center section.

The secondary truss will attach to four pads on the top surface of the center section. These shall be nominally parallel to the x_t-y_t plane and concentric with the z_t axis.

Mechanisms associated with the primary mirror cover will also be mounted on the top surface.

Two motorized counter weights (section 10) will mount on the center section at locations to be determined in the detail design.

Mounting pads located in four places on the outside walls at approximately 45° to the x_t axis shall be provided for stationary weights that may be required to achieve OSS balance about the elevation axis. The auxiliary control electronics box may also be mounted using one set of these pads (see section 14.11).

6.2 Elevation Drive Sectors

The OSS will be rotated about the elevation axis by a pair of traction drives and drive sectors. The drive sectors will be mounted on the bottom of the center section on either side of the primary mirror assembly and parallel to the fork tines. The drive surfaces are critical components for pointing and tracking performance of the telescope.

The incremental encoder will use a track on one of the drive sectors.

The drive sector shall subtend a sufficiently large angle to allow the drives, encoders, brakes, stow pin, etc. to operate over the full range of elevation rotation.

The Contractor shall make a best effort attempt to meet the following goals:

Maximum runout w.r.t elevation axis:	0.006 inch.
Maximum departure from mean center:	600 microinches.
Maximum RMS surface roughness:	100 microinches.
Surface hardness:	Rockwell 55.

A hole shall be provided through the web of the drive sector for service access to the blower in the Primary Mirror Assembly.

6.3 Primary Mirror Assembly

The Primary Mirror Assembly including the 3.5 meter mirror, its cell, supports, and thermal controls will be supplied by WIYN (see section 2.1). An assembly of the mirror cell is shown on WIYN drawing 3500.0003996E.

6.4 Tertiary Support Assembly

The Tertiary Support Assembly consists of the support base, turntable, tilt table and baffle as shown on the primary mirror assembly drawing. Technical requirements for the tertiary support assembly are contained in WODC 01-14. The Tertiary Mirror Assembly, provided by WIYN, consisting of the tertiary mirror, its cell and collimation actuators, mounts on the tilt table.

The cylindrical support base attaches to the upper plate of the primary mirror cell and extends up through the hole in the primary mirror. The axis of the base is nominally coincident with the primary mirror optical axis and the z_t axis. A flexible gasket around the inner edge of the mirror closes the gap between the mirror and base sealing the primary mirror ventilation system.

The turntable attaches to the top of the base and nominally rotates the tertiary mirror about the telescope tube (z_t) axis to direct the beam into one of the three folded foci. The turntable is rotated by a motor mounted in the base. A latch mechanism registers and locks the turntable in position.

Future plans call for an instrument position on the back of the primary mirror cell. The tilt table enables the tertiary to fold up out of the way and allows the beam to pass through a hole in the turntable and base to reach this focus.

6.5 Primary Truss

The primary mirror assembly will be supported from the center section by four short v-braces comprising the primary truss. The geometry and member sizes of the truss will be adjusted to achieve matched deflections of the primary and secondary mirrors under changing gravity loads.

Bolted connections will be made to the center section and primary mirror cell. During mirror removal, the primary truss will be unbolted from the center section and removed with the primary mirror assembly. Removal of the elevation drive sectors, drives, encoders, or other assemblies with critical alignment requirements shall not be required to gain access to the truss bolts. Contractor shall be responsible for designing the joint between the truss and center section so that the cell returns to within 0.010 inch of its initial position.

The joint between the primary truss and the cell shall be designed with sufficient lateral adjustment in x_t and y_t to align the center of the cell (defined by the tertiary mounting land) with the z_t axis during initial installation.

The height of the primary trusses shall be adjusted during installation with a final machining operation to achieve perpendicularity of the tertiary rotation axis and the z_t axis and to accommodate the as-built optics.

6.6 Secondary Truss and top frame

The upper square frame is supported by an 8-element space truss that connects the square headframe to the center section and controls the nominal spacing of the secondary mirror. The truss and frame members will be fabricated from structural tubing with bolted connections at the corners of the frame. Bolted joints will be used where the truss members attach to the center section.

1" thick shim plates will be installed between the secondary truss and the center section to allow the secondary spacing to be adjusted after installation at the site.

The connections between tubes shall be open on the inside so that the truss forms a continuous plenum for ventilating air. Holes in the top frame tubes with screens to exclude insects will provide make-up air. Holes through the bolted connections at the base of the truss will connect to the low-pressure plenum in the center section.

Connections for the secondary support vanes shall be provided in the corners of the frame.

6.7 Secondary Support Cage and Vanes

A box-shaped cage will support the secondary mirror and baffle. Mounting pads will be provided for the mirror lateral restraints, axial position actuators, and controls. The axial actuators will be mounted at the top of the cage and the support rods will extend down through the cage frame members. The baffle will mount directly to the cage without any direct connection to the secondary mirror cell.

A target and flat mirror shall be provided (by WIYN) at the vertex position of the secondary mirror for alignment during assembly testing.

The secondary support cage shall be suspended from the corners of the top frame by 8 vanes that connect to the corners of the cage. The vanes shall be pretensioned so as to remain under tension for all elevation angles of the fully assembled telescope. The pretensioning mechanism shall provide a minimum ±0.5" coarse adjustment of the cage position for initial collimation.

The width of the vanes including control cabling is not to exceed 0.5". The lower four vanes shall fall in the shadow of the upper vanes for on-axis targets. Sizing of the vanes shall be optimized so that the secondary and primary mirrors stay aligned and collimated as the structure deflects due to gravity.

Control cabling and utilities for the secondary mirror assembly will be attached to and routed in the shadow of the vanes (see section 14.7).

6.8 Baffles

A set of optical baffles shall be provided with the telescope and will include:

- Secondary baffle.
- Tertiary baffle assembly.
- Nasmyth baffles (2).

Baffle design requirements shall be determined by WIYN and provided to Contractor prior to the first design review.

7. Drives and Encoders

7.1 Azimuth Drives & Idler Units

The azimuth axis will be rotated by two traction drive units rolling on the perimeter of the azimuth drive disk (section 5.3). The drive units will be spaced 180° apart on the disk.

Each unit will have a 4" diameter drive capstan providing a 35:1 reduction between the capstan and drive disk and an idler wheel (size TBD during design) to react the drive torque and prevent wind-up of the drive mount. (The idler wheel should not be confused with the Idler Unit described below). Capstan and idler wheel shall be hardened to a minimum Rockwell 55. The capstan and idler wheel will be supported with angular contact bearings on each end. The bearings will be preloaded to remove clearance.

Three cam followers (one fixed, one adjustable, and the third spring loaded) mounted on the sides of the drive unit will roll on the top and bottom faces of the disk and constrain the drive to follow the disk.

The drives will be preloaded against the drive disk with push rods connected to the corners of the azimuth support frame. Overload springs in the push rods will prevent damage to the capstans or drive disk in the event of shock loads to the fork. The drive reaction torque will be transmitted by tangent arms to the mounting blocks of the azimuth frame.

The capstan will be driven by a frameless DC torque motor, Inland QT7801F, directly mounted on the end of the capstan shaft. The motor is rated 46 ft-lb and will be operated at a maximum output torque of 33 ft-lb.

The capstan and idler rollers are critical components for the pointing and tracking of the telescope. Precision bearings will be used to support the rollers and the indicated runout shall be less than 75 microinches RMS on a best effort attempt.

L&F drawing D305031 shows the drive assembly.

Two Idler Units will be located 90° to the drive units and are identical to the Drive Units without the torque motors.

7.2 Elevation Drives

The elevation axis will be rotated by traction drives mounted on both fork tines. The 60" radius drive sectors will attach to the bottom of the OSS center section.

The elevation drive boxes will be similar to the azimuth boxes. The preload push rod will connect to an arm mounted on the fork tine. The torque reaction force will be transmitted to the fork base by a tangent arm.

A 30:1 reduction exists between the capstan and the drive sector. The torque motors will be operated at a maximum torque of 21 ft-lb.

A shroud around the motor will scavenge waste heat and duct it to the ventilation plenum in the fork.

7.3 Azimuth Encoders & Index Sensors

Two rotational incremental encoders will be capstan coupled to the azimuth drive disk surface at 180° to each other. The encoders will be attached to the two mounting blocks of the azimuth frame that carry the (small) torque reaction from the idler boxes. The encoder capstans will roll on a track on the drive disk surface not contacted by the rollers of the drive or idler boxes.

The encoders shall provide better than 0.02 arcsecond resolution on the sky. The selected encoders are Heidenhain Model ROD 800 with multiplier electronics that provide a resolution of 0.36 arcseconds at their input shafts. This will require a minimum 18:1 increase from telescope to encoder.

The encoder shall be direct coupled to the capstan spindle supported by precision bearings in a housed mount. Preload and guide adjustments for aligning the capstan to the disk shall be provided as deemed necessary.

The azimuth encoders are critical components for the pointing and tracking of the telescope. The goal shall be to achieve 0.1 arcsecond RMS pointing accuracy for offsets up to 1 degree, 0.5 arcsecond RMS accuracy for offsets greater than that up to 10 degrees and 1 arcsecond RMS accuracy over the full azimuth range.

Absolute positioning of the azimuth axis will be referenced to an index position at the midpoint of the azimuth range (90° true azimuth). The reference position will be provided by a Sony B3 Magnesensor with its magnet mounted on the azimuth drive disk. The read head will be mounted on the azimuth support frame at a location to be determined in the detail design. Additional magnets may be provided on the disk as deemed necessary. Adjustments will be provided for setting the position and gap of the sensor with respect to the magnet. The goal shall be to achieve 1 arcsecond resolution on the sky from the position sensor. This will require approximately 315 microinches (8 microns) resolution from the sensor.

A toggle switch will be provided that changes state at the midpoint of azimuth rotation to allow the control system to locate the index mark. Contractor shall provide the switch assembly.

7.4 Elevation Encoders

A single encoder and a single index sensor will be provided on the elevation axis. Both will be mounted on the same fork tine and encode the same drive sector. A means of mounting a second identical encoder and sensor on the opposite fork tine shall be provided. The elevation axis will use the same encoder and index sensor as the azimuth axis.

The incremental encoder shall provide better than 0.02 arcsecond resolution on the sky. The goal shall be to achieve 1 arcsecond resolution on the sky from the index sensor.

The elevation encoder is a critical component for the pointing and tracking of the telescope. Pointing accuracy goals shall be the same as for the azimuth encoders.

8. Brakes and Rotation Locks

8.1 Azimuth and Elevation brakes

Caliper, disk type, failsafe brakes will be provided for the azimuth and elevation axes to stop the telescope in the event of power failure or other loss of drive control. The brakes will be spring actuated, pneumatically released and electrically controlled. Nominal air pressure shall be between 75 and 100 psi. The brakes will clamp on the sides of the azimuth and elevation drive disks but shall not contact the drive surface.

When sliding, the brakes will apply a torque of between 10,000 and 16,000 ft-lbs to the axis.

Sense switches on the brakes will allow the control system to determine the brake status.

8.2 Stow Pin

A manually actuated stow pin shall be provided to lock the elevation axis at 5°, 15°, and 90° elevation angle. The stow pin shall be designed for a 15,000 ft-lb imbalance and hold the elevation angle to ±1 arcminute.

A sense switch shall be provided to allow the control system to determine when the stow pin is engaged.

8.3 Stay bars

Stay bars shall be provided for:

- Locking the elevation axis during secondary and tertiary mirror installation/removal (horizon pointing).
- Locking the elevation axis during primary mirror installation/removal (zenith pointing).
- Locking the azimuth axis during primary mirror installation/removal.

General requirements are:

- Stay bars shall be designed for the maximum tensile and compressive loads that result from the operations listed above plus a generous (factor of 4 minimum) safety margin.
- Length adjustments shall be provided to allow some motion to align the telescope to handling fixtures, mirror cart rails, etc.
- Clevises, shackles, etc. shall be designed to handle the full load without distorting.
- Quick release fittings are acceptable but they must include a provision for lock out tags.
- Stay bars shall be tested at 200% overload prior to first use.

9. Axis Stops and Limits

9.1 Azimuth Limits

The mechanical rotation of the azimuth axis is limited only by cable wrap up. Two sets of switches shall be provided to limit the rotation and protect cabling:

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- Soft limits shall be activated when the azimuth angle exceeds ±250° from the midrange position. Switch contacts shall be rated for low voltage DC logic signals.
- Hard limits shall be activated when the azimuth angle exceeds ±270° from the midrange position. Switch contacts shall be rated for low voltage AC/DC relay control logic.

- A lanyard (supplied by others) that activates the emergency stop system shall provide failsafe limits for the azimuth rotation in the event the hard limits are exceeded.

These switches shall remain activated as long as the azimuth angle exceeds the limit.

9.2 Elevation Stops and Limits

Mechanical stops on the elevation axis shall limit travel to elevation angles between 0° and 92°. An energy absorbing mechanism shall decelerate the telescope from a 2°/sec (unpowered) rotation rate before the hard stops are reached when the telescope is approaching the limit at elevations greater than 90° (+0.5°,-0°) or less than 5° (+0°,-0.5°).

Two sets of limit switches shall allow the control system to determine when the end of travel is near:

- Soft limits shall be activated when the elevation angle is less than 32° (±2°) or greater than 73°(±2°). Switch contacts shall be rated for low voltage DC logic signals.
- Hard limits shall be activated when the elevation angle is less than 4.5° (±0.25°) or greater than 90.5° (-0.25°,+0°). Switch contacts shall be rated for low voltage AC/DC relay control logic.

Switches shall remained activated as long as the condition they sense exists.

9.3 Elevation Tachometer

A tachometer driven off the elevation axis shall be provided to sense a runaway condition and enable the safety controls to bring the telescope to a stop. A tilt sensor on the OSS will allow the control system to select the safe operating rate.

10. Counterweight Assemblies

Despite the fact that the WIYN telescope is primarily configured as a Nasmyth instrument, there will be several sources of imbalance about the elevation axis that will require balance adjustment:

- Operation of the mirror covers.
- Tilt-up of the tertiary mirror.
- Dewar change at the modified Cass focus.
- Secondary focus.

Total moment change will be (worst case) 8300 in-lb.

A motorized and encoded counterweight(s) shall be provided to balance these effects. Counterweight design requirements are given in WODC 01-17.

11. Primary Mirror Cover

A cover shall be provided to protect the primary mirror when not in use from dust, ice, snow and falling objects. Design requirements for the primary mirror cover and contained in WODC 01-16.

12. Ventilation Plenum

When assembled, the fork assembly, center section, secondary truss and top frame shall form a contiguous plenum. When connected to an exhaust plenum (provided by others), it provides a low pressure reservoir into which is vented air warmed or cooled by drive motors, controls, instruments and ambient air drawn from around the secondary truss and top frame. Making the telescope structure a plenum will also promote more rapid thermalization due to the constant flow of air.

Internal bulkheads shall be perforated or otherwise designed so as to preserve complete continuity of the plenum described above. The connection between the fork assembly and the center section will be a flexible hose(s) or rotating coupling(s).

An exhaust fan located remotely from the telescope and ducting (supplied by others) will evacuate the volume inside the pier around the azimuth axle. Holes through the axle will connect the telescope plenum to the exhaust system.

Holes provided for make-up air into the structure shall be provided with screens or filters to prevent the infiltration of insects.

The primary mirror assembly will have its own thermal controls (supplied by others) connected to a chilled water system located off the telescope.

13. Nasmyth Instrument Rotators

The Nasmyth Instrument Rotator consists of a rotating turntable mounted on the elevation journal block with its axis of rotation coincident with the telescope elevation axis. Science instruments will attach to a flange that extends beyond the surface of the fork. A hole through the center of the turntable provides clearance for the 1° FOV beam plus allowance for mounting a field corrector. L&F drawing E305020 shows the layout of the major components of the rotator. Rotator requirements are contained in WODC 01-15.

The turntable is rotated by a single DC motor and friction drive rolling on the perimeter of the disk. The rotator position is encoded by an incremental encoder friction coupled to the drive surface. Absolute position is referenced to an electronically readable position sensor that provides a fiducial position at one rotation angle.

A caliper, disk type, failsafe brake is used to prevent rotator motion when the motor drive is off. The braking force is applied by springs and pneumatically released. A manually operated locking pin will also be provided at the rotator stow position to prevent rotation during instrument changes. Hard stops and limit switches will restrict rotation to ±180°.

Identical rotators will be provided at both Nasmyth positions.

14. Utilities & Cabling

Contractor shall design and provide an on-telescope utilities distribution system that includes the functions specified in this section. Design shall include specification of cable and conduit routing, specification of flexible drape, specification of connectors, trays, strain reliefs, and all other components associated with the subsystems described below. Electrical and utilities connectors shall be selected to be compatible with the types of connectors in use at KPNO and subject to WIYN's approval.

Telescope wiring shall terminate at connectors or screw lugs located on or near components (motors, encoders, limit switches, etc.) served. Where a connector is required, Contractor shall provide the connectors and wiring from the component to the connector. Cabling from the connector to the system controls will be provided by others.

Instrument utilities shall terminate at a panels near instrument mounting surfaces on the fork and OSS. Cable drapes across the instrument rotator/fork interface will be provided by others. Contractor shall provide panels and routing for cables to the panels.

Suitable flexible conductors will be provided (by others) across the OSS/fork and fork/pier interfaces. Cable and utility routing from the fork to the OSS will be via a drape(s). Cable and utility routing from the pier to the fork will be through the axle and via a wrap around the outside of the axle.

Suitable utility/cable disconnects shall be provided (by others) (1) where the primary mirror assembly detaches from the OSS, (2) where the tertiary assembly detaches from the mirror cell, and (3) at science instruments. Contractor shall provide cable routing and mounts, where required, for the disconnects.

The on-telescope distribution system shall be designed for the following specified utilities:

14.1 Electrical power

Two classes of 120V AC power will be provided on the telescope: (1) Commercial power backed up by Kitt Peak generators and (2) Uninterruptible Power Supply (UPS) backed up by batteries.

Duplex convenience outlets for both classes of power rated at 15 A. shall be provided by Contractor near the Nasmyth and Folded Cassegrain foci, at four places on the fork base assembly under the skirt, and on the center section near the controller for the auxiliary functions (see 14.11). Connection of convenience outlets to the power sources will be by others during telescope installation.

Orange outlets with brass cover plates shall distinguish the UPS power.

14.2 Compressed Air

One dry compressed air circuit capable of 120 psi and 8 cfm flow rate shall be provided on the telescope to operate safety brakes. Connections to the circuit shall be quick-connect types that seal on the supply pressure side when disconnected. Connectors shall be located near the Nasmyth instrument rotators and elevation brakes. Contractor shall provide connectors, mounting, and routing for air lines. Connection to the compressed air source will be by others during telescope installation.

14.3 Dry Nitrogen Gas

Pressurized dry nitrogen gas shall be provided on the telescope structure near the Nasmyth and Folded Cassegrain foci. The circuit shall be capable of 75 psi max. and 10 cfm at each location. Connectors shall be quick-connect types that seal on the supply pressure side when disconnected. Connector types shall be different from the compressed air connector to avoid accidental cross-connection. Contractor shall provide connectors, mounting, and routing for gas lines. Provision of gas lines and connection to the dry nitrogen gas source will be by others during telescope installation.

14.4 Liquid Coolant

3/8" ID supply and return lines shall be provided at each focus to bring coolant (non-chilled) from off-telescope. Connectors shall be quick disconnect with shut-off on both the supply and instrument sides when disconnected. Contractor shall provide connectors, mounting, and routing for coolant lines. Coolant lines and connection to the liquid coolant source will be provided by others during telescope installation.

14.5 Waste Gas

By creating a low pressure plenum using the interior of the OSS and fork assembly the exhaust utility is essentially already distributed. It can be implemented at most needed locations by a simple port through the surface of the weldment into its interior. Distribution by surface mounted conduit is also acceptable. Contractor shall design the plenum connection across the OSS/fork interface.

Waste gases shall be non-toxic/non-corrosive.

Ports into the plenum shall be provided near heat producing components: (1) science instruments, (2) elevation motors, (3) telescope controller electronics, (4) flat field lamps, (5) mirror cover motors, (6) instrument rotator motors and (7) counterweight motors.

14.6 Primary Mirror Utilities

Routing shall be provided for the following primary mirror utilities: (1) 110V AC, 15A, commercial power, (2) Two 3" diameter flexible coolant lines, (3) 1" control/data cable, and (4) 1/2" DC power cable. Cables and hoses shall be provided by others.

14.7 Secondary Mirror Utilities

Routing shall be provided for the following secondary mirror utilities: (1) 1/2" serial control/data cable, (2) 1/4" ID vacuum line, and (3) 1/2" power cable, type TBD. Cables and hoses shall be provided by others.

The control and power cables shall originate in an electronics chassis (location TBD) and be routed across the vanes to the controller in the secondary cage so as not to add to the beam obscuration. Contractor shall provide a mount for the controller.

14.8 Tertiary Mirror Utilities

Contractor shall provide routing for the following tertiary mirror utilities: (1) shielded motor control cables for rotation and fold-up mechanism, (2) shielded control cables for the latching mechanisms, (3) limit switch cables and (4) collimation/alignment actuator cables. Control wiring for the motors, encoders, switches, etc. shall terminate at connectors located on or near the component. Cables from the connectors located at the tertiary to a control chassis (location TBD) shall be provided by others.

14.9 Drive Motors/Encoders

Control wiring for the elevation motors and encoders (provided by contractor) shall terminate at connectors near the motors and encoders. Controllers for the motors and encoders shall be contained in an electronics chassis at a location to be determined during the design. Shielded cables shall connect the elevation drives and encoder to their controllers. Cables and chassis shall be provided by others. Contractor shall provide the chassis mounting and cable routing.

Azimuth drive motor and encoder cabling resides on the non-rotating part of the telescope and is not included in the on-telescope distribution system.

14.10 Limit Switches/Brakes

Control wiring for elevation limit switches and brakes shall terminate at nearby connectors or screw connections provided by Contractor. Controllers for these shall be contained in an electronics chassis at a location to be determined during the design. Cables (provided by others) will connect the switches and brakes to their controllers. Contractor shall provide the routing for cables and a mounting for the chassis.

Azimuth limit switch and brake control cabling resides on the non-rotating part of the telescope and is not included in the on-telescope distribution system.

14.11 Auxiliary Functions

A electronics chassis (provided by others) will be mounted on the OSS to control the following systems: (1) Primary mirror cover, (2) counter weights, (3) flat field lamps, (4) temperature sensors, and (5) tertiary mirror. Cable routing shall be provided between the chassis and the controlled systems. Cabling to the chassis from off-telescope will be provided by others and include (1) 1/2" serial control/data cable and (2) Power.

Contractor shall provide the chassis mounting and routing for cabling to and from the chassis.

14.12 Instrument rotators

Shielded cabling (provided by others) will connect the instrument rotator motors, encoders, brakes, and limit switches to a controller (provided by others) mounted on the fork assembly. The location of the controller chassis will be determined during mount design. Cables shall terminate at connectors provided by Contractor near the motors, encoders, etc. Contractor shall provide the chassis mount and routing for cables from the connectors to the controller(s).

Cabling (provided by others) to the chassis from off-telescope will include (1) 1/2" serial control/data cable and (2) Power. Contractor shall provide routing for the cables.

14.13 Science Instrument Data/controls

Off-telescope routing shall be provided by contractor for the following cable bundles:

(A) Nasmyth Ports:

(1) Four 2" diameter flexible fiber bundles to be shared between the MOS and WIYN ports. These bundles will be installed with end fixtures attached. Clearance shall be provided in the cable route for the end fixtures. The fibers will terminate in the spectrograph lab. Routing will be designed to minimize the required cable length and number of bends. The minimum bend radius is TBD. A drape on the outside of the azimuth axle is preferred.

(2) Two 2" diameter control/data cables for each port.

(3) One 1" diameter video signal/gain cable for each port.

(B) Folded Cassegrain & Modified Cassegrain foci shared cables:

(1) Two 2" diameter control/data cables.

(2) Two 1" diameter video signal/gain cable.

15. Finish

Welds shall have high spots ground off. All sharp edges and corners will be ground off. All exposed non-critical surfaces shall be sandblasted, cleaned, degreased and painted with a high quality metal priming paint prior to shipping. Primed surfaces that are not to be covered with reflective mylarized tape shall receive a high quality finish coat of paint. Colors will be specified by WIYN during the detail design. Mylarized tape shall be applied by WIYN during assembly on site.

16. Acceptance Test Specifications and Procedures

This section sets forth specific criteria for tests that will be performed with the telescope assembled in Contractor's shop. Contractor is to provide dummy masses for the Primary Mirror Assembly/Tertiary Mirror Support Assembly/Tertiary Mirror Assembly combination and Secondary Assembly to simulate the complete telescope for the purpose of making mechanical performance tests with the telescope balanced. Contractor is entitled to rely on the accuracy of the weights and centers of gravity of these assemblies as specified by WIYN.

Contractor shall devise test procedures (subject to WIYN's approval) and supply required test equipment and fixtures necessary to demonstrate fulfillment of these specifications.

It is intended that all tests shall and can be performed in an enclosed shop in a time interval short enough to insure negligible test error due to changes in temperature. To the extent that the Contractor can successfully fulfill test requirements under these conditions, no other special control of the test environment is intended or required.

Levels of performance established by these tests shall be documented and included by the Contractor in the telescope maintenance documentation supplied by Contractor. Each reported level of performance shall include a short summary describing test apparatus and test conditions.

At the time of acceptance testing, the primary mirror cell may, or may not, be available in Contractor's shop for the tests. If it is available, Contractor shall supply a dummy weight to simulate the weight and c.g. of the tertiary mirror assembly. WIYN shall supply a dummy weight to simulate the weight and c.g. of the primary mirror. If it is not available, Contractor shall supply a dummy weight that simulates the weight and c.g. of the combined primary mirror assembly, tertiary mirror assembly, and Cass instrument from data provided by WIYN. In either case, a target shall be mounted at the nominal center of the cell for alignment tests during shop assembly.

16.1 Fit

The telescope shall be assembled to test for fit. This shall include:

- Azimuth Fork Assembly.
- Optics Support Structure.
- Secondary Mirror Cell and Actuators (supplied by WIYN).
- Drives and Encoders.
- Brakes and rotation locks.
- Axis stops and limit switches.

- Counterweight Assembly.
- Primary Mirror Cell (supplied by WIYN) or simulator (supplied by Contractor).
- Nasmyth Instrument Rotators.

16.2 Balance

Contractor shall provide a dummy weight to simulate the weight of the secondary mirror and dummy weights as specified above for the primary mirror assembly.

Any weights that must be added to achieve balance other than the dummy weights will become part of the telescope and deliverable under the contract at no extra cost to WIYN.

16.2.1 OSS Balance

Contractor shall demonstrate that the OSS balances to within 70 ft-lb of neutral at zenith and horizon pointing. Balance shall be measured with the mirror covers open and the counterweight in the middle of its range.

16.2.2 Vertical Balance

With no instrument load at Nasmyth and the OSS balanced, Contractor shall demonstrate that the c.g. of the telescope is within 0.38 inch of the azimuth (z_f) axis.

16.3 Function

Contractor shall demonstrate the following functional performance:

- Full range of motions of all axes (section 3.2).
- Limit switches activate at the specified angles (section 9.2).
- Hard stops and shock absorbers bring telescope to a stop under the conditions specified in section 9.2.
- Brakes operate and provide specified torque (section 8.1).
- Drives provide full torque without slip (sections 7.1,7.2).

WIYN shall supply the control system components necessary for for these tests.

16.4 Friction

16.4.1 Breakaway Torque

Starting torque in azimuth shall not exceed 400 ft-lbs and in elevation shall not exceed 175 ft-lbs. The above specification applies over the full range of azimuth and elevation axis travel.